# The development of a strategy for the implementation of expert system technology in corporate bank lending: including the production of a working prototype

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This thesis has been written entirely by the author stated on its cover (Gareth J Forsey) who was also responsible for all of the work submitted.

The entire thesis is original work apart from the specifically mentioned references indicated in the text.

Gareth J Forsey
June 1989

# THE DEVELOPMENT OF A STRATEGY FOR THE IMPLEMENTATION OF EXPERT SYSTEM TECHNOLOGY IN CORPORATE BANK LENDING - INCLUDING THE PRODUCTION OF A WORKING PROTOTYPE

By

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ABSTRACT

Software tools are now available that allow some forms of human knowledge to be held within a computer. These tools, known as expert systems, are enabling organisations to store the knowledge of their experts on computers which can be distributed across the organisation.

This project seeks to show how an expert system could be used to capture the knowledge of corporate lenders within a bank; thus enabling their specialist knowledge to be spread across the bank to non experts, speeding up and improving upon the manual lending decision making procedures currently used.

In order to demonstrate that the above is possible the following areas are examined:

The technology involved - a discussion of the techniques applied in expert systems technology to identify its relevance to corporate lending.
The "theory" of bank lending - an examination of the bank lending process to identify whether the theoretical practice of lending is able to be converted into a form suitable for inclusion in an expert system.

The knowledge elicitation process - the capturing of the knowledge involves using a number of different techniques. These are discussed to find the relevant techniques for the elicitation of corporate lending knowledge.

The development of a working expert system - to demonstrate whether it is actually possible to develop a working system.

System validation - as the technology to be applied is new, validation is of the upmost importance. This is discussed in detail to ensure that any system developed actually handles the knowledge used correctly.

The project concludes with an examination of future trends in expert system development and their likely impact on bank lending.

Key Words/Phrases: corporate lending, credit scoring, decision support systems, expert systems, expert system validation, knowledge elicitation, knowledge representation, management information systems, portfolio risk asset management, rule induction.

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"Commit to the LORD whatever you do,

... all your plans will succeed".

# CONTENTS

## INTRODUCTION

The research proposal developed from discussions with bankers about the impact of developments in expert systems on banks. Expert systems are able to hold and use some forms of human knowledge. It was therefore suggested that large parts of banking which rely on the expertise of a small number of highly paid experts could be assisted through expert systems.

Banks have been attempting to automate the decision making process of their experts for some time, particularly within the lending function. This has largely been with a view to improving efficiency, reducing costs, and enabling more complex decisions to be taken by more junior (and hence cheaper) staff. Methods employed have included credit scoring (largely of personal loans and credit card applications), and prediction of failure models (to spot likely corporate failures in advance and so reduce risk). These techniques, although effective (particularly credit scoring) have largely been statistically based on historic data, and bear no resemblance to the actual methods used by the acknowledged experts in lending.

One area of considerable importance to banks is corporate lending. The decision making process involved in a corporate lending deal can be highly complex in nature, and it is becoming more and more so as customers' themselves become more sophisticated. As competition in the market place increases, there also the need to match what the competition is doing just to maintain market share. Banks also need to ensure that their levels of exposure to different types of borrowing are not excessive, and that higher risks can be effectively identified so that higher charges can be made to cover against bad debts.

As mentioned above, historically statistical techniques have been used to assist the banker. These have proved to be relatively ineffective for the corporate lender. Better tools are required and fortunately technology is now offering such tools in the form of expert systems. These systems, which have arisen from the much publicised research into artificial intelligence, now allow the coding of logic as well as numbers. This means that heuristics (rules of thumb), and other forms of human knowledge can now be coded in expert systems. Such systems are claimed to be able to tackle problems where there is uncertainty about data, and where there is no one "right" answer.

This project seeks to demonstrate that the problems being encountered in corporate lending can be tackled through the use of an expert system. This will be shown by identifying the problem areas and then demonstrating how the application of the technology can assist in the solution to these problems.

Decision making in corporate bank lending occurs at three levels within a bank. These can broadly be identified as:

i) the corporate strategic level (decisions about the balance between the bank's major lending areas - i.e. its lending portfolio);
ii) the business strategic level (decisions made within the areas identified above, generally lower level decisions, but still strategic in nature);
iii) the individual proposition level which comprises of the lending proposals made to branch managers and regional managers.

The project is largely concerned with the third type of decision, the individual propositions. However, all three levels are discussed as any complete solution through the application of expert systems will ultimately involve all levels of bank lending.

The following method is pursued in the project:

- The technology available to bankers in the area of corporate lending is identified and the terminology clarified.
- A review of past and current methods of lending is made with the author identifying potential future courses for corporate bank lending.
- An expert system is then developed to demonstrate how expert systems technology could be used to assist in the decision making process.
- The system is then validated to ensure that the knowledge entered is actually producing the "right" answer and thus that

expert systems are the right way forward in the future of corporate lending.

Given the time constraints imposed on the project only a limited and fairly simple expert system was constructed. Following the completion of the research this system was re-built using a different expert system shell (which was not available at the time of initial development). It was also extended considerably to take into account many factors identified in the research but impossible to include because of the time constraints. The completed system has now undergone live trials in a U.K. clearing bank prior to an expected full roll-out of it over the next six months.

## CHAPTER ONE - THE TECHNOLOGY AND TERMINOLOGY INVOLVED

Before any analysis can begin it is necessary to have a clear understanding of the technology and the terminology being used in the research. The areas to be covered in the project also need to be listed and explained. This is done over the next few pages.

### 1) DECISION SUPPORT SYSTEMS

Decision Support Systems (DSS) imply the use of computers to fulfil three roles in the management decision making process:

i) Assist the decision makers in their decision processing of semi-structured tasks.

ii) Support managerial judgement. (Rather than replacing it).

iii) Make the decisions made more effective rather than more efficient.

This break down of the role of decision support tools, from Keen & Scott Morton (1978), identifies the general purpose of a decision support system. Indeed it was Keen himself who first coined the phrase DSS. Put simply he states that DSS is a tool for:

> "helping people in organisations do their job better".
>
> Keen (1986).

For the purposes of this research the term DSS needs to be further refined to distinguish it from other, simpler, computerised tools which are able to assist the decision maker, in that they provide information; but are unable to actually support the decision-making process by offering insight to the decision maker. Finlay & Forghani (1986) draw together the elements of a DSS in their list of characteristics necessary for a DSS. In their paper the list compares DSS with MIS but for the purposes of a DSS definition only the DSS characteristics have been reproduced:

DECISION SUPPORT SYSTEM CHARACTERISTICS

| | |
|---|---|
| 1) Type of System: | Planning system. |
| 2) Focus: | Effective decisions, use of models, user friendliness, flexible, adaptable. |
| 3) Objectives: | Adhoc, contingent. |
| 4) Situation Type: | In given scenario. |
| 5) Design Perspective: | Individual, small group. |
| 6) Models: | Evolutionary logic, probabilistic data. |
| 7) Output: | User specified, insight, learning, intelligence. |
| 8) Time-Scale: | Present & future. |
| 9) Context: | Dependent. |
| 10) Implementation: | 'Breadboarding' |
| 11) Exactitude: | Accuracy. |

This list identifies the characteristics of a DSS. These characteristics describe a system which can be seen as open and unstructured. The decision maker is able to enter a problem into the system and then change the parameters and context of the problem to identify possible solutions.

Drawing the above definition into a banking context, decision support systems can be seen to be those systems that would find their role in decision making at strategic levels within banks. These are the types of decisions made by top management about such things as: which economic sectors to lend in; and which parts of the country to site bank branches (to take two widely widely differing examples).

Here the decisions are unstructured, and there is no one 'right' answer. Decision Support Systems, as defined above, can fit here to offer insight into the problems posed, allowing the decision makers to test different hypotheses about the problems.

## 2) MANAGEMENT INFORMATION SYSTEMS

A Management Information System (MIS) can be defined as:

"An information system using formalised procedures to provide managers at all levels in all functions with appropriate information from all relevant sources to enable them to make timely and effective decisions for planning, directing and controlling the activities for which they are responsible."

Lucey (1984).

This definition identifies the main features of an MIS, however before the term MIS can be examined as a whole the concept of "what is information" must be explored. Lucey has also defined information as:

"data that have been processed into a form which is meaningful to (its) recipient and which is of real or perceived value in current or prospective decisions or actions."

Lucey (1984)

The difference between data and information can very simply be seen to be one of purpose and value. Data on its own holds no value or purpose, whereas information has both value and purpose, and is thus able to convey knowledge to its recipient. Having defined information, the system as a whole needs to be broken down so that a true understanding of an MIS can be shown. This has been done by Finlay & Forghani (1987) who, using the same method as in their classification of DSS, have classified management information systems as shown below:

MANAGEMENT INFORMATION SYSTEM CHARACTERISTICS.

| | |
|---|---|
| 1) Type of System: | Internal control. |
| 2) Focus: | Efficient & structured, information flow. |
| 3) Objectives: | Pre-specified. |
| 4) Situation Type: | Within fixed policies. |
| 5) Design Perspective: | Organisational. |
| 6) Models: | Fixed logic, mainly deterministic data. |

7) Output: General format, An answer, information.

8) Time-Scale: Past, present & future.

9) Context: Independent.

10) Implementation: Prototyping of inputs & outputs.

11) Exactitude: Precision & accuracy.

In a banking context the above definition of MIS can fit into the decision making made by branch managers and those in area offices, where the decisions made are mainly of a pre-programmed nature. - A series of questions are asked along a pre-defined route which will lead to a decision being made. (For example, a simple personal loan application where a credit score is worked out by asking a number of pre-set questions).

3) ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) has been defined as:

"a subfield of computer science concerned with the concepts and methods of symbolic inference by a computer and the symbolic representation of the knowledge to be used in making inferences. A field aimed at pursuing the possibility that a computer can be made to behave in ways that humans recognise as 'intelligent' behaviour in each other."

Feigenbaum & McCorduck (1983)

Artificial Intelligence is essentially a new development in computer science which was largely activated by Japan with their 5th Generation Project, (i.e. the next computer generation). In the brief to the project research brief they stated that knowledge and information were the products of the future, and that they intended to be world leaders in systems which could handle knowledge (i.e. knowledge based systems).
The United States and Europe responded with similar projects aimed at examining the potential to put human knowledge into a computer.

Areas of investigation within the artificial intelligence arena have included the research into the development of 'smart' weapons, natural language processors, parallel processing, voice recognition, and expert systems.

## 4) EXPERT SYSTEMS

An expert system can be defined as:
"a computing system which embodies organized knowledge concerning some specific area of human expertise, sufficient to perform as a skilful and cost-effective consultant".

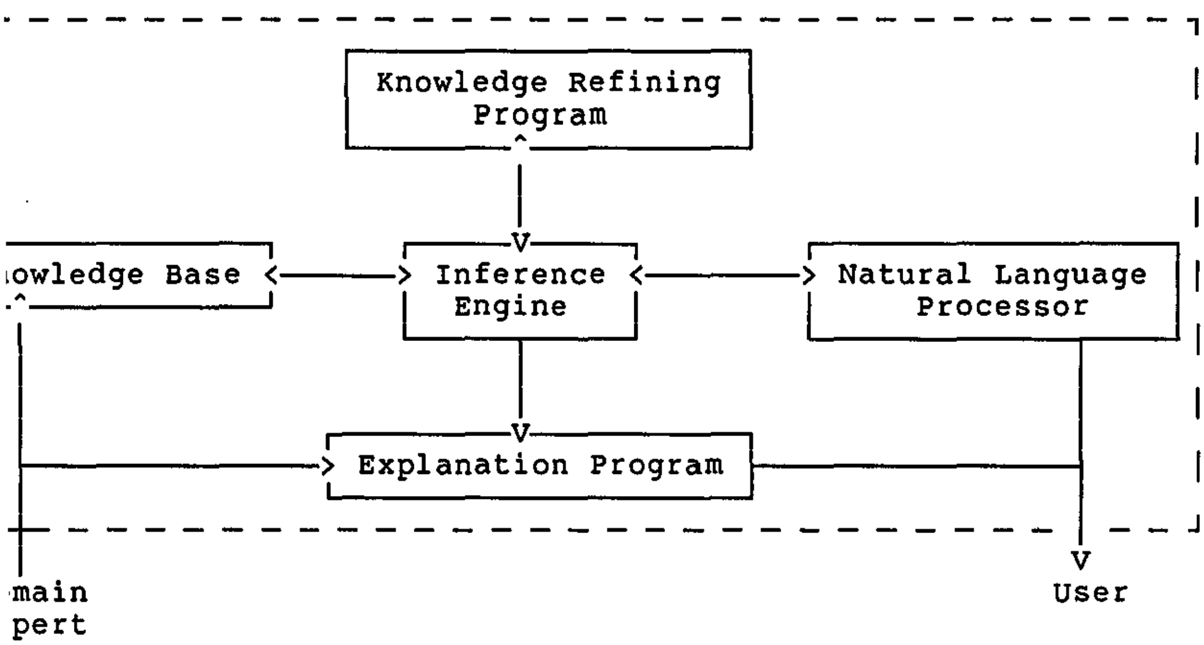
Bramer (1982)

From this it can be seen that an expert system is basically a special purpose computer program which is designed to capture the skill of an expert and pass this on to the user of the system.
This definition, although general in nature, highlights some of

the important areas in an expert system, namely the following:

- a computer program,
- a base of human expertise (knowledge),
- a means of consulting the system to access the stored knowledge.

These areas have been identified by Winfield (1982) who has also extended them to include a knowledge refining program and an explanation program, and has produced a diagram to show the relationship between these different components of the expert system.




**The knowledge base** is the expertise of the expert which is held by the system. This is usually in the form of rules, each being of the IF....THEN.... type. Rules such as these are the basis of most expert systems. They contain the knowledge from which any decisions made by the system at a consultation session are made.

**The Inference Engine** is the computer program which drives the system. It decides upon the order in which rules are "fired" (activated) and generally uses one of two methods; backward chaining (goal activated search) or forward chaining (data activated search). The inference engine will either be an integral part of the system, or it will be in the form of an expert system shell (when it is delivered together with the natural language front end and the explanation capability). In the case of a shell, this is simply an expert system which has an empty knowledge base. The developer only has to enter the rules to complete the system and get it working. This is becoming the common way of developing expert systems, as is evidenced by the plethora of expert system shells now available (some ten different ones at June 1987).

**The Natural Language Front End.** This is the user interface element of the expert system. Just as a human expert will attempt to respond in terms which the questioner can understand, so the front end of an expert system is designed to both ask questions, and answer queries in natural English; rather than giving a normal computer response. i.e. the replies to queries are geared to be understandable to people dealing in the domain of the experts, rather than to computer programmers.

**The Explanation Capability.** This is not mentioned explicitly by Bramer, however Winfield suggests that there is also a need for the system to be able to explain the way it reached its conclusion. It should also be able to answer WHAT...IF... questions as well. This would give the user insight into how the system is working. In terms of a general expert system, an explanation facility is vital if the system is to act in the role of decision support, i.e. as an advisor or consultant where the means of reaching a result are as important as the result itself. However, a simple query answering expert system need not have any explanation facility. The difference between the two types can be demonstrated in an example. A loan agreement system for use in branches by clerks seeking to agree loan requests does not need to be able to explain its reasoning to the clerk. However, the same system, if used by an experienced lender to give him advice on courses of action to take when evaluating a lending proposition, would then need to be able to justify its line of reasoning to the user.

**The Knowledge Refining Program.** In order for it to remain accurate, it must be possible to update the system as and when circumstances change. This is implied by Bramer in that this must be done if the system is to remain effective as a consultant. Winfield is more explicit and states that an expert system needs to have a program allowing access to the knowledge, to refine it as necessary. This indeed is essential if the system is to remain effective as circumstances change over time.

A final addition to this area is development of "self-learning" systems, where the system itself is able to update its own rules as new information is entered. This is possible to a limited extent with some rule induction packages, where new examples entered will change the rules generated. However, current technology is still some way off from a system which is able to adapt itself based on the queries entered and the feedback from the replies it gives. (For example, in bank lending a learning system would be one where the system could change its rules if some new accounting data from a company countered the figures "expected" by the system from its current knowledge base. The system would need to determine whether the new figures were flukes, or whether the information it had stored in its knowledge base was inaccurate.

All of the components identified together form a complete expert system. Expert systems can be used in any domain where the knowledge necessary to solve a particular problem in the domain can be put into rule form (or other forms which can be handled by the knowledge base). In banking this is particularly relevant in the lending field. Generally a number of pre-defined steps are followed when a lending proposition evaluated by a lending manager. These steps can be codified into a knowledge base and so an expert system can be developed to assist the lender in forming a decision.

## 5) VALIDATION AND VERIFICATION OF EXPERT SYSTEMS

It is important to define the terms validation and verification in relation to expert systems before any work is actually carried out to produce an expert system. Both verification and validation are involved with the testing of the system to ensure that it works satisfactorily, however this is where their similarity ends.

### EXPERT SYSTEM VALIDATION:

The validation of an expert system is concerned with ensuring that the system is giving an accurate representation of the domain expert which it is emulating. Fishman et al., when defining the term validation with reference to models state:

"model validation tests the agreement between the behaviour of the model and the real world system being modelled."

Fishman & Kiviat (1968)

This definition is suitable for the validation of an expert system as expert systems are basically models of the knowledge of experts in a particular domain (and the real world system identified can be seen to be representative of the expert's knowledge rather than of any tangible system).

Validation can be described as: the testing process whereby; entering a sample of known inputs into the system will produce a set of expected outputs. Here it is not the actual programming which is being tested but the ability of that programming to answer the queries posed by emulating the process used by the expert.

EXPERT SYSTEM VERIFICATION:

Verification of an expert system is concerned with the actual programming of the system. Here the emphasis is on the system builder rather than on the expert. Gass provides a good definition of verification for computer based models when he says that verification is:

"the process of demonstrating that the computer program 'runs as intended'".

Gass(1983)

For the purposes of the research, verification can be seen to be a part of the process of validation. Both activities are on-going through the development and the life of the expert system, and both are essential if the system is to be effectively tested in its role as a replacement for the expert.

Validation and verification are both seen as very important concepts in the development of an expert system and so they are discussed in full in a later chapter.

6) KNOWLEDGE ACQUISITION (ELICITATION)

The process of knowledge acquisition (by which knowledge is turned into a codable state) has been seen as a bottleneck in the development of expert systems. Few techniques have been developed that can fully elicit an expert's knowledge effectively and quickly. Several methods have gained some acceptance and the more common of these are listed below:

1) By protocol analysis. Watching the knowledge holder and developing the rules out of the actions he takes when faced with different situations designed to require the use of the knowledge.

2) By interview. Questioning of the knowledge holder. Asking him questions which are designed to expose different aspects of the knowledge. A number of different interview techniques have been identified to elicit different types of knowledge.

3) By rule induction. Here the knowledge holder is asked to give examples of what he would do in certain situations (i.e. when faced with different problems). These examples are then evaluated using the rule induction technique to develop a rule. This rule can then be placed in front of the knowledge holder for checking and verification, changes being made as necessary if it is inaccurate.

4) By forward scenario simulation. The expert is posed a number of hypothetical problems which are then solved in front of the knowledge elicitor.

5) By multidimensional scaling techniques. The knowledge is split into its component parts and then the relationships between the parts are described by the expert.

Where these techniques have been used in the project they are discussed in detail in Chapter Four.

7) KNOWLEDGE REPRESENTATION

In the description of knowledge acquisition above, knowledge was simply represented in the form of rules. Rules, however, are only one technique that can be used to represent knowledge in a form that can be codified into an expert system.

Generally a different method of knowledge representation has been developed for each type of knowledge identified. There are five main types of knowledge than can be represented currently:

i) Causal Knowledge - The knowledge that states the way in which Object A affects (or does not affect) Object B. For example:

If the traffic light (Object A) is green (state of A)
Then car (Object B) can proceed (state of Object B).

ii) Object Knowledge - Static knowledge about an object. In the above example a part of the object knowledge for Object A is that it is green. Object knowledge is generally descriptive.

iii) Process Knowledge - The knowledge which states how a pre-determined process should be carried out. This knowledge can be typically shown in a traditional computer program.

iv) Meta-Knowledge - Meta-knowledge is knowledge about knowledge. It is basically knowledge about how a piece of knowledge will react to changes in its environment.

v) Performance Knowledge - Performance knowledge (otherwise known as compiled knowledge) is knowledge which is so engrained in the expert that he is unable to describe how he uses the knowledge. A typical example of compiled knowledge is "how to ride a bicycle". There is a lot more to it than simply sitting on the seat, balancing, and then turning the pedals!

For each of the types of knowledge identified above, expert system developers have tried to produce tools capable of accurately and efficiently representing the precise meaning of the knowledge.

Most of these methods have developed out of the most general representational scheme: the semantic network (or net). Here, objects are linked together in a network which describes the inter-relationship between them. The objects (called nodes) may be physical objects (hat, ship, pen etc.), conceptual objects (acts, events etc.) or abstract objects (a number, a place etc.). Objects have knowledge about them stored with them (called descriptors). Links relate objects and their descriptors and other objects. A typical link might be "is-a" or "has-a" or "causes". For example, a dog "is-a" mammal. The representational methods which have emerged are described below:

i) Causal Knowledge - Fits very easily into production rules of the "IF X.. THEN Y" variety.

ii) Object Knowledge - Can be represented by frames. These can be likened to a relational database type structure, where the knowledge about an object is stored in "slots" attached to the object. These "slots" are then carried with the object (inherited) wherever it is used or referred to.

iii) Process Knowledge - Is very simply represented by traditional programming languages in the form of structured procedures which tell the system how to follow a precisely defined path.

iv) Meta-Knowledge - Can be represented by any of the three techniques described above, depending upon the type of meta-knowledge to be represented.

v) Performance Knowledge - Is very difficult to represent, as the knowledge itself is largely transparent and is subconsciously accessed. A technique to represent such knowledge involves the reverse engineering of the knowledge acquisition procedure that the expert originally used, i.e. going back over the original learning process in reverse order to generate the processes learned by the expert.

NOTE: For the purposes of the research the only knowledge representation technique available (within the expert system) was production rules. This obviously limited the scope of the representation of the expert's knowledge. However at the time of the development of the prototype no expert system shells offering the other representation techniques were available on personal computers. This situation has now changed with the arrival of Leonardo (Creative Logic Ltd.) and Egeria (I.S.I. Ltd.). This did not prevent an effective model from being produced, however it did reduce considerably the efficiency of the system.

# CHAPTER TWO - A REVIEW OF BANK LENDING AND ITS FUTURE

## TRADITIONAL BANK LENDING TECHNIQUES.

The traditional method of lending to the corporate sector has been formalised in many text books and training divisions within the banks: indeed, it is true to say that because of the Institute of Bankers and its universal examination system in lending, the methodology employed in lending is similar across all the U.K. Clearing Banks.

The basic lending technique can be classified into six elements which are all examined when a lending proposition is analysed. These are listed below. The elements may differ in name between the banks but they are basically the same.

1) The Borrower - His integrity and reliability. The money being lent belongs to the depositors and shareholders of the bank and so every effort needs to be made to avoid bad debts. The whole success of any lending proposition will usually depend on the true representation of the facts by the customer, and on his ability to carry through the proposition to a satisfactory conclusion. This should include an examination of the borrower's financial standing, e.g. company financial and management accounts, to ensure that the borrowing is being made by someone who has a sound and stable background. In set-up situations the personal

financial background of the borrower should be examined to establish this ability.

2) The Nature of the Proposition - Its purpose, duration, and amount. It must be clearly established that bank funding is the best option for the potential borrower. The potential returns of the proposition itself must also be clearly considered exclusively from the present state of the borrower to determine whether it is actually worthwhile undertaking.

3) The Amount - The exact amount required should be carefully calculated separately from the amount requested by the customer to ensure that the requested amount will be satisfactory to adequately cover the venture. This element should also raise the question of the borrower's stake in the business which should be known by the bank, and generally not exceeded in the lending. (Other than in certain specific situations such as venture capital lending and management buy-out situations).

4) Repayment Programme - A clearly defined repayment programme should generally be required. The source should also be obvious and the size of the repayments should be geared so that they do not themselves over-stretch the borrower. This should be established from the accounts of the borrower, especially taking into account future

predictions so that borrowing requirements in the future can be calculated.

5) Security - A good proposition should stand on its own. However the risk element of a borrowing proposition should, where possible, be covered by security. Where a proposition is bad, no amount of security should warrant the advance being granted. Security, when taken, should ideally be readily realisable and of a steady increasing value.

6) Value of Customer (Connections) - In cases where the proposition is less than ideal it may be agreed because of the customer's connections. For example, lending money to the student son of a company managing director may bring the company business to the bank.

Robbie et al. (1983)

For each of the elements described above only a very general picture has been drawn. In reality the elements serve as pointers to lending officers, focusing their thoughts on the particular areas mentioned. The actual lending decision is birthed by a combination of the above, together with experience gained from past lending, and knowledge of banking; both in terms of practice and theory.

## DEVELOPMENTS IN LENDING TECHNIQUES

In spite of the relative stability in lending methods adopted in banking, the traditional method of lending (as summarised above), has been challenged by some (eg. Beaver (1966) & Argenti (1976)) since the late 1960's and early 1970's. This has been due to two main reasons:

(1) A spate of large corporate bad debts forcing the banks to tighten up their credit control.

(2) Banks have also faced increased competition from each other, and also from foreign lenders and other finance houses. This competition, together with pressure from within to increase profitability has meant that they have had to look to new ways of improving their profitability, the bulk of which has traditionally come from advances.

These two challenges have led banks to search for new lending techniques to enable them to both improve credit control (and so reduce risk), and improve market positions and profitability, through more efficient and more effective lending. The major developments which have enabled this to happen have arisen in four main areas:

1) Use of Prediction of Failure models to produce indicators of the likelihood of a company failing. These models have developed along two avenues. First the use of qualitative data about a company to predict failure; and second, the use of quantitative

data to predict failure. Both methods need further examination and comparison to show how they seek to identify the causes of failure. However, before any effective comparison can be made between the two types, a definition of the term failure needs to be established. A good definition is given by Storey, Keasey et al. who regard a company as failed:

"when it has ceased trading and when there is no likelihood of it restarting".

Storey, Keasey, Watson & Wynarczyk (1987).

This definition is simple but it will adequately serve to allow a comparison between the qualitative and quantitative approaches. Both approaches can be identified by looking at the process of business failure. This is most simply displayed in the form of a diagram:

| CAUSES | | |
|---|---|---|
| DEFECTS ---------------> | MISTAKES -------------> | SYMPTOMS |
| eg. Management not responsive to change in markets. | eg. Bad planning & control | eg. Balance Sheet ratios, personalised number plate. |

The qualitative approach examines the causal side of the above diagram, i.e. seeking to identify the problems in management and mistakes made by them (eg. planning and control errors). The main proponent of this approach has been Argenti (1976) who argued that, in terms of establishing the underlying reasons behind a business failure, financial ratios are only of limited use. He said that to find the true causes the reasons behind the figures had to be exposed. This led him to develop a dynamic model of business failure which did not rely on financial ratios. Storey, Keasey et al. have described the model in which failure is viewed:

"in terms of the interaction of a number of inherent defects in the actual organisation and financial structure of the company with changes in the macro-economic environment and the occurrence of 'normal business hazards' such as strikes and the loss of a large customer".

Storey, Keasey, Watson & Wynarczyk (1987).

From within this framework Argenti was able to identify three typical paths which a company might experience in the period leading up to failure. These being in the areas of: management weaknesses (for example, the presence of one dominant individual on the board ignoring the advice of others); technical and commercial problems (inability to serve the market because of technical deficiencies); and, financing problems (in his thesis he suggested that the chief cause here was over-borrowing).

Argenti was able to offer little empirical evidence for his model, (other than two studies of large companies), so it is difficult to accept his findings unreservedly. However they do offer a framework within which to direct a search for the causes of company failure.

More recently research has been undertaken into company recovery using qualitative techniques. One such advocate of a predictor of recovery is Slatter (1984) who set out ten common strategies used in successful turnarounds. These strategies go beyond the scope of this research however, as they begin at the stage where a bad lending decision has already been made.

The quantitative approach was developed far earlier (in the 1960's as opposed to the 1970's) than the qualitative approach and it seeks to examine the symptoms of company failure. Here the focus is on the financial records of the company - normally the audited balance sheets and profit and loss accounts. The basic method has been summed up by Boocock when he states that:

"a sample of companies which have failed is compared with an equivalent sample of companies remaining solvent (to establish a ratio which is a good predictor of failure, i.e. one which produces values which can distinguish solvent companies from failed companies)....Once a predictor of failure has been established, the quantitative techniques are used to identify presently trading companies which might be at risk of failure"

Boocock (1987), (parentheses mine).

The production of a predictor of failure has evolved in two directions: uni-variate analysis and multi-variate analysis. Both of these techniques use ratios to identify possible failure symptoms.

Uni-variate analysis is basically the process of examining a series of single ratios to establish which ones (on their own) are good predictors of failure. The best known advocate of the uni-variate technique is Beaver (1966). He examined the financial statements of a matched (in Boocock's terminology: equivalent) sample of 79 failed and 79 non-failed companies. He compared a large number of financial ratios over time by examining their means between the solvent and failed companies (derived from a theory of a cash flow model) and found that the means of six of the ratios varied significantly between failed and non-failed companies. He concluded that the examination of these ratios singularly up to five years before a potential failure could identify the failure.

There are many criticisms of this approach, however these are beyond the limits of this description of the technique, as its purpose is simply to highlight the method used. (A full analysis of these criticisms can be found in Storey, Keasey et al. (1987)).

Multi-variate analysis evolved out of uni-variate analysis as financial analysts realised the limitations of relying on individual ratios examined in isolation as an indicator of failure. (Often more than one ratio was examined (eg. Beaver) but each ratio was examined independently). The approach undertaken is basically the same at its outset, in that a series of ratios are compared between failed and non-failed companies. However, the ratios are not treated in isolation. A statistical technique known as multiple discriminant analysis is used to classify the companies (failed vs. non-failed) on the basis of a statistic (eg. a Zeta or Z-score) which is a combination of ratios that best separates the failed from non-failed companies. The technique involves examining repeated combinations of variables until the best predictor of failure emerges. There have been many different studies undertaken (in excess of 100) to calculate an effective Z-score, the most famous being by the pioneer of the technique, Altman (1968). The most recent article of this genre is that of Storey who examined 636 companies in his study, Financial Times (10/2/87). Multi-variate techniques also have their critics, based largely on the complicated nature of the indices and the ability to get all of the data necessary to identify a failing company. However, these are also beyond the scope of this description. One factor is important though; this is the use of historic data in the analysis. Company failures can be predicted only one or two years before collapse, and this is only when all of the data needed by the model has been supplied. As bank lending (other than simple short run overdrafts) is generally over terms greater than two years, the use of such models is severely limited. In saying this the researcher also realises that any method of identifying possible failure can become a useful tool to the banker, and indeed the banks are increasingly looking at prediction of failure techniques to analyse propositions, and more importantly given the time scale of the models, to monitor their current lending.

2) The use of credit scoring techniques to establish the risk of a proposition based on previous experience. This technique has

mainly been used in the personal sector (indeed in most banks all personal lending is now done by credit scoring), however the small business sector in at least one bank is now being evaluated by credit scoring.

Credit scoring works in a very similar way to the establishment of a predictor of failure described above: Indeed it can be viewed as a very simple form of prediction of failure model. Matched pairs of accounts (good and bad) are examined to find any factors which vary greatly between good and bad cases. Cut off points for each factor are then calculated and an index is produced to identify both the factors which demonstrate the differences best, and the values of these factors between good and bad cases.
In doing this a very basic risk index is produced. The bank can then lend against this index knowing that if a case scores higher than a given "risk acceptable" score its level of risk will fall within an agreed range for the borrowing. This does not mean that the case will necessarily be good. What it does state is that given a sufficiently large enough sample the bank can be assured that only x% will go bad. (x being agreed by the bank before-hand as the maximum amount of bad debts they are prepared to accept. Obviously as x tends to zero the number of cases which will be accepted will also tend to zero).

3) Increasing use of lending packages, where the bank seeks to tailor the lending to the needs of the borrower. For example,

entering into share ownership (venture capital deals), and leasing, as well as the more traditional short term financing of working capital. Here the bank is looking to increase its lending by offering the customer a complete service to cover all his financial requirements, while it is also seeking to reduce its risk by having a far greater control over the actions of the customer. The customer is also better served as he is able to use the correct types of financing to meet his varying needs - avoiding the financial strain of using incorrect financing. (eg. the strain on liquidity caused by over reliance on overdraft facilities).

This area has been extensively researched by Robbie, Coulbeck & Moulds. They demonstrate its importance as changes are taking place within banking when they state that banks, in the eyes of the borrower, do not simply lend money but:
"make a college education possible;... build a home;...expand employment opportunities in a community"

Robbie, Coulbeck & Moulds (1983), quoting Capaldini (1974).
Although this is essentially an American view, it is becoming more prominent in the U.K. as the use of bank credit is becoming more acceptable.

4) Education of the borrowers. Encouraging them to think out their requirements before coming to the bank for finance. Most of the banks have now produced booklets and advice for borrowers on business plans and management accounts, to show them how they

can monitor their businesses more effectively and how they can best present their case to the bank when requesting finance. (eg. See National Westminster Bank (1986)).

These four areas, although very different in application, all have the common thread of attempting to make bank lending safer, and therefore more profitable, while at the same time allowing the overall level of lending to increase with the ability to minimise the additional risk encountered.

## EXPERT SYSTEMS IN BANKING

Over the past ten to fifteen years a new area in computing technology has emerged - the area of artificial intelligence. Many steps have been made towards the development of computers that are able to represent human intelligence. The ability for a computer to "think" for itself is still a dream in the minds of computer philosophers, however some would argue that computers can now create new knowledge and so the next step of "thinking" is very close. Michie & Johnston are two such advocates clearly revealing their beliefs in the new technology when they state:

"Poverty, hunger, disease, and political strife are widespread, and new technology is often held responsible, but now solutions to these problems are within sight, and the solutions are going to come from computers.....computers (that) genuinely create new knowledge in a way that was long thought impossible".

Michie & Johnston (1984), (parentheses mine).

Although the true artificial intelligence realm is still many years in the future, the research into this technology has had several commercial successes, the most notable one being the area of expert systems. It is this area that offers the most hope for the solution of logic related problems by computers today. Friis has said that:

"expert systems are designed to make the knowledge of experts in particular subject areas available to others through the use of computer terminals. In commercial applications such as banking, the primary objective of these systems is to make the knowledge of the most experienced members of the organization readily available to less experienced people as an aid in their decision making".

Friis (1985).

This description presents a useful focus to identify why banks are now beginning to examine the expert systems technology as the next step in their development of more efficient and effective lending methods. A fuller definition of expert systems which is required for the research undertaken can be found in Chapter One.

The use of expert systems in banking is still largely in its infancy. There are as yet only a handful of fully developed systems in operation across the world, (less than 20% of banks surveyed by Coopers & Lybrand have applied expert systems on a pilot or full scale basis. Willis (1986)). The U.S. is several years ahead of the U.K., and as such it is from the U.S. that many of the different uses described come. Before a description of typical banking uses given, it is necessary to highlight the improvements which can be made by the application of expert system technology. Turner (1987) has provided list for the area of loan appraisal:

1) Focusing both analysis and customer interviews to reduce overall analysis time and to spend less time on obviously bad loans.
2) Streamlining review of existing loans while identifying early warning signs.
3) Ensuring awareness of and adherence to relevant bank policies.
4) Encouraging thorough, thoughtful analysis of new loans without the need for time-consuming supervision.

Onto this list need to be added the benefits for other more general banking expert systems:

5) Taking over of the more routine (yet sophisticated) duties of senior personnel, freeing them to pursue the more challenging aspects of their jobs.
6) Putting the knowledge and judgement of recognised experts at the fingertips of novices, supplementing their experience and expanding their capabilities.
7) Performing many clerical tasks, which have until now resisted automation.

8) Making many complex services inexpensive enough to offer to 'down-scale' customers for the first time.

From Wiig, Rockwell et al. (1986).

These potential benefits have led many banks in the U.S. (and worldwide more recently) into researching the expert system field. Some of the areas currently being examined include: cash management advisors, and a foreign exchange arbitrage system (all Security Pacific Bank); investment portfolio management system (Generale de Banque, Belgium); foreign exchange currency predictor (Data Logic software house); loan applications assessment system (Robson Rhodes Accountants, Valley National Bank, Mellon Bank, Citibank, Midland Bank, TSB Group, Co-Operative Bank, and several others); securities system (TSB Group).

An Ovum report on expert systems in finance (1988) suggests that this research has been far from problem free. The development costs have been large in terms of monetary outlay, time and commitment. Syntelligence Inc. (a software house) demonstrate the scale of the monetary costs in the price of their own, off the shelf, system which is being sold for between $250,000 and $500,000. The other costs have largely come through the need for total commitment to the systems for them to work effectively. In the U.S. where working systems have already been put into operation there has been much reluctance from management, fearing that their jobs might be at risk. This has been so prevalent that the Expert System Team at Security Pacific Bank have totally avoided the terms "expert systems" and "artificial intelligence"; replacing them instead with the term "expert assistant". This was done:

"to convey the idea that these systems extend the capacities of people, that they are not designed to replace humans and their thinking processes."
Friis (1985) quoting Heinen, vice president, AI-based Activities, Security Pacific Bank.

As seems to be typical in banking, a mnemonic has appeared to assess the use of expert systems in bank lending. The "Three C's" have been put forward by Andren (1987). These consist of:
1) Cost - What will the cost be in dollars (pounds), manpower, and hardware to develop the system?
2) Capacity - Does the bank have the necessary resources to carry off the project?
3) Commitment - Does the bank have the commitment to stay with the project? This is particularly relevant as results will not come overnight, and may require much effort before any return is gained.

In conclusion, expert systems have a role in the future of banking in many areas of their business. This is particularly the case in loan assessment where much of the research to date has centred. Banks need to extend their lending if they are to keep up in ever stronger markets; but the costs in training staff to lend are high. i.e. The development of "experts" is expensive and takes a long time. It has been shown that expert systems can cut these costs by making the expertise of a small number of experts available to all staff. I doing this they will reduce training time and expenses, allowing the bank to compete more effectively. Summing up is probably best left to Wiig et al. who more than adequately assess the need for expert systems in banking:

"AI has made its debut in the banking industry, attracting many of the industry's biggest players. The potential rewards are rich; AI systems can differentiate a bank's product offering (in a market where such advantages are hard won) and cut its outlays for both clerical and professional services. And, although new users face the challenges and uncertainties associated with a new technology, they can minimise these risks by learning before doing, and then proceeding with a well-reasoned development program based on a firm understanding of the field. It is those who do nothing who will face the greatest risk: the risk of being left behind".

Wiig, Rockwell & Martin (1986)

It is on this basis that the research is justified. There is a need for banks in the U.K. to respond more to challenges like this if they are to be able to compete effectively against the users of the technology in the future; and this is the purpose of the research: to provide a basis for the development of a banking expert system for the corporate lending sector.

# CHAPTER THREE - THE AVENUES OF APPROACH

## EXPERT SYSTEMS IN BANK LENDING

The role which expert systems can have in bank lending is determined largely by the overall lending strategy employed by individual banks. For the purposes of the research one particular strategy has been set out. This strategy has been developed out of a paper produced by the author of the research and Finlay (1987). The paper outlines what is believed by the authors to be the best approach for bankers in the future as the new technology is embraced. The reasoning behind the paper came from two views: the systems view provided by Finlay (a systems analyst), and a banking view provided by the researcher (from his own personal experience and from discussions with senior bankers and banking academics).

Before the view given in the paper is discussed, it is necessary to outline other avenues of approach open to bankers, as the approach adopted in the research is only one of several which could have been taken. These other methods were rejected, not because of any inherent faults in them, but simply because the researcher cannot see them being adopted in the future as new technology developments allow more effective methods to be employed. (This view arose out of discussions with bankers directly concerned with strategic policy implementation in their various banks). As only descriptions are given, no evaluation is made directly, other than the fact that the full analysis of the preferred methodology shows up the problems in the other methods.

Three basic approaches have been identified. These can be termed: The Portfolio based approach; The Lending based approach; and the Hybrid approach. The first two of these are extremes and the last approach is a compromise between the two extremes.

## THE PORTFOLIO BASED APPROACH.

This approach to bank lending is the most radical change away from present bank practice. It involves the use of the new expert system technology to form a centralised decision making function for lending at head office. All banking would be based around centralised account managers and so all information would be geared to meeting their needs.
In this system branches would become purely service outlets from which banking salesmen could sell the bank's products. Lending in its conventional sense would become extinct, with the portfolio managers "lending" based on their portfolios rather than on an individual basis. This can best be explained in the form of an example.

The portfolio manager would analyse his portfolio, deciding the areas to be lent to in order to obtain the best return on his investment, and to limit his exposure in a particular field. This information would be remitted electronically to the branches where the "salesmen" would then go out to potential customers in the areas identified to try to "sell" the bank's products to them. These salesmen would be trained, not in bank lending, but in selling, and they would also have a deep knowledge of the industries identified as potential customers.

In order to facilitate such a shift away from the security of tried and tested lending techniques, an accurate measure of risk would need to be developed to ensure that lending standards would be maintained. It is here that the expert system would fit. By producing a sophisticated adaptive credit scoring model for corporate lending, banks could identify the risk of each type of borrowing requested, and so lend based on the acceptable level of risk, rather than on the individual ability of a customer to repay.

This method is clearly a radical departure from traditional bank lending and to many bankers it appears, at a first glance, to be utterly ridiculous. However, on reflection it will be noticed that much of the personal lending now carried out by banks and credit card organisations is beginning to follow this pattern. The high level of sophistication required for such a system is not yet fully evident but the principles are the same. Indeed, some U.S. Venture Capital Institutions are already successfully using portfolio techniques to identify industries in which they want to place finance.

## THE LENDING BASED APPROACH.

This approach is the total opposite from the one described above. It follows very similar lines to the methods currently used by most banks in their corporate lending. The new technologies would be used as a back up to the present lenders, providing them with faster and better information regionally.

Lending would be based on the needs of the customer rather than directly on the profit maximisation of the bank. (With the assumption that successfully meeting the needs of profitable customers will in the long term maximise profits).

The use of expert systems would be limited to assisting lending managers by sieving out propositions which would obviously be rejected, and acting as an electronic "aide memoire" to ensure that all aspects of a proposition were covered. In this case the expert system would not become an electronic credit scoring model, but an emulator of the present lending decision process.

## THE HYBRID APPROACH.

This is the approach which has been recognised by the researcher as the most suitable. It utilises the beneficial parts of the above two approaches and develops a strategic model for bank lending from these. This approach is developed in detail below.

## IT FRAMEWORK WITHIN WHICH EXPERT SYSTEM WILL RESIDE

As identified in the Introduction, decision-making in bank lending can be broadly categorised into three areas. At the top level there are the corporate strategic decisions concerned with the balance between the bank's major activities. An example of this is the level of activity the bank thinks wise in such areas as sovereign lending and lending to the corporate sector.

Within each of these sectors there are lower level decisions to be made, which are nevertheless strategic in nature. These can be termed business strategic decisions. Taken within the strategy for corporate lending for example, business strategic decisions would be concerned with the balance between the types of industries and businesses within the bank's portfolio.

The two strategic levels of decision-making provide the framework within which individual lending propositions would be appraised and it is this level which makes up the third category of decision-making, comprising the individual lending proposals evaluated by branch managers and regional head offices.

The strategic decisions and the evaluation of individual lending propositions are essentially different in their make-up. To follow Dermer's terminology (1977) the strategic decisions are mainly unstructured: in contrast, the evaluation of individual lending propositions is a structured activity. Here a number of pre-defined steps are followed within a fixed, externally defined policy.

MANAGEMENT INFORMATION AND DECISION SUPPORT SYSTEMS.

The distinction between Management Information Systems (MIS) and Decision Support Systems (DSS) has been discussed by many authors, most recently by Finlay and Forghani (1987). This view categorises DSS and MIS through a number of key elements. A part of their classification is reproduced below. (This is a development of the two diagrams shown in Chapter One). This division of the systems into their key elements makes it possible to examine (unstructured) strategic decision-making and the (structured) evaluation of individual lending propositions to establish whether they are best served through the development of a DSS or an MIS.

| Characteristic | M.I.S. | D.S.S. |
|---|---|---|
| 1) Type of System: | Internal Control. | Planning Systems. |
| 2) Focus: | Efficient & Structured. Information Flow. | Effective Decisions Use of Models, User friendliness, flexible, adaptable. |
| 3) Objectives: | Pre-specified. | Adhoc, contingent. |
| 4) Situation Type: | Within Fixed Policies. | In Given Scenario. |
| 5) Design Perspective: | Organisational. | Individual/Small Group. |

| | | |
|---|---|---|
| 6) Models: | Fixed Logic, Mainly Deterministic Data. | Evolutionary Logic, Probabilistic Data. |
| 7) Output: | General Format, An Answer, Information. | User Specified, Insight Learning, Intelligence. |
| 8) Time-scale: | Past, Present & Future. | Present & Future. |
| 9) Context: | Independent. | Dependent. |
| 10) Implementation: | Prototyping of Inputs & Outputs. | 'Breadboarding' |
| 11) Exactitude: | Precision and Accuracy. | Accuracy. |

It is clear from an examination of the above diagram that the strategic decisions display all the characteristics listed in the DSS column. Of particular concern for the subsequent discussion, is the view that DSS are not producing answers themselves but acting as a vehicle through which a decision-maker can obtain insights and thus learn about his system and its environment. The end result of using a DSS is to create intelligence, a term not used with its common meaning of 'nous' but as:

"the outcome of the meshing and reconciliation of a set of information carrying inferences."

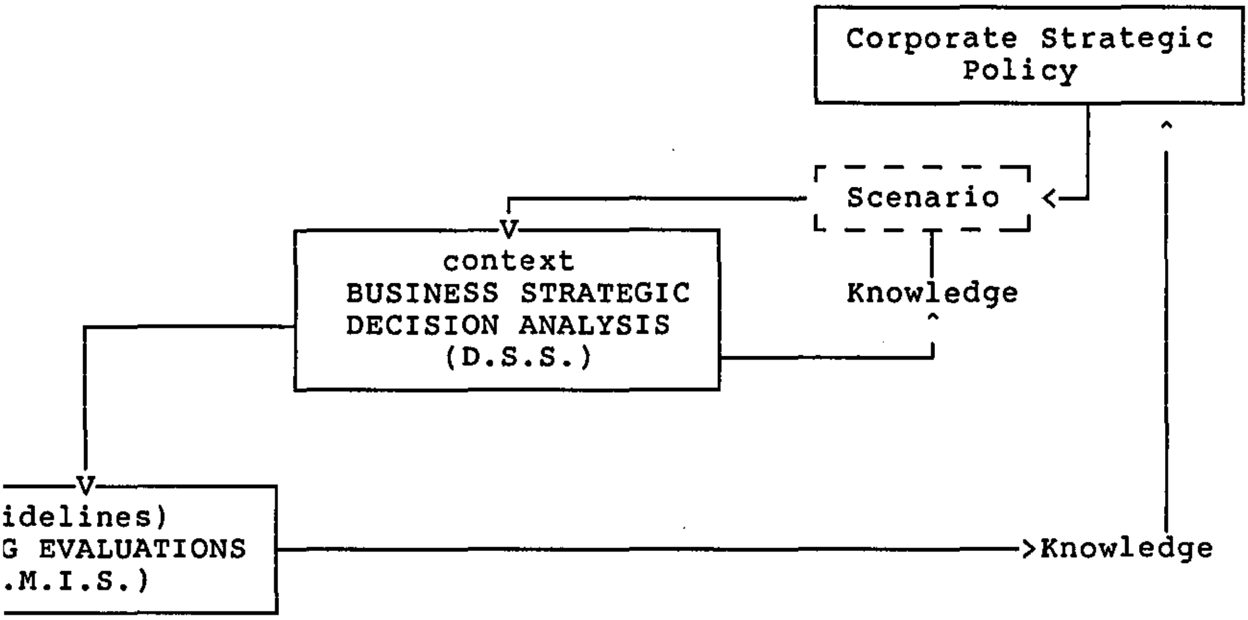
Murray (1979).

It is also important to note that the processing and required outputs are context dependent - dependent on the decision-maker himself, and on the circumstances he finds himself in.

The characteristics of decisions made by bankers when evaluating individual lending propositions can be seen to fit closely those listed in the MIS column above. One point of possible contention concerns the focus of the system on the flow of information. An MIS geared towards lending evaluation needs to produce an effective decision rather than concentrating on information flow. This could be resolved by placing some form of front end onto the MIS in order to produce an 'answer'. Indeed this is suggested in Section 7 where MIS are seen to be required to produce 'an answer'.

## THE LINK BETWEEN STRATEGIC DECISIONS AND THE EVALUATION OF INDIVIDUAL LENDING PROPOSITIONS.

Although the strategic decision-making and the evaluation of individual lending propositions are of different types, they are not mutually exclusive. The strategic decisions provide the policy under which the lending propositions are to be evaluated. However, a feedback loop is also in operation. This loop acting as one of the inputs in the strategic decision-making process, as shown in the diagram below.




In the diagram the scenario equates to the overall policy produced by the corporate strategic decision-makers, and it is from this that the business strategic decision-makers draw the basis of their decision-making process. The link between strategic decision-making and the evaluation of individual lending propositions is only present in banks where lending directives are made to managers, requiring them to fit within an overall, well-defined bank lending portfolio. At present the policy link does not appear to operate in any formal way amongst the UK clearers (i.e. the main link in the diagram is weak). However, talks with lenders seems to indicate that such controls are likely in the future.

## IT SYSTEMS TO AID STRATEGIC DECISIONS.

Decisions made at the business strategic level are normally about the contents of the bank's lending portfolio. Such decisions made by the portfolio manager will be based on his portfolio preferences and upon his exposure in a particular area.

IT support systems for strategic decision-making cannot rely totally on pre-determined algorithms and logic, since the factors influencing the decisions are context dependent: it is thus not possible to pre-define them. In such a situation the current generation of expert systems will not offer much in the way of support. Systems are required, which will offer the decision-maker a means of enhancing his intelligence through insightful learning.

## IT SYSTEMS TO AID INDIVIDUAL LENDING EVALUATIONS.

Individual lending propositions are usually evaluated by examining a number of pre-defined criteria (see above) which are combined to produce a decision for or against the proposition. The majority of the criteria are objective and readily quantifiable. This means that, in principle, they can be computerised and placed into an MIS. This allows manipulation of the data to be carried out to the lender's specifications. For example, accounting data can be summarised on a spreadsheet and then the salient points can be highlighted. In order to fully support the lender however, the MIS has also to be able to deal with subjective data: indeed, this is the type of data that the bank manager would be collecting and attempting to evaluate. As conventionally developed, MIS do not have the ability to deal with subjective data easily. However, expert systems can be created to do this.

## EXPERT SYSTEMS

Expert systems, as defined in Chapter One, offer an ability to take subjective data and use the experience of the knowledge supplier to evaluate them. In the case of bank lending, the knowledge base is the distilled knowledge of experienced lenders.

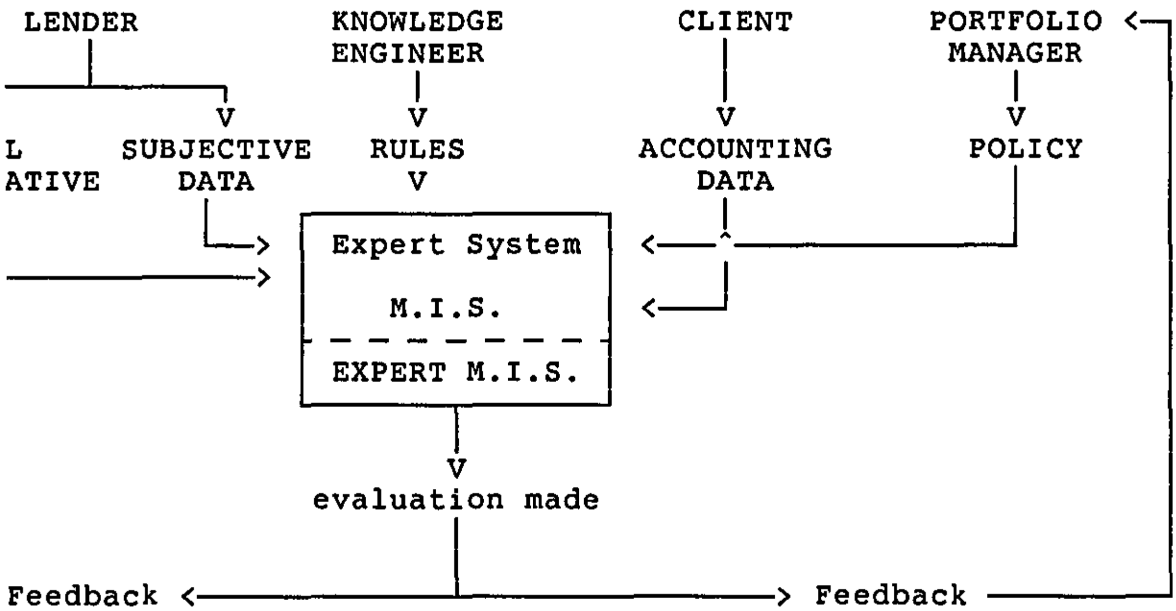
Systems of the type described above are already in use in some expert domains, examples being: Prospector - a system which discovered mineral deposits missed by geologists; and DEC's XCON - This was developed to solve configuration problems in VAX computer systems.

The XCON system has been estimated to have saved DEC many hundreds of man hours by substantially reducing the potential for later maintenance problems. The need for systems such as these in bank lending was recognised by Zocco when he commented that:

'every bank would like to have an individual or a group of individuals with a high degree of knowledge, experience, and expertise on the front line making every loan decision. Unfortunately, that is not possible for two reasons. First, the bank may not have an individual with that degree of expertise. Second, even if that person existed within the bank, he may not be able to make decisions on every loan. Expert systems are designed to address these situations."

Zocco (1985).

He then went on to develop a model of a banking expert system containing characteristics similar to that described in the diagram below. This draws together the characteristics of MIS and expert systems to create a picture of an IT system appropriate to support the evaluation of individual lending proposals. The model below is different from that described by Zocco (1985) in that it is far broader based, and has been developed as a part of a total IT strategy for corporate bank lending, rather than as a stand alone expert system.




The information needed to make an evaluation of an individual lending proposition is drawn from four sources. The portfolio manager provides the information on policy (e.g. lending directives). The knowledge engineer produces the rules on which the system is based, and the client provides data about himself (e.g. company accounts, bank accounts, customer record). The lender then adds any local information and relevant subjective data, (for example, his view of the customer's business acumen), but only as requested by the expert system. These factors are then processed by the system and an evaluation is produced. This may be a straight forward acceptance or refusal decision, or it may be a request for further information. In some cases the IT system may refer the whole evaluation to the lender if a solution cannot be found. For example, this might happen where there is irreconcilable data. In these cases the system can still assist the lender by offering a report of its evaluation process, showing the information used, and the clashes found.

The system thus described has assumed that the best way to assist the lender is to emulate his decision-making process following the 'rules' of lending to produce a decision. It must be emphasised that this is not the only way that a lending expert system could be developed. The other alternative would be to produce a form of adaptive credit scoring system which could be developed in the same manner that current credit scoring models have been created, simply placing the questions and answers into the expert system and allowing it to make the decisions based on samples of past lending cases. A system developed in this manner would be able to offer a lending decision-making product: however it could not be classified as an E.M.I.S. as there would be no assistance in it for the lender, simply an index of risk based on "brute empiricism".

Moving back to the E.M.I.S. there will obviously be a need to maintain and enhance it. There will have to be an ability to change the rules of the expert system if the portfolio policy is changed, and as the rules of lending are refined in the light of greater experience gained in lending.

One way in which the expert system could be used is as a coarse filter on propositions. The client would interact with the system in an initial probe of his proposition, without the lender being involved. Only clients that pass this initial screening would be seen by the lender. In this way, the lender would be spared the necessity of dealing with hopeless cases. Indeed it is in this area that credit scoring models - offering an index of the risk involved in the lending - could be used as effective policy screens. The portfolio manager specifying to the system the level of risk exposure he is prepared to accept.

Systems which are able to adapt and 'learn by their mistakes' are only currently in the research stage. Rule induction packages can be made to update their rules as new information is gathered. However it is extremely difficult, even in very simple situations, to produce an expert system that can automatically change its rule base without outside intervention.

Technology is changing rapidly and procedures are on the horizon which look like being able to allow for such automatic updating. However these developments are unlikely to nullify the value of developing non-automatic expert systems. Thus there is no requirement to wait upon such developments before proceeding with the development of an expert management information system (EMIS) for the evaluation of individual corporate bank lending propositions. Indeed, it might be suggested that to wait would remove the competitive advantage of using the systems, and may even place a bank at a disadvantage if other banks do begin using them successfully.

## THE METHOD CHOSEN.

The role of MIS and DSS in bank decision-making is by no means clear-cut. It is confused by the lack of any comprehensive IT strategy by most UK clearers. Both the proposed strategic decision types and the lending decision-making process present a demanding challenge for systems developers. With the wide ranging differences between the types of decision-making involved in strategy formulation and in the evaluation of individual lending propositions, it is unlikely that the greatest gains will come from an attempt to create an all embracing IT system that supports both types of decision-making. At this stage in the development of IT support in banking, the preferred approach would seem to be to move ahead with the development of the thinking behind each type of support tool, implementing prototype systems to aid in this development process. These developments can readily proceed in parallel, but with each aware of the interactions between them. Once prototype systems have been evaluated, a reappraisal of the overall approach should be undertaken.

## THE FOCUS OF THE EMPIRICAL RESEARCH

The actual practical research undertaken was focused on the expert system part of the EMIS described above. This was done for several reasons:

1) A study period of approximately one year placed considerable time restrictions on the research. Meaning that only one area in the framework described above could be effectively covered.

2) It was felt that it would be better to concentrate on one area rather than attempting to fill in the whole framework.

3) It was the desire of the researcher to examine in greater detail the role of expert systems in bank lending as they are likely form the central part of any future "intelligent" systems used by the banks. It is also a new area to banking and its potential is not yet realised by most bankers.

Thus, the research undertaken has centred around the production of an expert system lending advisor. The actual system produced is a prototype, which is to correctly identify good and bad lending propositions. The advisor was developed using all of the theoretical principles found to be necessary for a full system. It therefore provides a good foundation for any future developments by banks in the area of expert systems for corporate loan appraisal.

# CHAPTER FOUR - KNOWLEDGE ACQUISITION

## KNOWLEDGE ACQUISITION - The Theory

The acquisition of the knowledge in an expert system has been recognised by many expert system designers as the primary bottleneck in the process of building the system. (See Evers & Hoyland 1986; Buchanan et al. 1970; Hayes-Roth et al. 1983). There are few formalised procedures for knowledge acquisition in spite of the fact that people have been acquiring expert knowledge for many years. This has been happening in such varied areas as students acquiring knowledge from lecturers to journalists acquiring knowledge from their interviewees. (Some of the generally accepted methods have been described in Chapter One).

A major problem for the expert system designer has been that although it is possible, and indeed fairly simple, to acquire general knowledge from an expert, the elicitation of detailed knowledge is far more difficult. Expert systems which are going to produce answers, rather than just advice (See Chapter One), require that all the details about the particular subject under scrutiny are known. This differs greatly from, for example, student knowledge acquisition where effectively only background knowledge is imparted by the lecturer - as opposed to every detail about a subject.

In order to acquire knowledge suitable for use in an expert system a methodology needs to be established. Such a methodology has been produced by Buchanan et al. (1983). This has been summarised in a diagram as given below:

1) Identify Problem Characteristics

(IDENTIFICATION)

REQUIREMENTS

2) Find Concepts to Represent Knowledge

(CONCEPTUALISATION)

CONCEPTS

3) Design Structure to Organise Knowledge

(FORMALISATION)

STRUCTURE

4) Formulate Rules to Embody Knowledge

(IMPLEMENTATION)

RULES

REFINEMENTS

REDESIGNS

REFORMULATIONS

5) Validate Rules That Organise Knowledge

(TESTING)

The five stages in the knowledge acquisition process can be identified as follows:

1) IDENTIFICATION.

Establish the class of problems that the system is expected to solve. The criteria which the system must meet and the basic source of the data to be used must also be identified, as must the resources available for the project. The products to be used in the project must also be evaluated with a view to identifying their limitations at the outset. This would involve an examination of the various expert system shells and toolkits available along with an examination of the ability to produce an integrated expert system without the use of a shell or toolkit, i.e. building the expert system in a lower level language or indeed at machine code level.

2) CONCEPTUALISATION.

The key concepts and the relationships between them need to be uncovered. This should include the overall structure of the domain and the flows of information within it. A model of the knowledge domain should be drawn up to identify the factors involved in the production of a decision. At this stage of development only broad relationships between variables need be shown so that the concepts involved in the decision are identified and are not clouded by excessive detail. This part of the development would be done in the very early stages of production and would involve the knowledge engineer and his contractor. The expert may not even be involved yet.

3) FORMALIZATION.

The source of the expertise for the expert system needs to be formally stated. This must include an agreement about the completeness of the knowledge and a list of any restraints about it, for example time dependency. This is the first real entry of the domain expert. He will be available in the earlier stages, however it is at the formalisation stage where he will take the identification of the domain and the key concepts within it and will formalise them into a more precise statement of the limits of the project, and the knowledge to be contained within it.

4) IMPLEMENTATION.

This is basically the formulation of the rules from the knowledge into a format which can be run within an expert system shell (or simply in an executable program).
The implementation part in the knowledge acquisition process can be divided into three distinct phases, each of which needs to be passed through by the expert knowledge engineer. These were first mooted by Bennett (1981) who suggested that the order is as follows:

a) The knowledge needs to be structured in such a way that it can be represented in the form of rules. This structure is developed out of discussions between the knowledge engineer and the domain expert. Here the primary goals are established and their component parts described. These components are then examined and possible values for each are worked out. This process is carried out for each goal at each level of the knowledge hierarchy until a total picture of the problem is established.

b) Produce a first working system.

c) Test and debug the system.

In order to carry out Parts b and c the knowledge acquired in Part (a) needs to be refined as the working system is produced and tested. The detailed knowledge can come from four main sources; structured interview, on task analysis, questionnaires and rule induction. Rule induction is described in Chapter Six and so need not be further described here. The other three methods require further examination:

STRUCTURED INTERVIEWS

There are three main techniques of structured interview useful in knowledge acquisition (as identified by Burnett (1986)), these being critical incident, repertory grid, and reclassification.

The critical incident technique involves getting the expert to consider an "especially significant event" and to explain the reasoning used to resolve the key issues. This method is useful as it can serve to focus attention on one memorable event and so can reduce the possible confusion of trying to cover the whole domain at once. Problems can arise however, in that it may not be apparent which "memorable events" are representative of the domain, and whether using only a sample of occurrences will provide enough knowledge to cover the whole domain.

The repertory grid allows the comparison of specific variables (objects) by a systematic approach. Representation of the knowledge in a domain is analysed using a composition of constructs and elements (objects). A construct is a characteristic with two opposite (polar) values which each element identified possesses to some degree. For example, a set of objects may be classified by the construct weight. Here the polar values of the construct could be light and heavy. Combining the objects within a domain using various constructs will eventually create a picture (grid) of knowledge in the domain. It also helps the expert to accurately classify objects in relation to one another.

Once a grid has been produced, analysis of it can begin. This analysis may be in the form of cluster analysis where objects are clustered together by construct values in order to find patterns and structure to the knowledge in order that it might be represented effectively.

Several expert system tools are available to assist with such knowledge elicitation. Generally they seek to split the objects identified within a domain into sets of threes. They then look for constructs to identify the differences between the objects.

This process is repeated until the computer has successfully uniquely identified each object, and a full picture of the domain has emerged.

Reclassification has been found by Grover (1983) to be a very effective method of knowledge elicitation. The technique basically works in the following way:

1) Take a goal.
2) Find out the facts that will provide evidence for it.
3) Delineate the test for the facts.
4) Make one of the facts the current goal and repeat the process.

This method allows the knowledge engineer to take the expert through the knowledge acquisition process from a general framework to the very specific rules in a manner which will produce structured results which can be easily reproduced as rules.

ON TASK ANALYSIS (Protocol Analysis)

This is an alternative approach to interviewing the expert. It basically involves the knowledge engineer observing the expert at work and from this either inferring the relevant rules or questioning the expert about what he is doing and why. This approach is useful in that it does not place the expert in an artificial situation where he has to reason theoretically, but it allows him to act naturally and in doing so is more likely to reveal those rules which are subconsciously carried out, and those which might be concealed by the expert.

A possible problem with this observation technique is that it is dealing solely with empirical examples and so no clear theory can be stated. This need not be a problem except that events occurring in the domain with only a small probability may not be observed, and so the knowledge to deal with these situations would not be acquired. Smith and Baker (1983) suggest that the expert could be placed in an artificial situation which would make him have to think about all of the possible outcomes and so solve the problem. However this would only cover up the subconscious rules again, and it would be impossible to generate a situation where all possible eventualities would arise - especially since the rules in the domain would not yet be fully established anyway.

USE OF QUESTIONNAIRES

The use of a questionnaire can allow well structured interviews to take place using a far wider sample of experts than is possible with structured interviews where the knowledge engineer interviews the experts in person.

Questionnaires are of great use where the knowledge is held by more than one expert, however the technique is only really useful in producing a very low level of knowledge, i.e. the first stage in the development of an expert system where the general knowledge about a topic is being laid down. Many problems with the use of questionnaires stem from their impersonality. There may be ambiguity in the questions posed, or the expert might not understand the precise meaning of the question leading him to answer a slightly different question from that meant by the expert system designer. The most serious failing of questionnaires is the inability for them to reach the more difficult knowledge which is only elicited after deep probing. This is the knowledge that sometimes only becomes apparent when more obscure parts of the domain are explored, and it is often knowledge that the expert himself does not realise he has.

5) TESTING.

Once the knowledge has been acquired and turned into rules by the knowledge engineer they need to be validated. This is to ensure that they work both independently and as a part of the whole system. Errors through missing and incomplete rules also have to be tested for. Although Buchanan (1983) has stated that validation and testing comes once the rules have been elicited the researcher would suggest that the validation process is an on-going process which continues through the whole of the development period. Each development needs to be tested and then evaluated with regard to the four stages in knowledge acquisition described above. As validation is such an important part of the development of an expert system a chapter has been devoted to exploring the whole area in more detail.

## KNOWLEDGE ACQUISITION - THE PRACTICE

Each of the above methods has advantages and limitations as discussed. As a result of this, in the development of the expert system prototype several of the methods were used in unison to ensure that together all possible limitations were covered. There were differences however, as a large part of the knowledge came from the researcher himself who acted in both the role of the expert and the role of the knowledge engineer. The knowledge was acquired from four sources, each of which followed on from the other to form a total picture of the knowledge.

### STAGE ONE - THE IDENTIFICATION

The initial domain of the expert system was identified broadly as lending by banks in the corporate sector. In the course of the research the initial domain was redefined as:

"any lending proposition by a limited company between £500 and £150,000 where the proposition is for a project with a definable monetary return, with repayments up to 25 years from the company profits and where a maximum interest of 30% is allowed."

This definition was set up, not as any particular guide to banks as the best area to apply expert systems, but simply so that effective evaluation could be undertaken, and to see whether it was possible to produce an expert system for lending. The figures in the definition are purely convenience ones. They could obviously be changed to suit the requirements of future users, bearing in mind that if this was done some rules within the system would have to be changed to compensate.

## STAGES TWO AND THREE - THE CONCEPTUALISATION AND FORMALISATION

In practice stages Two and Three were developed together as the conceptualisation was partly achieved as the domain was identified and defined.

Once the area and definition had been chosen the sources of knowledge had to be ascertained. As mentioned above, four sources were used. These were chosen as the most available means of acquiring the relevant knowledge, and because together they would present a far fuller picture of the lending decision making process than only using one source of reference ("expert"). The four areas used were:

1) Lending theory techniques as described in various banking textbooks, and as taught by academics at Loughborough University Banking Centre.

2) The lending experience of the researcher. (Approximately one year's lending experience).

3) A questionnaire sent to a random sample of five hundred lending bankers in six clearing banks.

4) Interviews with a sample of four lending bankers. These were chosen from bankers known by the researcher personally.

1) THE TEXT BOOK TECHNIQUES

The initial body of knowledge for the expert system was derived from the various lending textbooks available. A full list of the sources used can be found in the Bibliography. However, the bulk of the knowledge was taken from Robbie, Coulbeck and Moulds (1983) whose book was aimed directly at the area to be covered by the expert system.

This part of the knowledge acquisition process was used to find out the factors which are important in a lending decision and to identify the relationship between these factors. Once they had been ascertained they were passed around the academic bankers at the university for comment and expansion. This provided the first break down of the lending process into its component parts. A list of which can be seen below: (The list has been split into levels of detail with the highest levels at the top).

THE LENDING DECISION

BUSINESS      RETURN      ACCOUNTS      PROPOSITION      SECURITY

PROPRIETOR      PRODUCT      ECONOMICS      RECORD

PERSON      AGE      STAKE      EXPEDIENCY

SECTOR      LOCATION      NATIONAL

TYPE      COMPETITION

BANK PROFIT      TIE INTO BANK      OTHER BANK SERVICES

FINANCIAL ACCOUNTS      MANAGEMENT ACCOUNTS

BALANCE SHEET      P+L A/C      AUDITORS TALKS      BANK ACCOUNT

ASSET STRUCTURE LIABILITY STRUCTURE

RATIOS PREDICTION OF FAILURE

DIRECT COSTS OVERHEADS

COSTS SALES

MAX & MINS HARDCORE/EXCESSES TRENDS

BUDGETS BUSINESS PLAN CASHFLOW

SENSITIVITY ANALYSIS CREDITORS DEBTORS

COMPETITION EXPERIENCE NEED FOR LOAN

VALUE APPRECIATE LIQUIDITY REALISABLE TYPE RESTRICTION

2) THE LENDING EXPERIENCE OF THE RESEARCHER

Once the initial knowledge had been acquired from the text books and the academics, a simple knowledge base was produced by the researcher. This was tested against his own lending experience, and in this way the links between the various elements in the lending decision begun to be established.

3) THE QUESTIONNAIRES

In order to ensure that the domain knowledge was fully elicited, a questionnaire was sent out to a random sample of lending bankers, to ask them which factors they considered important when lending in the corporate sector. It also sought to identify the relative importance of each individual factor against the others.

The questionnaire (a sample of which can be found in the Appendix) was devised from the factors identified by the

:extbooks and the academics. It was then taken to a statistician at the university who suggested the most effective way to structure the questions to obtain a fair response.

)nce a format had been worked out a sample of 15 questionnaires vas sent out to Midland Bank branches for completion and evaluation. The bank's Management Sciences Department was also asked to make comments on the format and content of the questionnaires.

All of the comments made were drawn together to form the final questionnaire format. For each factor listed the lender was requested to give a rating between zero - for not used, to ten - for essential. Although this scale is ordinal and so no direct quantitative statistical analysis could be performed on the results, the design was such that the results would give an appreciation of the relative importance of the various factors, thus showing a general picture of the elements bankers use when lending. A picture which was accurate enough for the purposes of the expert system development. The factors were also listed in alphabetical order to remove any inherent suggestion of importance within them.

The final questionnaire was sent to a random sample of five hundred branches across six clearing banks. The return rate was rather low at approximately 32%, however this presented a large enough sample on which to perform an analysis. The figures were described by mean, mode and standard deviation to show the spread of the data as well as the factors with the highest score. A full listing of the results can be found in Appendix 3, however for demonstration purposes the top and bottom factors are summarised below:

| FACTOR | MEAN | MODE | STANDARD DEVIATION |
|---|---|---|---|
| The Repayment Ability | 9.40 | 10 | 1.07 |
| The Business Viability | 9.16 | 10 | 1.41 |
| Customer Honesty | 8.95 | 10 | 1.50 |
| Maximums & Minimums | 8.86 | 10 | 1.20 |
| Customer Reliability | 8.50 | 10 | 1.70 |
| / | | | |
| \ | | | |
| / | | | |
| \ | | | |
| Talks with Auditors | 4.16 | 3 | 2.10 |
| Cross Selling Capabilities | 3.60 | 3 | 1.90 |
| Sensitivity Analysis | 3.50 | 0 | 3.10 |
| The Tax Returns | 3.30 | 0 | 2.90 |
| Prediction of Failure | 2.35 | 0 | 2.90 |

This sample of the results shows which factors came out top and bottom in importance. The results of the questionnaire were then fed back into the expert system to show the relative importance of each factor in the evaluation process. In terms of the development of the expert system this affected the order in which factors were evaluated by the system. For example, the tax returns are seen to have little importance to lenders and so their use in the system is limited only to marginal cases where no evaluation can be made by any other means.

It must be emphasised that just because the questionnaire stated that a factor was relatively unimportant it does not mean that the factor is not of use in making a lending decision. This can be seen by the fact that the use of prediction of failure techniques came at the bottom of the list, indicating that they are not used by bankers - not that they are not of any value, but simply that they are not used. This was seen as a problem at first, however the use of structured interviews, where all of the factors were explained, and their uses displayed, allowed a clearer picture to emerge of the actual importance of each factor in a lending decision. This can be seen by examining the difference between the actual rules elicited and the questionnaire results. It also raised an important issue in the concept of the expert system methodology:

"is it expected to mimic the expert, or does it seek to supersede him by making better decisions."

If the aim is to mimic then the relative importance of factors revealed in the questionnaire is far more important than if the aim of the system is to "beat" the expert - using him only as a basis for the knowledge but ignoring him when his knowledge can be superseded by other means.

:n the development the latter course was chosen as several ;ources of knowledge were available, and together they ware able :o produce a more complete picture of the domain knowledge.

l) THE INTERVIEWS

ıll of the knowledge acquired was taken to a sample of four ›ankers known to the researcher personally. They were asked to :omment on the knowledge which was displayed in the form of a ;tructure showing the lending decision making process. The .nterview was structured by the use of a lending example case ;tudy (Fulton Construction, which can be found in Appendix Six) :o focus attention, and to allow the lenders to evaluate the case ;tudy using the data presented to them.

'he interviews produced final comments on the knowledge itself ınd its structure, which allowed the researcher to build a 'orking expert system prototype. This prototype was then taken ›ack to the bankers who again commented on its rule structure and .he knowledge inherent in the rules. This allowed for further 'efinement. This process was carried out a number of times ıntil a satisfactory working expert system prototype lending .dvisor was completed. A demonstration of this advisor can be ;ained by running the program on the disk in the Appendix.

STAGES FOUR AND FIVE - IMPLEMENTATION AND TESTING

The areas of rule development from the knowledge (implementation) and the validation process used both require further examination. This follows in the next two chapters beginning with how the expert system shell to contain the rules was chosen.

# CHAPTER FIVE - THE DEVELOPMENT OF THE PROTOTYPE

Once the knowledge acquisition process was begun, the problem of knowledge representation was encountered. Several different types of knowledge were found to be present within the domain indicating that different representation techniques should be used to represent the knowledge in the expert system prototype. (A discussion of these techniques can be found in the Introduction). In the actual development of the expert system prototype none of the representation methods apart from production rules were available to the researcher (because of time and cost) and so the prototype had to be produced purely from rules. This can be seen in the examination of the expert system shells available to the researcher which follows.

This reliance upon production rules did not mean that any knowledge was left out of the system. However, it did mean that the representation of some of the knowledge was very inefficient.

## EXAMINATION OF SHELL TYPES

The shell type chosen to produce the expert system was selected from a number of products available at the start of the research. A full listing of packages currently available can be found in the Appendix. The choice was made easier by the fact that the Civil Engineering Department at Loughborough University of Technology had already conducted a study into expert system shells for use in the construction industry (Evaluation of Expert System Shells For Construction Industry Applications (1985)). Although their use for expert systems was different, the underlying characteristics and the features of the packages examined is the same and so the report could be used to present an analysis of eight different expert system packages. The study also gave the basis for evaluation of the other packages and allowed effective comparisons with those products not in the study.

Availability and price of products also played a major part in the selection. In all, outside the Civil Engineering Department study, four shells were considered in detail; with a further four being examined in brief, as only limited demonstration copies could be obtained. The detailed examination was carried out over Deja Vu; Crystal; SuperExpert and Xi Plus; and brief studies were made of Micro Expert; MicroSYNICS; Expert Ease & ES/P Advisor. The comparison made was based on the production of a small advisor. The main aim was to establish ease of use, with the subsidiary aim to establish expansion capabilities. In the evaluation small knowledge bases were produced. For each product slightly differing examples were used in the creation of the knowledge bases. This was done so that the major characteristics of the packages could more easily be displayed. To ensure that all would be capable of the production of a lending advisor however, only problems in relation to lending and credit were tested.

Looking closer at the packages examined in detail the following picture emerged:

1) DEJA VU (PRODUCED BY INTELLIGENT ENVIRONMENTS LTD).

Deja Vu is basically a decision support shell rather than an expert system shell. It allows the developer to enter a number of points relevant to a particular subject. These points can then be expanded to form further points about the points and so on to give greater detail about a particular item. This can best be explained by an example:

For the subject "Evaluating a Lending Proposition" a banker would typically look at a number of areas which can be regarded as points eg.

LENDING EVALUATION......

The Proposition

The Security

The Accounts

The Customer etc...

These can then themselves be broken down into further points. For example:

The Accounts......

- The Balance Sheet
- The Profit & Loss Account
- The Management Accounts
- The Bank Account etc...

These points can also be broken down:

The Bank Account.......

Maximum & Minimums

Hard Core Development

Overdraft Limits etc.....

Once a subject has been broken down into its finest component parts, weightings can be given to each point based on its value when compared with the other points. Completing this for all of the individual points at each level will give the developer the ability to assess any proposition which fulfils the criteria shown in the points. This is done in Deja Vu through the use of Options. In a lending example these would be the various decisions the banker could come to in his evaluation, i.e. Lend Secured; Lend Unsecured; Refer to Higher Authority; Refuse etc.

Taking each of the options in turn, the relative values for each of the points to arrive at that option can then be entered to produce the result for a general case. When a lending proposition is to be evaluated, the ANALYSE key is pressed and the system will ask for the various values of each of the points. Once all have been entered it will produce a result showing the options in a ranked order with the "best" option at the top, i.e. the one which has the closest fit to the values entered. The ranking is shown as a percentage, with 100% providing an exact match (i.e. the points entered exactly fit the options in the system). The display of all the alternatives allows the user to select any number of options rather than just one. It will also show him where the proposition lies, (eg. how close a proposition was to actually being agreed if it was rejected). Factors can then be changed to see what would be necessary for a positive lending decision to be made for the proposition.

Deja Vu provides a system where the process of lending can be broken down into its component parts and then an evaluation can be made by weighting each part. This appears to be a very useful way of evaluation. However there are severe limitations surrounding this method:

(1) It cannot take into account any unique features of a particular proposition, but relies on the general factors entered by the developer.

(2) It is also a closed system which has, by nature, to be viewed in isolation, and so it cannot offer a true reflection of "real world" situations i.e. it does not allow inputs from other sources to be added once the system is operating.

(3) Deja Vu is also unable to allow the knowledge engineer to perform calculations. This means that all data entered has to be in the refined state required by the system. This means that although a banker could use it as his personal tool to assist him in his evaluations, it would be very difficult to develop a universal lending tool which could be understood and used by all bankers.

2) CRYSTAL (PRODUCED BY INTELLIGENT ENVIRONMENTS LTD).

:rystal is an expert system shell which uses rules rather than ›oints to break up a problem. These rules are supported by :onditions which are either true or untrue. For example a :ypical rule might be:

THE CUSTOMER CAN HAVE CREDIT IF ADEQUATE IDENTIFICATION IS SHOWN
AND
THE CUSTOMER'S SALARY IS ABOVE THE MINIMUM LEVEL
AND
THE CUSTOMER HAS A SATISFACTORY EMPLOYMENT RECORD.

:he three elements in the above rule are the conditions for the :ule. Crystal allows rules to be linked together and for each :ondition to be expanded to gather further detail in a similar ıanner to Deja Vu. For example, the first condition above might ›e expanded to suggest the types of adequate identification ıllowed and those which are not permitted.

)nce the rules have been entered, Crystal will work through them ıttempting to validate or reject the first rule entered (known as :he Crystal Master Rule). This first rule is the conclusion being ıimed at by the system user. For example, a decision to give or :o refuse credit. This process of evaluation is known as ›ackward chaining or goal orientated evaluation.

Crystal is best demonstrated through a worked example as given below. (This example being one of the examples provided by the package for tutorial purposes).

(1) CRYSTAL MASTER RULE

(2) GIVE THE CUSTOMER CREDIT

IF Salary is sufficient

AND Employer record is good

AND Identification is available

AND DO: CONCLUSION DISPLAY

OR DO: DISPLAY FORM

CREDIT APPLICATION

This person does not qualify for credit.

(3) SALARY IS SUFFICIENT

IF DO: DISPLAY FORM

SALARY CHECK

What is the person's current salary? <salary>

AND DO: TEST EXPRESSION

salary > 8000

(4) EMPLOYER RECORD IS GOOD

IF the person has been at work for two years

OR employer references are available

OR the person is self employed

AND salary > 20000

(5) IDENTIFICATION IS AVAILABLE

IF DO: MENU QUESTION id

IDENTIFICATION CHECK

Which of the following ID has the person got?

{Passport }

{Credit Card }

{Addressed Envelope}

{None of the Above }

AND DO: TEST EXPRESSION

id < 4

This simple list of five rules is enough to check the three main details required to give credit to an individual. The system will work backwards through the rules, as described above, (backward chaining) aiming to reach the Master Rule conclusion, this being the outcome of Rule 2 (accepting or refusing credit).

Following the example through; the customer would first be asked his salary details (trying to evaluate the first part of Rule 2 from Rule 3). If a salary of over £8000 is entered then the test is passed and the second part of Rule 2 is queried. If the test is failed (i.e. a salary of less than £8000 is entered) then the advisor falls to the OR part of Rule 2 and refuses the customer credit. Assuming that a figure greater than £8000 is entered the advisor will then question the employer record shown in Rule 2.

This is established from Rule 4. First length of time at work is asked. If this is greater than 2 years the rule is proved and the system switches back and the next part of Rule 2 is queried. If the work time is too short employer references are requested. If these are available the system will move on. If not a test is done for self employment, here to pass the salary must be greater than £20000. If all these tests fail the OR condition of Rule 2 will again be enacted and credit will be refused.

This process continues right through the system at each stage attempting to reach the final result. If all the conditions in Rule 2 are met then the top line of Rule 2 is proved and this is displayed as the final result i.e. GIVE THE CUSTOMER CREDIT.

An examination of the above process shows clearly that Crystal is able to offer a system which is capable of producing a lending advisor. The main problems found with Crystal which led to its rejection for the final system are shown below:

(1) User unfriendliness - for the knowledge engineer. Crystal is very professional to look at and simple systems can be developed very quickly. However it becomes very difficult to know the structure of the rules needed to make a large system effective, or even for it to work properly. This is because in Crystal the developer is tied to the hierarchical structure of rules set out in the package. It is easy to expand a rule, but once a system has been developed, it is very difficult to add new rules which would change the shape of the rule structure, or to

change the master rule being evaluated, without having to start from scratch again.

(2) Flexibility. The structure of Crystal is very inflexible, in that all rules must be entered in the order that they will be required to be analysed in the advisor. This makes using the package frustrating as all elements must first be thoroughly tested on paper.

3) SUPEREXPERT (PRODUCED BY INTELLIGENT TERMINALS LTD).

SuperExpert is an expert system shell which uses a process called rule induction to develop its rule base. It is a very simple system to use as it is based on the popular spreadsheet format and rules are not entered directly, but in the form of examples. This makes life much easier as the rules do not have to be worked out for each possible situation. Instead, examples can be entered to cover a sample of differing situations. The system can then induce a rule from the examples using only those it needs to actually produce a general rule. An explanation of the induction process and its validity is given after the description of the packages which were evaluated.

A lending advisor was easily produced on SuperExpert as the package gave, as one of its demonstrations, a simple lending advisor. This was developed through assistance with Citibank in the U.S. and is described in the booklet "The Adaptive Credit Scorer", Intelligent Terminals (1986). The development of a system in SuperExpert can best be described through a simple example.

Firstly the elements of the knowledge domain need to be identified and presented to SuperExpert. These are basically the criteria for assessment, the values these criteria can take, and the possible outcomes. In SuperExpert these criteria are known as attributes. The aim of selecting and presenting the elements to SuperExpert is to find out how examples of different combinations of attribute values allow the outcome to be predicted: For example, in corporate lending the attributes needed to come to a decision to lend money or to refuse or refer a request might be: personality, security, repayment and accounts. i.e. an examination of these elements would lead the expert to a decision about whether to lend or not. The formulation of the attributes and their values to fit into SuperExpert can be shown in a diagram, as below:

| ATTRIBUTES: | Personality | Security | Repayment | Accounts |
|---|---|---|---|---|
| VALUES: | good | good | high | good |
| | average | average | average | average |
| | poor | poor | low | poor |
| | | none | | none |

OUTCOMES: Lend Refuse Refer

Each of the attributes can itself be an outcome of a higher level set of attributes. For example the value of accounts as good, average, poor, or none could have been derived by an analysis of the ratios rather than simply entered from the keyboard.

Once all the attributes and their values have been entered the system allows the developer to enter any number of examples to demonstrate the combinations of the various attribute values which will lead to the different outcomes. These are then compiled by the system, using an algorithm called ID3, to produce a rule base. (The way in which this is done is discussed at the end of this section).

Onto the rule base SuperExpert allows the developer to add a text based questioning system. This simply means that when the rule is being used in an advice session and the value for a particular attribute is being requested, text can be attached to the attribute to make sense to the user. For example, the attribute Repayment might have the text "What is the repayment ability of the borrower like from any previous lending?". This text makes the system easier to use and far more friendly.

SuperExpert seems like the ideal system for the advisor, however it is severely limited in two areas.

(1) No calculations can be performed in the package. This means that all calculations (eg. ratios) have to be calculated in a different package and then imported to SuperExpert. This greatly

reduces the ease of use of the shell and it is made especially difficult as a special reporting package needs to be used for the data transfer.

(2) Expansion of the system to include several levels of rules needs to use chained knowledge bases. This is not a problem in itself, although results cannot be carried across knowledge bases and so some questions may sometimes need to be asked by the system more than once. It also slows the system up greatly whilst it is chaining across knowledge bases.

(3) Rules are generated in SuperExpert using the rule induction process. This process does not always produce a good rule set as it is dependent upon the integrity of the example set.

4) XI PLUS (PRODUCED BY EXPERTECH LTD).

Xi Plus is an expert system which uses (in Expertech's terminology) "know-how programming". This is the use of rules containing knowledge to evaluate queries set by the user. In Xi Plus the know-how is expressed explicitly as a rule which can be directly entered into the system. eg. IF situation X, THEN DO Y. The whole of Xi Plus is based around simple IF...THEN production rules. These can be entered in any order, and rules can draw information from the keyboard, data files, and from other rules. As with the other shells, Xi Plus is best described with a simple example:

```
QUESTIONS:
QUESTION SALARY =
TEXT: WHAT IS THE CUSTOMER'S ANNUAL SALARY?
QUESTION IDENTIFICATION IS
TEXT:  WHAT  IDENTIFICATION  DOES  THE  CUSTOMER  HAVE?  DRIVING
LICENCE, ADDRESSED ENVELOPE, CREDIT CARD, OTHER
RULES:
1) IF SALARY > 8000
   AND IDENTITY IS SATISFACTORY
   THEN DECISION IS LEND
2) IF SALARY > 8000
   AND IDENTITY IS UNSATISFACTORY
   THEN DECISION IS REFER
3) IF SALARY <= 8000
   THEN DECISION IS REFUSE
4) IF IDENTIFICATION IS CREDIT CARD OR DRIVING LICENCE
   THEN IDENTITY IS SATISFACTORY
5) IF IDENTIFICATION IS ADDRESSED ENVELOPE OR OTHER
   THEN IDENTITY IS UNSATISFACTORY

QUERY:
DECISION
```

In the above example (which is set out in a typical Xi Plus print-out format) the user will enter a query (in this case there is only one, i.e. DECISION). The system will then try to evaluate the query from the rules present in the knowledge base.

The questions described are simply there to provide text for the rules. Assuming that a query is made, the system will attempt to evaluate DECISION using backward chaining (as described earlier). A result for decision can be found in Rules 1, 2, & 3. It will therefore attempt to arrive at one of these conclusions. Xi Plus decides on the rule giving the answer by working through the rules in the order they are entered (unless the developer tells it to do otherwise). In the example, the system will first attempt to see whether the result can be LEND (from Rule 1). So the user will be asked the salary level. If it is greater than £8000 the identification of the customer will be checked. This can be evaluated from another rule so the system will switch to Rule 4 to evaluate identity. If Rule 4 fails it will switch to Rule 5 to determine the value of the variable identity. Once a value has been ascertained the system will switch back to Rule 1 with the value. If it agrees with the value in Rule 1 then the value for DECISION in Rule 1 will be given as the answer to the query. If it does not agree with the value in the rule then the system will shift to Rule 2 and so on until a match is found.

Xi Plus also allows forward chaining to be used. Here, instead of entering a query, the user simply enters all of the data known about a situation. The system will take the data and will move forward through the rules, of its own accord, or as directed by the developer, and will present any conclusions it can make from the data entered to the user. In this way WHAT...If? queries can be entered. This method can also be used to speed up enquiries by entering data already known from files before the actual query is made. This can considerably reduce the number of questions that need to be entered from the keyboard during an advice session.

Although Xi Plus was by far the most flexible of the packages tested it has several major failings:

(1) The system is written in Prolog and even running on an Olivetti M24SP Micro-computer was incredibly slow, some questioning response times taking up to a minute or more. (Slow it is recognised that a typical session might include 50 or more questions). The Olivetti is also a very fast computer (it runs at about two and a half times faster than an IBM PC XT) which highlights the true extent of the speed problem.

(2) The user interface for developers is daunting to say the least. The learning curve for Xi Plus is very steep and it was several days before a simple working system could be produced. This problem was found to be common across a number of people in the university using the package. The problem was largely eradicated, however, once a working knowledge of the various aspects of the system were learned.

(3) The documentation with the package, although professionally packaged and extensive, was very difficult to use because of a seemingly random order of explanation of facilities available. There is also a lack of simple examples in the documentation to work through to demonstrate the various functions available.

## THE PACKAGE SELECTED

The four packages tested in detail offer very different ways of producing an expert system advisor for loan evaluation. A working system was able to be developed in each package, indicating that any one of them COULD have been used. However it was felt that the limitations of the first three packages described, mainly the expansion capabilities and flexibility, were too strong to make them viable propositions. That left Xi Plus which, in spite of its speed problems, (which Expertech say is being sorted out), it was felt would best serve the purposes of the advisor development.

The other packages examined in brief, and the analysis of the Civil Engineering Department report also suggested that Xi Plus was the best way forward. The final element of the decision had to be made, as discussed at the outset of this chapter, with regard to constraints on time, and of money. These aspects put considerable pressure on the analysis for the decision to go to a system which was readily available in the university. It is recognised that a further study of other packages now available might present a more usable alternative, however it was felt that Xi Plus was capable of providing all of the facilities needed in the development of the system, and so it was chosen as the best alternative available to the research.

USE OF THE RULE INDUCTION PROCESS TO DEVELOP RULES.

The expert system prototype was developed in the package Xi Plus, however the rules were generated in the package SuperExpert using the rule induction technique. This is a process whereby the rules (The basic IF...THEN... statements) are not entered directly into the system but are automatically produced by the computer which is able to extract general conclusions from a list of specific examples. This method of generating rules is considerably quicker than entering rules directly as the induction process will allow unused consequences to be ignored. When entering rules directly ALL consequences have to be entered as it is very difficult to work out which ones will actually be needed. It also allows the developer to enter examples rather than rules. These can be entered as they are thought of, so the system can be developed as the expert's knowledge is gathered rather than having to wait until the gathering is finished and a plan of the system has been produced.

In order to use rule induction processes effectively the user has to be assured that the algorithms behind the method are actually valid. The mathematical basis is sound but there are dangers in the use of examples. The user needs to enter intelligent examples if he is to elicit a good general rule. This becomes apparent once the rule induction methodology is explained:

Rule induction is basically concerned with brevity rather than in the creation of any new information, i.e. it can only transform the examples given into a simpler form. It cannot of itself generate anything new from the examples. The process of rule induction uses a mathematical concept called entropy. Weber (1987) has produced a very succinct reiteration of the definition of the process when he describes it as a measure of disorder or randomness. Entropy is a probability function which is calculated from the presence of a factor within an example. Rule induction systems calculate the entropy for each attribute value and then compare the totals for each attribute to calculate the most important.

This process is described in detail by Mingers (1986) where he splits the process into three steps (from Quinlan's ID3 Algorithm (1984)):

1) Take each attribute in turn, and calculate a measure of how well the different values of the attribute allow different outcomes to be discriminated.

2) Choose the attribute with the most discriminatory power and partition the data according to the values of the attribute.

3) For each partitioned set, repeat steps 1 and 2 until all the attributes are ranked by the order of their discriminatory power.

The mathematical proof for the above is beyond the scope of the project: it is fully explained by Mingers, and has been proved for all nominal and logical attributes. It is not valid however for numerical attributes.

The rule induction process was used in the development of the expert system as a method for extracting rules from examples provided by bank lenders and by academics in the university. None of the examples contained numerical data so the algorithm for rule induction described above was applicable. The production of the rules was done, as mentioned above, using the package SuperExpert. Once the basic rules had been elicited in this manner they were rewritten in Xi Plus format and then placed onto the system being developed in that package which inter alia included rules covering numerical attributes. The development of the rules in this manner considerably reduced the programming time.

The process used can best be demonstrated through an example taken from the prototype. The example shows how the rules for the accounts were developed. The accounts were evaluated using five criteria (known as attributes in the package):

1) available (yes or no) - were the accounts available;
2) liquidity (high, average, or low) - liquidity ratios;
3) efficiency (good, average or poor) - efficiency ratios;
4) gearing (high, average, or low) - gearing ratios;
5) profits (high, average, low, or losses) - profits ratios.

Examples were entered using the above criteria to produce a decision for the value of the accounts. (Possible values being: good, average, poor, & none). The following set of examples was entered:

| | AVAILABLE | LIQUIDITY | EFFICIENCY | GEARING | PROFITS | ACCOUNTS |
|---|---|---|---|---|---|---|
| 1 | no | * | * | * | * | none |
| 2 | yes | high | good | low | high | good |
| 3 | yes | average | good | low | high | good |
| 4 | yes | high | average | low | high | good |
| 5 | yes | high | good | average | high | good |
| 6 | yes | * | * | * | losses | poor |
| 7 | yes | low | * | high | * | poor |
| 8 | yes | - | - | - | - | average |

The term "*" in an example is a "don't care" response, i.e. in the example the value of a particular attribute doesn't matter. The term "-" is a general case term. It means that if there isn't a particular example to cover an occurrence then the general case should apply. In Example 8 above the example is stating that if none of the other examples apply then the accounts can be taken as being average.

Applying the rule induction process to the above example produced the rule shown below. The rule implies from the theory above that available is the best discriminator, followed by profits, then liquidity, then efficiency, and finally gearing.

```
AVAILABLE
 yes : PROFITS
      high : LIQUIDITY
           high : EFFICIENCY
                good : GEARING
                        high : average
                     average : good
                         low : good
             average : GEARING
                        high : average
                     average : average
                         low : good
                        poor : average
            average : EFFICIENCY
                good : GEARING
                        high : average
                     average : average
                         low : good
                     average : average
                        poor : average
                 low : GEARING
                        high : poor
                     average : average
                         low : average
       average : LIQUIDITY
           high : average
        average : average
            low : GEARING
                high : poor
             average : average
                 low : average
       low : LIQUIDITY
                high : average
             average : average
                 low : GEARING
                        high : poor
                     average : average
                         low : average
    losses : poor
 no : none
```

Each node (the underlined result) of the above rule corresponds to an Xi Plus rule. For example, the first node can be rewritten in Xi Plus format to give the following rule:

if ACCOUNTS are AVAILABLE
and PROFITS are high
and LIQUIDITY is high
and EFFICIENCY is good
and GEARING is high
then ACCOUNTS are average

This method of rule production meant that a total of twenty seven rules were generated from eight examples. If the rules had been entered directly into Xi Plus a total of 109 rules would have had to have been entered (to cover every eventuality). This being calculated as follows:

((Attribute 1 values) x (Attribute 2 values) x (Attribute 3 values) x (Attribute 4 values) x (Attribute 5 values)) + (cases with no accounts)

which equals (3 x 3 x 3 x 4) + 1 = 109 rules possible.

Obviously when developing the rule base a large number of rules would immediately be seen as not being required, however it would be very difficult to see that actually only 27 of the rules will ever be used by the system, and so only these 27 need be entered. The example above clearly demonstrated the benefits of using the rule induction process to find out the rules which will actually be needed by the expert system. One possible failing does need to be highlighted however. The process is only as good as the examples entered. If the examples are inappropriate or incomplete the whole rule base produced will be inaccurate. The rules produced must be exhaustive within the domain if the expert system is going to function correctly. If the rule induction technique is used, the validation process employed must be able to cope adequately with inexhaustive example sets - clearly identifying them when they occur. In cases where no clear distinguishing examples can be laid down the only method which will accurately allow rules to be entered, is to enter them directly into Xi Plus; entering all of the feasible combinations of values of a variable, and so allowing the expert system to decide which ones it needs to use.

## THE EXPERT SYSTEM PRODUCED

The expert system prototype was developed during the collection of the knowledge and the development of the rules. Simple examples were used to produce an early prototype to explore the package chosen for the expert system. Once the framework for the system was established the work was started on the actual expert system prototype. This was built up in a series of modules, each representing a different area of the lending decision. This meant that testing could begin almost immediately on each part of the system. It also allowed the different areas of the decision making process to be evaluated and tested separately as well as together.

A listing of the expert system prototype can be found in the Appendix. This listing is given exactly as it appears in the working system. In order to make reading easier a description of the expert system as shown in the Appendix with explanations is given below:

PART ONE : THE FACTS.

These are the statements within the system which never alter. They are all mathematical formulae, the components of which do not change, and they are used to tell the system how to calculate certain variables needed by the system in consultations. For example, Fact 5 is:

assets1 = curr.assets1 + fixed.assets1

This tells the system that the variable 'assets1' is equal to the sum of the variables 'curr.assets1' and 'fixed.assets1'. This means that if the variable 'assets1' is ever needed in a consultation it can be derived from 'current.assets1' and 'fixed.assets1' if it is not already known.

PART TWO : THE QUESTIONS.

The question section is the way in which Xi Plus is told by the programmer how to phrase the way it requests values for the variables required to come to a decision.

For example, if a value for the variable 'amount' is required then Question 1 will fire and instead of the user being faced with 'amount =' he will be faced with the textual question: 'How much borrowing is required?'

PART THREE : THE DEMONS.

Demons are special control rules which fire whenever their conditions are met during a consultation. They are checked every time a new piece of information is entered and as such can be used to identify special circumstances. For example, Demon 1 checks to see whether the variable 'repayment' is greater than 'retprofit'. If at any time in a consultation this becomes true, then the report shown in the demon will be displayed, and the decision in the demon will be reached immediately.

PART FOUR : THE RULES.

The rules are the basic building blocks of the system. They have been described in detail earlier and so all that is required here is to describe how the rules have been set out in the actual expert system prototype. The rule hierarchy follows the following order:

1) Rule 1. Check rule to determine order of questioning during a consultation.

2) Rules 2 - 6. Rules to establish whether the lending request falls within bank lending limits.

3) Rules 7 - 79. Bottom level rules to establish the actual lending decision.

4) Rules 80 - 92. Rules to determine the security position.

5) Rules 93 - 108. Rules to determine the risk of the industry.

6) Rules 109 - 126. Rules to establish the abilities of the business.

7) Rules 127 - 161. Rules to establish the value of the accounts.

8) Rules 162 - 164. Rules to establish the value of the proposition.

9) Rules 165 - 179. Rules to establish the liquidity of the business.

10) Rules 180 - 192. Rules to establish the profitability of the business.

11) Rules 193 - 201. Rules to establish the efficiency of the business.

12) Rules 202 - 206. Rules to determine the report given to the user once a decision has been reached.

PART FIVE : THE DEFAULTS.

The defaults are set values for variables which are taken up by the system if they are unknown by the user at a consulting session.

PART SIX : THE QUERY.

The query is the question asked by the system, of the user, to get the consultation underway. This is present as there may be more than one query. This is possible, as in theory any variable can be set up to be queried.

# CHAPTER SIX - THE VALIDATION PROCESS

## VALIDATION OF THE EXPERT SYSTEM

Validation of an expert system is an essential part of its development. This is for two main reasons. Firstly, expert systems rely on heuristics, rules of thumb, and formulations borne out of practice. As it is virtually impossible to prove directly these will work effectively in all cases, validation is essential before any serious use of an application is undertaken. (Unless the expert system is seeking to simply "mimic" the expert. Here, arrival at the "right" answer is unimportant - as long as the system does what the expert would do in the same circumstances). The second need for validation arises out of the difficulty in actually seeing when an expert system is going wrong. Even if the results produced are correct, this does not necessarily mean that the system is functioning correctly i.e. the correctness of judgements cannot be established by results alone. If results alone are relied upon then the system cannot be guaranteed to make the correct response in the future except to the same inputs. For example, if a set of inputs - not tested in the development stage of the system - should be entered, a rogue result might be produced which was not noticed by the developer of the system.

Validation is therefore demonstrating that, with a reasonable probability, the relationships within a system are appropriate.

The absolute truth of the relationships is not being tested however, as this is impossible. The term "appropriate" has been used rather than "right" or "correct" since the aim of the expert system is to produce a useable model of the expert's knowledge. This knowledge is only one viewpoint of the decision process, and so no absolute "answer" can be stated (except as above where the system is seeking to mimic the expert and not necessarily to reach a "right" answer). This concept of usefulness allows a definition of validation to be produced such as that suggested by Finlay et al. where the process of validation is stated as:

"the checking of the appropriateness of a model (expert system) to help tackle real world problems, as seen from the viewpoint of those involved in the model's creation and use".

Finlay, Forsey & Wilson (1988).

Verification is a subset of validation as explained in the definitions in Chapter One. The aim of the verification process is to ensure that the model performs as expected, when the various components work as expected; for example, totals being calculated properly. Here there is no viewpoint about the "right" answer and so "an answer" can be pre-defined then testing the model. Verification can simply be seen as the testing and debugging of programs - for the expert system it concerned with ensuring that the computer software was running correctly and debugging the rules to make sure that they were entered correctly.

## THE VALIDATION PROCESS

Validation of an expert system is possible in two main ways: analytical validation and synoptic validation. The former method involves the checking of each part of the system individually and in conjunction with other interacting parts. Synoptic validation is concerned with checking that an acceptable output is achieved for each of a set of inputs. Here an overview of the system is being taken, and the total performance of the system is established.

These two processes of validation will establish whether the expert system is replicatively valid - when the data produced matches data already produced in the real world system; or predictively valid - when the data produced by the expert system is subsequently checked and found to match the real world. The system which is predictively valid is a far more powerful model of the expert's knowledge as it is following his reasoning pattern and is coming out with answers which the expert is then subsequently producing. Expert systems which are predictively valid are able to predict outcomes rather than just describe outcomes.

The validation of an expert system can be likened to the relatively established method of validation of mathematical models. Here five dimensions of validation are examined. These fit closely with five dimensions laid down by Sell (1985), however parts of Sell's descriptions are somewhat dubious. The five dimensions considered by Sell are:

Consistency

Completeness

Soundness

Precision

Useability

In terms of mathematical models these dimensions can be split into two parts; those pertaining to the logical model and those pertaining to the data model of the expert system.

## LOGICAL MODEL VALIDATION

The first dimension considered is that of consistency. Sell states that this means that similar questions in the system should produce similar results. As he gives no definition of "similar" it is impossible to operationalise this definition. In order to produce a working dimension Sell reduces the requirement to the concept of:

"same inputs should result in the same outputs".

This, in other words, is the same as verification which was discussed earlier.

Sell (1985).

The second dimension considered is completeness. This is the requirement that within the range of application of the expert system all possible solutions can be derived, and that all acceptable inputs will produce an outcome.

The third dimension is that of soundness. Sell regards this as the converse of completeness, i.e. that everything that is derivable within the system is true. (Completeness demands that everything which is true is derivable). This term could much more simply be referred to as accuracy.

Precision is a dimension specific to systems which are able to produce probabilistic outcomes. This was not tackled in the project as the package used for the expert system development (Xi Plus) was unable to handle probabilities, however it is necessary to explain the dimension as it will become relevant as expert system development advances to be able to handle uncertainty.
Sell considers precision to be an extension of the requirements of soundness, i.e. it can simply be seen as a measure of random bias in the system.

Taking precision and soundness together can produce the mathematical model validation dimension of exactitude i.e. a measure of the systematic and random bias in the system.

## DATA MODEL VALIDATION

The final dimension produced by Sell is that of useability. This is the requirement that the interaction between the user and the system should proceed in the way in which the system designer intended. This has been included under the title of data model validation, as useability has a direct parallel with data model validation in mathematical modelling.

A comparison with mathematical modelling has been made as the validation process in mathematical modelling is, as mentioned above, relatively established and, as such, can be relied upon. Expert system validation has no such track record, and so in its own right cannot be heavily relied upon. If it can be shown that the processes are suitably similar then the validation process for expert systems, if it is able to follow that for mathematical models, can be accepted and used confidently.

## DIFFERENCES BETWEEN MATHEMATICAL MODELLING AND EXPERT SYSTEM VALIDATION

1) Mathematical models consist of variables which are measured using interval and ratio scales. Expert systems generally use variables at the ordinal and nominal levels of measurement. This means that in expert systems all feasible states of the variables present need to be known and stated (with mathematical models they are automatically specified when the range of application of the model is specified). In addition, the combinatorial possibilities of the variables needs also to be stated and known. i.e. all possible states of the variables, and their meaning with relation to the other variables, needs to be established and stated at the outset before any computation can take place. This is important as without this the expert system results will be

meaningless to anyone other than the person producing the system, i.e. the states of the variables directly affects the discriminatory power of the expert system.

2) In an expert system the possibility of more than one answer to a problem must be addressed. This is not possible in mathematical models where outcomes will always be mutually exclusive. If an expert system does produce more than one answer this can be for any of three reasons:

i) The knowledge base contains conflicting rules - this can be dealt with as it is simply a verification problem. The confliction is located by testing and then removed.

ii) The knowledge is not defined accurately enough. Sell tackles this problem through an illustration of what constitutes baldness. If this is done on the area of scalp showing then there may be a conflict if another test is done by number of hairs on the head. This anomaly can be simply removed by tightening up definitions, and presenting less ambiguous questions to the user.

iii) There is genuinely more than one answer to the problem. This eventuality cannot be addressed in any simple way as it does not arise in mathematical modelling. Comfort can be taken though from the fact that this should only occur where more than one expert is involved in developing the knowledge base or alternatively where two (or more) acceptable solutions can be recognised in the real world - here the solution may come through the use of probabilities to separate the solutions.

3) Expert system development involves the need to be able to capture judgement. This requirement is not normally present in mathematical models, however models do exist where judgement is required. (See Finlay (1982)). Here a validation process has been used in the same model as for non-judgemental mathematical models, so the validation process identified is still applicable.

4) The goal of an expert system is somewhat different from that of a mathematical model. Expert systems generally aim to emulate the decision making process of the expert whose knowledge is captured within them. This is a different concept from that in a mathematical model where the "knowledge" used is the "truth" - not one person's view of it. This potential problem can be overcome in two ways. - The first involves recognising that a mathematical model is not necessarily dealing with the "truth" but is also presenting a view of the world as seen in the eyes of the modeller, and so the two techniques are recognised as being similar. The second involves altering the expert system by using a number of experts to produce it. If this is done the aim will be to produce "the answer" to the problem rather than the best of a combination of answers given by the experts. The reasoning behind this is complex, and not yet possible in expert system technology, as the only way to cope with such a problem is through probabilities. The use of which will not produce "the correct answer" but the most "acceptable" answer given the criteria presented by the experts. Validation of mathematical models is undertaken with full knowledge of the former situation,

so as long as it is recognised that the expert system is giving a view and not "the answer" the validation techniques remain applicable.

Although there are marked differences between expert systems and mathematical models, none of these differences are great enough to invalidate the use of mathematical model validation techniques for expert systems. This accordingly was done in the development of the expert system prototype produced in the project.

The five dimensions identified by Sell were each considered in the development of the prototype expert system, both at the outset and during the building and testing of the rules. The method of validation undertaken is described below:

i) Consistency - (verification). This was checked upon the selection of the package. It simply involved ensuring that all computations within the system were correct and that the package was functioning as it should. This was achieved by testing a selection of known data against the system as changes were made to it.

ii) Completeness - That all solutions within the domain could be reached was a very difficult dimension to validate. This was done using a rule induction process (See the section on rule induction for details on the process) whereby all attributes within the system and their associated values were tested to ensure that each had an acceptable outcome. It was necessary to do this every time a new attribute was added to the system as each new attribute had an effect on all other related attributes already within the system.

iii) Soundness - (accuracy). Accuracy in concept was a very simple dimension to check for, however in practice the system on several occasions proved to be inaccurate in its actions. This was very difficult to comprehend at first as seemingly logical rules were producing inaccurate and in some cases totally wrong answers. This problem was solved through understanding gained in two areas:

(1) The rule induction process mentioned above is useful for ensuring that the system was complete, however the algorithm used in its calculation (Quinlan's ID3 algorithm) is imprecise in its handling of numeric data. As a result those rules which contained numeric data and were entered directly into the expert system from the rule induction process could not be guaranteed to be accurate.

(2) The package selected for the development of the expert system (Xi Plus) is written in the language "Prolog". Prolog is not a conventional procedural language but is a declarative language which works through the seeking of solutions to goals set by the programmer. This meant that it often followed a reasoning pattern which was different from that expected by the researcher

until he had suitably examined the Prolog language to understand how it worked.
Once these two problem areas had been recognised, the validation of the system's accuracy was a relatively simple matter, proved by entering known test cases through the system and examining their results.

iv) Precision - Precision was not validated in the project as the system produced was deterministic and did not use uncertainty.

v) Useability - the expert system prototype developed is "usable", and all of the questions asked by the system at a consultation have been checked with several bankers to ensure that they are not ambiguous. The removal of ambiguity is an on-going process which will develop with the system. The problem of usability can be typified by one of the questions in the expert system prototype:
"What is the competition like in the field?"
To an expert lending banker this question is not ambiguous. However if a layman was to be asked the question he would need to know what the definition of competition was, as well as knowing exactly the meaning of "field" in bank lending. In the expert system prototype this ambiguity was removed by help screens which can be called by the user at any time. This help needs to be extensive for any fully developed system if it is to be used by people other than those specifically trained in bank lending and

its terminology. Testing here needs to be carried out on all possible types of people who would come into contact with the system. This was done to a certain extent in the prototype where several non-bankers were asked to use the system, and their comments were then used to simplify the questions. However, to effect a more reliable test of any full system a sample of potential users would need to be consulted and their comments and abilities to use the system noted.

There is one other area of validation which was not noted by Sell (1985) which needs to be addressed to complete the research in this area. This is that of the interaction of the system with the final user (the lending banker). (This could be seen as a part of useability, however it goes further than just examining ambiguities). This area is probably the most important to the user as he is not really concerned with the "guts" of the system but with his day to day encounters with it. This area of validation is concerned with the user interface of the expert system.

It is very difficult to validate this part of the system as it is totally dependent upon the eventual users of the system. The only method of validation is in the field testing on lending bankers and other possible users. This testing needs to take into account such wide ranging factors as; speed of the system, sequence of questioning, and method of questioning. Here again a test pack needs to be developed in the future to cover these possibilities. The expert system prototype was tested on academic bankers in the university and on several bank managers during its development. This small sample was in no way large enough to validate the user interface of the system, and further testing needs to be carried out in this area. As with the other validation tests, validation of the user interface is an on-going process which will not be complete even when the final expert system is in use in "real" lending situations. Continuous evolution of the system needs to be maintained, adapting to the users needs as they alter and grow.

The validation process for expert systems is still very much in its infancy. The parallels drawn with mathematical modelling allowed an effective validation process to be applied to the expert system prototype. However, in the future a validation process which is unique to expert systems needs to be established. This will enable those parts of expert systems which differ from mathematical models to be more effectively tackled, rather than being broken down into sections which can be identified in a mathematical model. In concluding, Gaschnig, Klahr et al. (1983) suggest that expert systems should be constantly evaluated within the bounds of five typical questioning areas:

- Is the knowledge representation scheme adequate or does it need to be extended or modified?
- Is the system coming up with the right answers for the right reasons?

- Is the embedded knowledge consistent with the experts?
- Is it easy for users to interact with the system?
- What facilities and capabilities do the users need?

These questioning areas fall largely within the five elements produced by Sell (1985), however they provide the on going user of the system with a series of simple questions which can be referred to during the life of the system, and if necessary allow for referral back to the system developer if any go amiss. Something which should be easily noticeable given the general nature of the questions.

# CHAPTER SEVEN - THE CONCLUSIONS

The aim of this project was:

(1) to identify the need in corporate bank lending for an automated lending advisor to assist lenders.

(2) to produce a possible solution to this problem.

This has been achieved in the production of the expert system prototype. The system is able to offer to the lending corporate banker an automated advisor which can, if required, produce a lending decision based on the factors commonly used by bankers in their evaluation of lending proposals.

The advisor developed in the research is a stand alone system which has been produced to fit into a very tightly identified niche in the corporate lender's portfolio. This was done so that the capabilities of expert systems for lenders could be established, rather than producing a total system to cover the whole portfolio.

The major problems identified in the research were overcome in that a working model has been produced, and the method for the production of a full system has been set out.

## THE FUTURE

As the system was being developed a larger strategy for corporate lending emerged. This was based largely on the portfolio methodology already identified. The use of expert systems in lending does not only enable more rapid and more effective decisions to be made, but it also opens up the whole area of the inherent management information generated by the system itself. It has been recognised through the research that this information is of direct use, both as a feedback tool to the portfolio managers (the strategic decision makers) which has already been identified; and perhaps more importantly, as a feedback mechanism into the expert system (the EMIS) itself. This would allow the system to undertake its own 'on line' validation. Taking the concept one stage further the system could also be expanded to allow not only validation to take place but also the automatic updating of the model parameters as they might need to change through time.

Such future development of the EMIS model may seem to be a long way off. However, new research into expert systems (see Chorafas (1987)) is suggesting that such systems are not only possible, but essential, if the true power of expert system technology is to be applied in the corporate lending area.

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## APPENDIX ONE - THE KNOWLEDGE BASE

```
fact  1     liabs1 = overdraft1 + taxation11 + dividend11 +
            creditors1 + accruals1
fact  2     curr.assets1 = stock1 + cash1 + debtors1 +
            prepayments1
fact  3     cur.ratio1 = curr.assets1 / liabs1
fact  4     quickratio1 = ( cash1 + debtors1 ) / liabs1
fact  5     assets1 = curr.assets1 + fixed.assets1
fact  6     profit.ratio1 = preprofit1 / assets1
fact  7     gearing1 = ( liabs1 + ltliabs ) / ( capital1 +
            reserves1 )
fact  8     performance1 = 365 * stock1 / sales1
fact  9     efficiency1 = debtors1 / creditors1
fact 10     repay = amount / years
fact 11     retprofit = return / 100 * amount + preprofit1 -
            taxation21 - dividend21
fact 12     repayment = amount * interest / 100 + repay
fact 13     ltliabs = dirloans + debentures + mortgages + ltbank +
            defertax
question  1  amount =
            question text How much borrowing is required ?
question  2  type is
            question text What type of security is available ?
question  3  value =
            question text What is the realisable value of the
            security ?
```

```
question  4  industry is
          question text What industry is the company in ?
question  5  age =
          question text How old is the company ( in years ) ?
question  6  availability is
          question text Are audited accounts available ?
question  7  return =
          question text What is the expected return of the
          proposition (as a percentage ) ?
question  8  directors are
          question text How would you describe the directors'
          business abilities ?
question  9  competition is
          question text How strong is the competition against
          the company ?
          question help from file helpcomp.txt
question 10  years =
          question text How many years are required to repay ?
question 11  interest =
          question text What will be the interest rate charged
          ( % ) ?
question 12  sales1 =
          question text type in year one sales
question 13  preprofit1 =
          question text type in year one pretax profit
question 14  taxation21 =
          question text type in tax payable on year one profits
```

```
question 15  dividend21 =

          question text type in dividend payable on year one
          profits

question 16  fixed.assets1 =

          question text type in fixed assets at year one

question 17  stock1 =

          question text type in stock for year one

question 18  cash1 =

          question text type in cash for year one

question 19  debtors1 =

          question text type in debtors for year one

question 20  capital1 =

          question text type in capital for year one

question 21  reserves1 =

          question text type in reserves for year one

question 22  overdraft1 =

          question text type in overdraft for year one

question 23  creditors1 =

          question text type in creditors for year one

question 24  taxation11 =

          question text type in tax due to be paid in year one

          from b / s )

question 25  dividend11 =

          question text type in div due to be paid in year one

          from b / s )

question 26  accruals1 =

          question text Type in the level of accruals for year 1
```

```
question 27  prepayments1 =
          question text Type in the level of prepayments for
          year 1
question 28  dirloans =
          question text What is the value of any directors
          loans ?
question 29  debentures =
          question text What is the value of any debentures
          already outstanding ?
question 30  mortgages =
          question text What is the value of any mortgages
          already taken out ?
question 31  ltbank =
          question text What is the value of any long term bank
          finance already taken out ?
question 32  defertax =
          question text What is the amount of deferred taxation
          outstanding ?
demon 1   when check decision
          and repayment > retprofit
   then report repayment is impossible from present
          and report profits even assuming that the proposal
          and report will bring in a return of [return] %
          and decision is don't lend as profits too low
         when check borrow
          and repayment <= retprofit
   then check decision
```

```
rule 1   if   query borrowing request
         then report from file open.rpt
                and check amount
                and check return
                and check years
                and check interest
                and check preprofit1
                and check taxation21
                and check dividend21
                and check retprofit
                and check repayment
                and check borrowing request
rule 2   if   amount > 150000
         then request is outside limits
rule 3   if   amount < 500
         then request is outside limits
rule 4   if   request is outside limits
         then decision is request is beyond system
rule 5   if   interest > 30
         then request is outside limits
rule 6   if   years > 25
         then request is outside limits
rule 7   if   proposition is good
                and request is not outside limits
                and accounts are good
                and security is good
         then decision is lend
```

```
rule 8   if   proposition is good
                and request is not outside limits
                and accounts are average
                and security is good
         then decision is lend
rule 9   if   proposition is good
                and request is not outside limits
                and accounts are poor
                and business is good
                and security is good
         then decision is lend but ensure that a charge is taken
         over the security
rule 10  if   proposition is good
                and request is not outside limits
                and accounts are poor
                and business is average
                and security is good
         then decision is lend but ensure that a charge is taken
         over the security
rule 11  if   proposition is good
                and request is not outside limits
                and accounts are poor
                and business is poor
                and security is good
         then decision is refer
rule 12  if   proposition is good
                and request is not outside limits
```

```
            and accounts are none
            and security is good
       then decision is lend but ensure that a charge is taken
       over the security
rule 13  if   proposition is good
            and request is not outside limits
            and accounts are good
            and security is average
       then decision is lend
rule 14  if   proposition is good
            and request is not outside limits
            and accounts are average
            and security is average
       then decision is lend
rule 15  if   proposition is good
            and request is not outside limits
            and accounts are poor
            and business is good
            and security is average
       then decision is lend
rule 16  if   proposition is good
            and request is not outside limits
            and accounts are poor
            and business is average
            and security is average
       then decision is lend
rule 17  if   proposition is good
```

```
          and request is not outside limits
          and accounts are poor
          and business is poor
          and security is average
     then decision is refer
rule 18  if   proposition is good
          and request is not outside limits
          and accounts are none
          and security is average
     then decision is lend
rule 19  if   proposition is good
          and request is not outside limits
          and accounts are good
          and security is poor
     then decision is lend
rule 20  if   proposition is good
          and request is not outside limits
          and accounts are average
          and business is good
          and security is poor
     then decision is lend
rule 21  if   proposition is good
          and request is not outside limits
          and accounts are average
          and business is average
          and security is poor
     then decision is refer
```

```
rule 22  if   proposition is good
                and request is not outside limits
                and accounts are average
                and business is poor
                and security is poor
         then decision is refer
rule 23  if   proposition is good
                and request is not outside limits
                and accounts are poor
                and security is poor
         then decision is refer
rule 24  if   proposition is good
                and request is not outside limits
                and accounts are poor
                and security is poor
         then decision is refer
rule 25  if   proposition is good
                and request is not outside limits
                and accounts are good
                and security is none
         then decision is lend
rule 26  if   proposition is good
                and request is not outside limits
                and accounts are average
                and business is good
                and security is none
         then decision is lend
```

```
rule 27  if   proposition is good
                and request is not outside limits
                and accounts are average
                and business is average
                and security is none
         then decision is refer
rule 28  if   proposition is good
                and request is not outside limits
                and accounts are average
                and business is poor
                and security is none
         then decision is refer
rule 29  if   proposition is good
                and request is not outside limits
                and accounts are poor
                and security is none
         then decision is refer
rule 30  if   proposition is good
                and request is not outside limits
                and accounts are none
                and security is none
         then decision is refer
rule 31  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are average
                and security is good
```

```
        then decision is lend
rule 32  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are poor
                and security is good
        then decision is refer
rule 33  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are none
                and security is good
        then decision is refer
rule 34  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are average
                and security is average
        then decision is lend
rule 35  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are poor
                and security is average
        then decision is refer
rule 36  if   proposition is average
                and request is not outside limits
```

```
            and business is good
            and accounts are none
            and security is average
        then decision is refer
rule 37  if    proposition is average
            and request is not outside limits
            and business is good
            and accounts are average
            and security is poor
        then decision is lend
rule 38  if    proposition is average
            and request is not outside limits
            and business is good
            and accounts are poor
            and security is poor
        then decision is refer
rule 39  if    proposition is average
            and request is not outside limits
            and business is good
            and accounts are none
            and security is poor
        then decision is refer
rule 40  if    proposition is average
            and request is not outside limits
            and business is good
            and accounts are average
            and security is none
```

```
        then decision is refer
rule 41  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are poor
                and security is none
        then decision is refer
rule 42  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are none
                and security is none
        then decision is refer
rule 43  if   proposition is average
                and request is not outside limits
                and business is good
                and accounts are good
                and security is good
        then decision is lend
rule 44  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are good
                and security is good
        then decision is lend
rule 45  if   proposition is average
                and request is not outside limits
```

and business is average
and accounts are average
and security is good
then decision is lend but ensure that a charge is taken over the security

rule 46 if proposition is average
and request is not outside limits
and business is average
and accounts are poor
and security is good
then decision is don't lend

rule 47 if proposition is average
and request is not outside limits
and business is average
and accounts are none
and security is good
then decision is refer

rule 48 if proposition is average
and request is not outside limits
and business is poor
and accounts are good
and security is good
then decision is lend but ensure that a charge is taken over the security

rule 49 if proposition is average
and request is not outside limits
and business is poor

```
            and accounts are average
            and security is good
       then decision is don't lend
rule 50  if   proposition is average
            and request is not outside limits
            and business is poor
            and accounts are poor
            and security is good
       then decision is don't lend
rule 51  if   proposition is average
            and request is not outside limits
            and business is poor
            and accounts are none
            and security is good
       then decision is don't lend
rule 52  if   proposition is average
            and request is not outside limits
            and business is good
            and accounts are good
            and security is average
       then decision is lend
rule 53  if   proposition is average
            and request is not outside limits
            and business is average
            and accounts are good
            and security is average
       then decision is lend
```

```
rule 54  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are average
                and security is average
         then decision is lend but ensure that a charge is taken
         over the security
rule 55  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are poor
                and security is average
         then decision is don't lend
rule 56  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are none
                and security is average
         then decision is refer
rule 57  if   proposition is average
                and request is not outside limits
                and business is poor
                and accounts are good
                and security is average
         then decision is refer
rule 58  if   proposition is average
                and request is not outside limits
```

```
           and business is poor
           and accounts are average
           and security is average
      then decision is don't lend
rule 59  if   proposition is average
           and request is not outside limits
           and business is poor
           and accounts are poor
           and security is average
      then decision is don't lend
rule 60  if   proposition is average
           and request is not outside limits
           and business is poor
           and accounts are none
           and security is average
      then decision is don't lend
rule 61  if   proposition is average
           and request is not outside limits
           and business is good
           and accounts are good
           and security is poor
      then decision is lend
rule 62  if   proposition is average
           and request is not outside limits
           and business is average
           and accounts are good
           and security is poor
```

```
        then decision is refer
rule 63  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are average
                and security is poor
        then decision is refer
rule 64  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are poor
                and security is poor
        then decision is don't lend
rule 65  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are none
                and security is poor
        then decision is don't lend
rule 66  if   proposition is average
                and request is not outside limits
                and business is poor
                and accounts are good
                and security is poor
        then decision is refer
rule 67  if   proposition is average
                and request is not outside limits
```

```
            and business is poor
            and accounts are average
            and security is poor
       then decision is don't lend
rule 68  if   proposition is average
            and request is not outside limits
            and business is poor
            and accounts are poor
            and security is poor
       then decision is don't lend
rule 69  if   proposition is average
            and request is not outside limits
            and business is poor
            and accounts are none
            and security is poor
       then decision is don't lend
rule 70  if   proposition is average
            and request is not outside limits
            and business is good
            and accounts are good
            and security is none
       then decision is lend
rule 71  if   proposition is average
            and request is not outside limits
            and business is average
            and accounts are good
            and security is none
```

```
        then decision is refer
rule 72  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are average
                and security is none
        then decision is refer
rule 73  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are poor
                and security is none
        then decision is don't lend
rule 74  if   proposition is average
                and request is not outside limits
                and business is average
                and accounts are none
                and security is none
        then decision is don't lend
rule 75  if   proposition is average
                and request is not outside limits
                and business is poor
                and accounts are good
                and security is none
        then decision is refer
rule 76  if   proposition is average
                and request is not outside limits
```

```
            and business is poor
            and accounts are average
            and security is none
       then decision is don't lend
rule 77  if   proposition is average
            and request is not outside limits
            and business is poor
            and accounts are poor
            and security is none
       then decision is don't lend
rule 78  if   proposition is average
            and request is not outside limits
            and business is poor
            and accounts are none
            and security is none
       then decision is don't lend
rule 79  if   proposition is poor
            and request is not outside limits
       then decision is don't lend
rule 80  if   type is property
            and value > amount
       then security is good
rule 81  if   type is property
            and value = amount
       then security is good
rule 82  if   type is property
            and value < amount
```

```
        then security is average
rule 83 if   type is shares
               and value < amount
        then security is poor
rule 84 if   type is shares
               and value = amount
        then security is poor
rule 85 if   type is shares
               and value > amount
        then security is average
rule 86 if   type is plant & machinery
               and value > amount
        then security is good
rule 87 if   type is plant & machinery
               and value = amount
        then security is average
rule 88 if   type is plant & machinery
               and value < amount
        then security is poor
rule 89 if   type is guarantee
               and value < amount
        then security is poor
rule 90 if   type is guarantee
               and value = amount
        then security is poor
rule 91 if   type is guarantee
               and value > amount
```

```
        then security is average
rule 92  if   type is none
        then security is none
rule 93  if   industry is mining and quarrying
        then risk is high
rule 94  if   industry is chemicals and allied
        then risk is low
rule 95  if   industry is metal manufacturing
        then risk is average
rule 96  if   industry is vehicle manufacturing
        then risk is high
rule 97  if   industry is food and drinks and tobacco
        manufacturing
        then risk is average
rule 98  if   industry is other manufacturing
        then risk is average
rule 99  if   industry is agriculture and forestry and fishing
        then risk is high
rule 100 if   industry is construction
        then risk is high
rule 101 if   industry is public sector transport and
        communications
        then risk is average
rule 102 if   industry is social services
        then risk is low
rule 103 if   industry is other public services
        then risk is low
```

```
rule 104 if   industry is professional and scientific
        then risk is low
rule 105 if   industry is insurance and recognised banks and
        building societies
        then risk is average
rule 106 if   industry is other financial services
        then risk is high
rule 107 if   industry is distribution
        then risk is high
rule 108 if   industry is any other industry
        then risk is high
rule 109 if   business is not good
                and business is not average
                and age <= 1
        then business is poor
rule 110 if   directors are good
                and risk is high
                and competition is average
        then business is average
rule 111 if   directors are good
                and risk is high
                and competition is weak
        then business is average
rule 112 if   directors are good
                and risk is average
                and competition is strong
        then business is average
```

```
rule 113 if   directors are good
                and risk is average
                and competition is average
         then business is good
rule 114 if   directors are good
                and risk is average
                and competition is weak
         then business is good
rule 115 if   directors are good
                and risk is low
         then business is good
rule 116 if   directors are average
                and competition is strong
                and risk is high
         then business is poor
rule 117 if   directors are average
                and competition is strong
                and risk is average
         then business is poor
rule 118 if   directors are average
                and competition is strong
                and risk is low
         then business is average
rule 119 if   directors are average
                and competition is average
                and risk is high
         then business is poor
```

```
rule 120 if   directors are average
                and competition is average
                and risk is average
         then business is average
rule 121 if   directors are average
                and competition is average
                and risk is low
         then business is average
rule 122 if   directors are average
                and competition is weak
                and risk is high
         then business is average
rule 123 if   directors are average
                and competition is weak
                and risk is average
         then business is average
rule 124 if   directors are average
                and competition is weak
                and risk is low
         then business is good
rule 125 if   directors are poor
         then business is poor
rule 126 if   directors are good
                and risk is high
                and competition is strong
         then business is poor
rule 127 if   availability is no
```

```
        then accounts are none
rule 128 if   availability is yes
                and profits are high
                and liquidity is high
                and efficiency is good
                and gearing is high
        then accounts are average
rule 129 if   availability is yes
                and profits are high
                and liquidity is high
                and efficiency is good
                and gearing is average
        then accounts are good
rule 130 if   availability is yes
                and profits are high
                and liquidity is high
                and efficiency is good
                and gearing is low
        then accounts are good
rule 131 if   availability is yes
                and profits are high
                and liquidity is high
                and efficiency is average
                and gearing is high
        then accounts are average
rule 132 if   availability is yes
                and profits are high
```

```
            and liquidity is high
            and efficiency is average
            and gearing is average
       then accounts are average
rule 133 if   availability is yes
            and profits are high
            and liquidity is high
            and efficiency is average
            and gearing is low
       then accounts are good
rule 134 if   availability is yes
            and profits are high
            and liquidity is high
            and efficiency is poor
       then accounts are average
rule 135 if   availability is yes
            and profits are high
            and liquidity is average
            and efficiency is good
            and gearing is high
       then accounts are average
rule 136 if   availability is yes
            and profits are high
            and liquidity is average
            and efficiency is good
            and gearing is average
       then accounts are average
```

```
rule 137 if   availability is yes
                and profits are high
                and liquidity is average
                and efficiency is good
                and gearing is low
         then accounts are good
rule 138 if   availability is yes
                and profits are high
                and liquidity is average
                and efficiency is average
         then accounts are average
rule 139 if   availability is yes
                and profits are high
                and liquidity is average
                and efficiency is poor
         then accounts are average
rule 140 if   availability is yes
                and profits are high
                and liquidity is low
                and gearing is high
         then accounts are poor
rule 141 if   availability is yes
                and profits are high
                and liquidity is low
                and gearing is average
         then accounts are average
rule 142 if   availability is yes
```

```
            and profits are high
            and liquidity is low
            and gearing is low
        then accounts are average
rule 143 if   availability is yes
            and profits are average
            and liquidity is high
            and gearing is low
        then accounts are average
rule 144 if   availability is yes
            and profits are average
            and liquidity is average
            and gearing is low
        then accounts are average
rule 145 if   availability is yes
            and profits are average
            and liquidity is low
            and gearing is high
        then accounts are poor
rule 146 if   availability is yes
            and profits are average
            and liquidity is low
            and gearing is average
        then accounts are average
rule 147 if   availability is yes
            and profits are average
            and liquidity is low
```

```
            and gearing is low
       then accounts are average
rule 148 if   availability is yes
            and profits are low
            and liquidity is high
            and gearing is low
       then accounts are average
rule 149 if   availability is yes
            and profits are low
            and liquidity is average
            and gearing is low
       then accounts are average
rule 150 if   availability is yes
            and profits are low
            and liquidity is low
            and gearing is high
       then accounts are poor
rule 151 if   availability is yes
            and profits are low
            and liquidity is low
            and gearing is average
       then accounts are poor
rule 152 if   availability is yes
            and profits are low
            and liquidity is low
            and gearing is low
       then accounts are average
```

```
rule 153 if   availability is yes
                and profits are average
                and liquidity is high
                and gearing is average
         then accounts are average
rule 154 if   availability is yes
                and profits are average
                and liquidity is high
                and gearing is high
         then accounts are poor
rule 155 if   availability is yes
                and profits are average
                and liquidity is average
                and gearing is average
         then accounts are average
rule 156 if   availability is yes
                and profits are average
                and liquidity is average
                and gearing is high
         then accounts are poor
rule 157 if   availability is yes
                and profits are low
                and liquidity is high
                and gearing is average
         then accounts are average
rule 158 if   availability is yes
                and profits are low
```

```
              and liquidity is high
              and gearing is high
          then accounts are poor
rule 159 if   availability is yes
              and profits are low
              and liquidity is average
              and gearing is average
          then accounts are poor
rule 160 if   availability is yes
              and profits are low
              and liquidity is average
              and gearing is high
          then accounts are poor
rule 161 if   availability is yes
              and profits are losses
          then accounts are poor
rule 162 if   return > 11
          then proposition is good
rule 163 if   return <= 11
              and return > 4
          then proposition is average
rule 164 if   return <= 4
          then proposition is poor
rule 165 if   cur.ratio1 <= 2
              and cur.ratio1 >= 1.5
          then liquidity1 is average
rule 166 if   cur.ratio1 > 2
```

```
        then liquidity1 is good
rule 167 if   cur.ratio1 < 1.5
        then liquidity1 is poor
rule 168 if   quickratio1 > 1
        then liquid1 is good
rule 169 if   quickratio1 <= 1
                and quickratio1 >= 0.7
        then liquid1 is average
rule 170 if   quickratio1 < 0.7
        then liquid1 is poor
rule 171 if   liquid1 is poor
                and liquidity1 is poor
        then report from file bk1.rpt
                and liquidity is low
rule 172 if   liquid1 is poor
                and liquidity1 is average
        then report from file bk2.rpt
                and liquidity is low
rule 173 if   liquid1 is poor
                and liquidity1 is good
        then report from file bk2.rpt
                and liquidity is average
rule 174 if   liquid1 is average
                and liquidity1 is poor
        then report from file bk3.rpt
                and liquidity is average
rule 175 if   liquid1 is average
```

```
                and liquidity1 is average
         then liquidity is average
rule 176 if   liquid1 is average
                and liquidity1 is good
         then liquidity is high
rule 177 if   liquid1 is good
                and liquidity1 is poor
         then report from file bk4.rpt
                and liquidity is low
rule 178 if   liquid1 is good
                and liquidity1 is average
         then report from file bk4.rpt
                and liquidity is average
rule 179 if   liquid1 is good
                and liquidity1 is good
         then liquidity is high
rule 180 if   profit.ratio1 > 0.15
         then profits are high
rule 181 if   profit.ratio1 <= 0.15
                and profit.ratio1 > 0.1
         then profits are average
rule 182 if   profit.ratio1 <= 0.1
                and profit.ratio1 >= 0
         then profits are low
rule 183 if   efficiency1 > 1.5
         then effic is good
rule 184 if   efficiency1 <= 1.5
```

```
            and efficiency1 > 0.9
        then effic is average
rule 185 if   efficiency1 <= 0.9
        then effic is poor
rule 186 if   gearing1 > 1.5
        then gearing is high
rule 187 if   gearing1 <= 1.5
            and gearing1 > 1.25
        then gearing is average
rule 188 if   gearing1 <= 1.25
        then gearing is low
rule 189 if   preprofit1 < 0
        then profits are losses
rule 190 if   performance1 > 90
        then perf is poor
rule 191 if   performance1 > 30
            and performance1 <= 90
        then perf is average
rule 192 if   performance1 <= 30
        then perf is good
rule 193 if   perf is good
            and effic is good
        then efficiency is good
rule 194 if   perf is good
            and effic is average
        then efficiency is good
rule 195 if   perf is good
```

```
            and effic is poor
       then efficiency is average
rule 196 if   perf is average
            and effic is good
       then efficiency is good
rule 197 if   perf is average
            and effic is average
       then efficiency is average
rule 198 if   perf is average
            and effic is poor
       then efficiency is average
rule 199 if   perf is poor
            and effic is good
       then efficiency is average
rule 200 if   perf is poor
            and effic is average
       then efficiency is poor
rule 201 if   perf is poor
            and effic is poor
       then efficiency is poor
rule 202 if   decision is lend
       then borrowing request is lend
            and report from file lend.rpt
rule 203 if   decision is refer
       then borrowing request is refer
            and report from file refer.rpt
rule 204 if   decision is don't lend
```

```
         then borrowing request is refuse
                and report from file refuse.rpt
rule 205 if   decision is request is beyond system
         then borrowing request is outside limits
                and report from file outside.rpt
rule 206 if   decision is lend but ensure that a charge is
         taken over the security
         then borrowing request is lend secured
         and report from file lendsec.rpt
default 1    directors are average
default 2    type is none
default 3    competition is average
query 1   borrowing request
```

# APPENDIX TWO - THE REPORT FILES

## Opening Report File

BANK CORPORATE LENDING EXPERT SYSTEM

Developed By

Gareth J. Forsey

Spring 1987

Department of Management Studies

Loughborough University of Technology

Liquidity Report File One

## COMPANY LIQUIDITY REPORT

The company appears to be HIGHLY ILLIQUID. The current assets should be carefully checked to ensure that they are readily realisible and the position of the creditors should be established. Extreme caution should be taken if a decision is made to lend, and checks should be made to ensure that the company is not overtrading.

Liquidity Report File Two

## COMPANY LIQUIDITY REPORT

The company appears to be CASH DEFICIENT. The current assets should be carefully checked to ensure that they are readily realisible and the position of the creditors should be established. There may be a requirement for some short term finance to cover the liquidity problems. Rapid expansion of the business should also be discouraged to avoid overtrading.

Liquidity Report File Three

## COMPANY LIQUIDITY REPORT

The company appears to be RUNNING DOWN STOCKS. The stock type and levels should be physically checked and a reason sought for the poor stock figure. Concern here may be unjustified if the company is simply turning over its stock more quickly. But the situation needs to be verified.

Liquidity Report File Four

COMPANY LIQUIDITY REPORT

========================

The company appears to have VERY POOR STOCK LEVELS. The stock type and levels should be physically checked and a reason sought for the poor stock figure. Concern here may be unjustified if the company is simply turning over its stock more quickly, or if it can be established that low levels of stock are usual for the company. However the situation needs to be verified by asking the company.

Competition Help File

CORPORATE LENDING ADVISOR

========================

HELP FOR DEFINITION OF COMPETITION STRENGTH:

-------------------------------------------

The competition is strong when there are other businesses already in operation in the field in which the proposer is operating. This includes examples where another firm is making a similar product.

The competition is weak when there are no direct competitors. This includes situations where there are competitors in a different field who might possibly, in the future move into the field in question.

The competition is none when there is no chance of any competition for the competitor now, nor at any time in the near future. (One year minimum).

Lend Unsecured Report File

CORPORATE LENDING EXPERT SYSTEM

============================

LENDING DECISION IS: LEND THE FUNDS REQUESTED.

=======================

The funds requested can be lent. This lending may be done unsecured, however if security is readily available a charge should be taken.

Lend Secured Report File

CORPORATE LENDING EXPERT SYSTEM
===============================

LENDING DECISION IS: LEND THE FUNDS REQUESTED TAKING SECURITY.
========================================

The funds requested can be lent. This lending must be secured by a charge over the security present. If the security is unavailable for any reason the lending decision will automatically become: REFER THE LOAN REQUEST. In this case please refer the request to a higher authority lending officer for sanctioning.

Outside Limits Report File

CORPORATE LENDING EXPERT SYSTEM

==============================

LENDING DECISION IS: OUTSIDE THE BOUNDS OF THE EXPERT SYSTEM

======================================

SO NO RECOMMENDATION CAN BE MADE

===============================

Please refer the request to a higher authority for possible sanction although this is unlikely as it is outside the normal lending parameters for the bank.

Refer Decision Report File

CORPORATE LENDING EXPERT SYSTEM

================================

LENDING DECISION IS:  REFER THE LOAN REQUEST.

======================

The loan request cannot be decided from the information entered. Please refer it to a higher authority lending officer for sanctioning.

Refuse Borrowing Report File

CORPORATE LENDING EXPERT SYSTEM

===========================

LENDING DECISION IS: REFUSE THE LOAN REQUEST.

=====================

APPENDIX THREE - IT SUPPORT FOR CORPORATE BANK LENDING

THE POSITION PAPER PRODUCED

# INFORMATION TECHNOLOGY SUPPORT FOR CORPORATE BANK LENDING

By

Paul N. Finlay

Gareth J. Forsey

Department of Management Studies

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## ABSTRACT

Decision-making in corporate bank lending occurs at both the strategic and the individual proposition level. In principle, these levels will require a different type of IT support for the decisions taken therein.

This paper discusses the concepts of decision support systems and management information systems, in the light of recent developments in information technology, particularly those in the field of expert systems. The conclusions drawn are that a decision support system will be needed at the strategic level, whilst an augmented management information system will be required for dealing with individual propositions. This augmentation is seen to come from an expert system 'front-end' to the information system, providing an expert management information system.

INTRODUCTION.

Banking has traditionally been seen as a large consumer of computer technology products. An examination of the uses of this technology shows that in the UK clearing banks the consumption may be high, but this is largely in the data processing departments where large numbers of calculations take place. The latest developments in management assistance in decision making by computer has yet to be incorporated in banking. (A picture which is certainly not the case in the U.S. if Willis (1) is to believed when he says 'of all financial industry segments, banking is the most active when it comes to making the best use of new technologies. Bankers could even be considered technology trailblazers.'). This paper seeks to demonstrate to UK bankers that there are opportunities in management IT support systems which need to be taken up in order to provide lending decision makers with effective computerised tools, allowing them to compete more effectively in the corporate lending market.

Decision-making in bank lending can be broadly categorised into three areas. At the top level there are the corporate strategic decisions concerned with the balance between the bank's major activities. An example of this is the overall level of activity the bank thinks wise in such businesses as sovereign lending and lending to the corporate sector.

Within each of these sectors there are lower level decisions to be made, which are nevertheless strategic in nature. These we term business strategic decisions. Taken withing the strategy for corporate lending for example, business strategic decisions would be concerned with the balance between the types of industries and businesses within the bank's portfolio.

The two strategic levels of decision-making provide the framework within which individual lending propositions would be appraised and it is this level which makes up the third category of decision-making, comprising the individual lending proposals evaluated by branch managers and regional head offices.

The strategic decisions and the evaluation of individual lending propositions are essentially different in their make-up. To follow Dermer's terminology (2) the strategic decisions are mainly unstructured: in contrast, the evaluation of individual lending propositions is a structured activity. Here a number of pre-defined steps are followed within a fixed, externally defined policy.

## MANAGEMENT INFORMATION AND DECISION SUPPORT SYSTEMS.

The distinction between Management Information Systems (MIS) and Decision Support Systems (DSS) has been discussed by many authors, most recently and extensively by Finlay and Forghani (3)

This view categorises DSS and MIS through a number of key elements. A part of their classification is reproduced in Figure 1. This division of the systems into their key elements makes it possible to examine (unstructured) strategic decision-making and the (structured) evaluation of individual lending propositions to establish whether they are best served through the development of a DSS or an MIS.

FIGURE 1: Finlay & Forghani's Categorisation of MIS and DSS.

| Characteristic | M.I.S. | D.S.S. |
|---|---|---|
| 1) Type of System: | Internal Control. | Planning Systems. |
| 2) Focus: | Efficient & Structured. Information Flow. | Effective Decisions Use of Models, User friendliness, flexible, adaptable. |
| 3) Objectives: | Pre-specified. | Adhoc, contingent. |
| 4) Situation Type: | Within Fixed Policies. | In Given Scenario. |
| 5) Design Perspective: | Organisational. | Individual/Small Group. |
| 6) Models: | Fixed Logic, Mainly Deterministic Data. | Evolutionary Logic, Probabilistic Data. |
| 7) Output: | General Format, An Answer, Information. | User Specified, Insight Learning, Intelligence. |

| | | |
|---|---|---|
| 8) Time-scale: | Past, Present & Future. | Present & Future. |
| 9) Context: | Independent. | Dependent. |
| 10) Implementation: | Prototyping of Inputs & Outputs. | 'Breadboarding' |
| 11) Exactitude: | Precision and Accuracy. | Accuracy. |

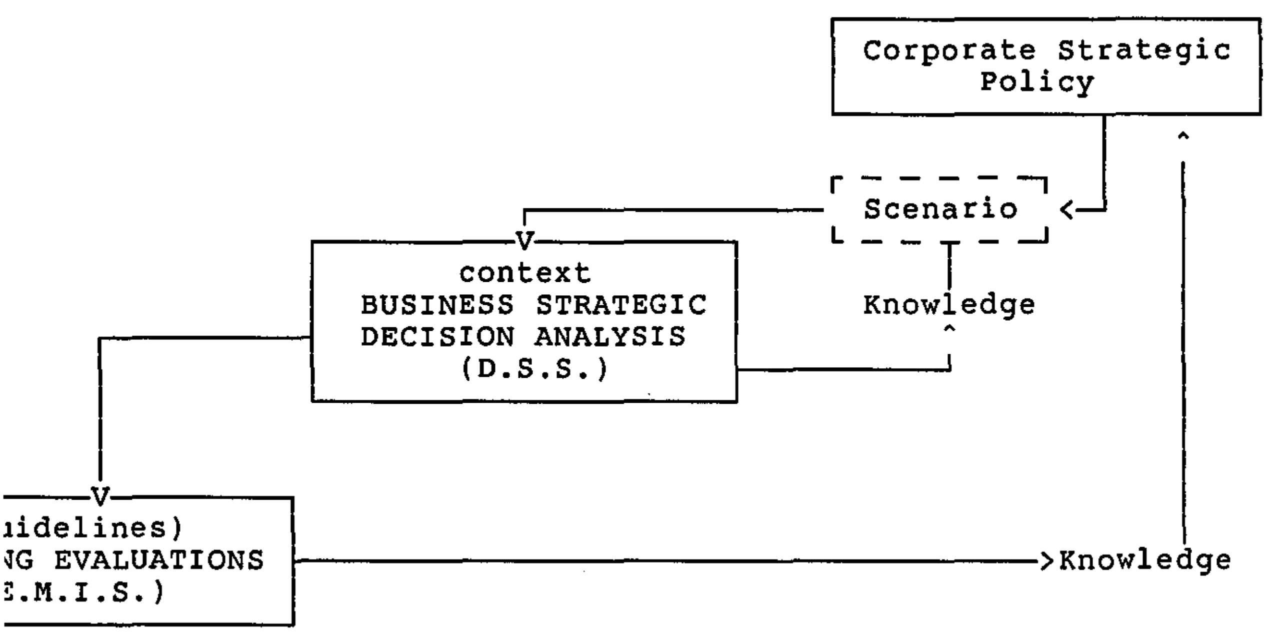
It is clear from an examination of Figure 1 that the strategic decisions display all the characteristics listed in the DSS column. Of particular concern for the subsequent discussion, is the view that DSS are not producing answers themselves but acting as a vehicle through which a decision-maker can obtain insights and thus learn about his system and its environment. The end result of using a DSS is to create intelligence, a term not used with its common meaning of 'nous' but as 'the outcome of the meshing and reconciliation of a set of information carrying inferences.' Murray (4). It is also important to note that the processing and required outputs are context dependent - dependent on the decision-maker himself, and on the circumstances he finds himself in.

The characteristics of decisions made by bankers when evaluating individual lending propositions can be seen to fit closely those listed in the MIS column in Figure 1. One point of possible contention concerns the focus of the system on the flow of information. An MIS geared towards lending evaluation needs to produce an effective decision rather than concentrating on information flow. This could be resolved by placing some form of front end onto the MIS in order to produce an answer. Indeed this is suggested in Section 7 of Figure 1 where MIS are seen to be required to produce 'an answer'.

THE LINK BETWEEN STRATEGIC DECISIONS AND THE EVALUATION OF INDIVIDUAL LENDING PROPOSITIONS.

Although the strategic decision-making and the evaluation of individual lending propositions are of different types, they are not mutually exclusive. The strategic decisions provide the policy under which the lending propositions are to be evaluated. However, a feedback loop is also in operation. This loop acting as one of the inputs in the strategic decision-making process, as shown in Figure 2.

FIGURE 2. The Links Between the Strategic Decision-Making and the the Evaluation of Individual Lending Propositions.



In Figure 2 the scenario equates to the overall policy produced by the corporate strategic decision-makers, and it is from this that the business strategic decision-makers draw the basis of their decision-making process. The link between strategic decision-making and the evaluation of individual lending propositions is only present in banks where lending directives are made to managers, requiring them to fit within an overall, well-defined bank lending portfolio. At present the policy link does not appear to operate in any formal way amongst the UK clearers (i.e. the main link in Figure 2 is weak). However, talks with lenders seems to indicate that such controls are likely in the future.

IT SYSTEMS TO AID STRATEGIC DECISIONS.

Decisions made at the business strategic level are normally about the contents of the bank's lending portfolio. Such decisions made by the portfolio manager will be based on his portfolio preferences and upon his exposure in a particular area.

IT support systems for strategic decision-making cannot rely totally on pre-determined algorithms and logic, since the factors influencing the decisions are context dependent: it is thus not possible to predefine them. In such a situation expert systems will not offer much in the way of support. Systems are required, which will offer the decision-maker a means of enhancing his intelligence through insightful learning.

## IT SYSTEMS TO AID INDIVIDUAL LENDING EVALUATIONS.

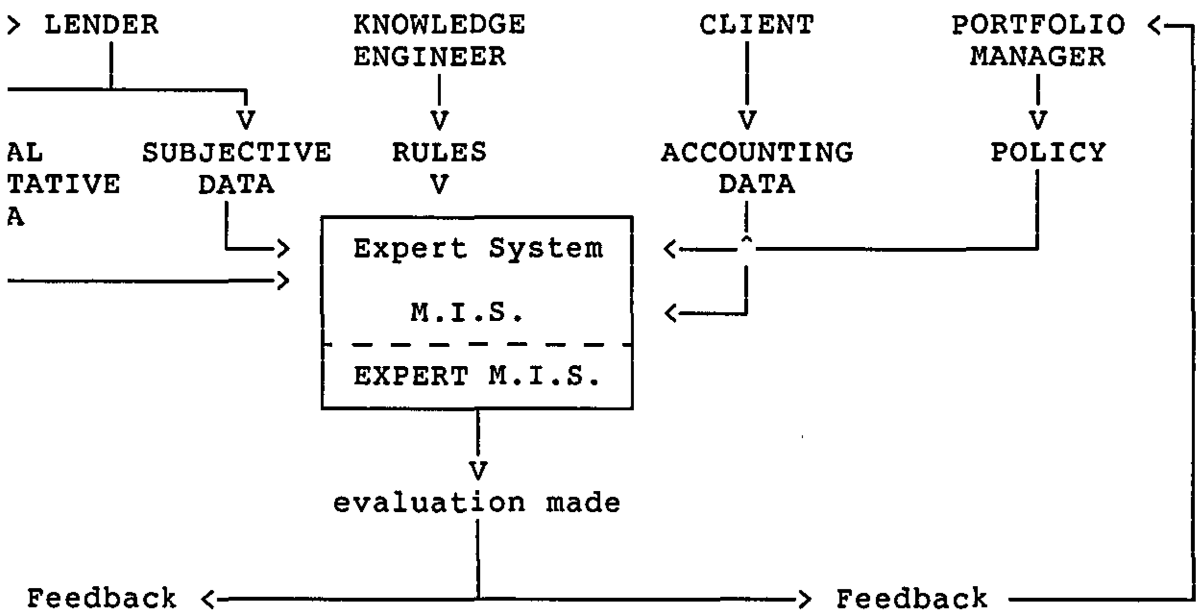
Individual lending propositions are usually evaluated by examining a number of pre-defined criteria which are combined to produce a decision for or against the proposition. The majority of the criteria are objective and readily quantifiable. This means that, in principle, they can be computerised and placed into an MIS. This allows manipulation of the data to be carried out to the lender's specifications. For example, accounting data can be summarised on a spreadsheet and then the salient points can be highlighted. In order to fully support the lender however, the MIS has also to be able to deal with subjective data: indeed, this is the type of data that the bank manager would be collecting and attempting to evaluate. As conventionally developed, MIS do not have the ability to deal with subjective data easily. However, expert systems can be created to do this.

## EXPERT SYSTEMS

Expert systems offer an ability to take subjective data and use the experience of the knowledge supplier to evaluate them. In the case of bank lending, the knowledge base is the distilled knowledge of experienced lenders.

Such systems as described above are already in use in some expert domains, examples being Prospector - a system which discovered mineral deposits missed by geologists; and DEC's XCON. This was developed to solve configuration problems in VAX computer systems. The XCON system has been estimated to have saved DEC many hundreds of man hours by substantially reducing the potential for later maintenance problems. The need for systems such as these in bank lending was recognised by Zocco (5) when he commented that 'every bank would like to have an individual or a group of individuals with a high degree of knowledge, experience, and expertise on the front line making every loan decision. Unfortunately, that is not possible for two reasons. First, the bank may not have an individual with that degree of expertise. Second, even if that person existed within the bank, he may not be able to make decisions on every loan. Expert systems are designed to address these situations.' He then went on to develop a model of a banking expert system containing characteristics similar to that described in Figure 3. This draws together the characteristics of MIS and expert systems to create a picture of an IT system appropriate to support the evaluation of individual lending proposals. The model below is different from that described by Zocco (6) in that it is far broader based, and has been developed as a part of a total IT strategy for corporate bank lending, rather than as a stand alone expert system.

FIGURE 3. Expert Systems Linked with an MIS to Form the Support for the Evaluation of Individual Lending Propositions.




The information needed to make an evaluation of an individual lending proposition is drawn from four sources. The portfolio manager provides the information on policy (e.g. lending directives). The knowledge engineer produces the rules on which the system is based, and the client provides data about himself (e.g. company accounts, bank accounts, customer record). The lender then adds any local information and relevant subjective data, (for example, his view of the customer's business acumen), but only as requested by the expert system. These factors are then processed by the system and an evaluation is produced. This may be a straight forward acceptance or refusal decision, or it may be a request for further information. In some cases the IT system may refer the whole evaluation to the lender if a solution cannot be found. For example, this might happen where there is irreconcilable data. In these cases the system can still assist the lender by offering a report of its evaluation process, showing the information used, and the clashes found.

The system thus described has assumed that the best way to assist the lender is to emulate his decision-making process following the 'rules' of lending to produce a decision. It must be emphasised that this is not the only way that a lending expert system could be developed. The other alternative would be to produce a form of adaptive credit scoring system which could be developed in the same manner that current credit scoring models have been created, simply placing the questions and answers into the expert system and allowing it to make the decisions based on samples of past lending cases. A system developed in this manner would be able to offer a lending decision-making product: however it could not be classified as an E.M.I.S. as there would be no assistance in it for the lender, simply an index of risk based on brute empiricism. We would suggest that such a system should be developed to run as a test for the true E.M.I.S. along side and possibly within it.

If we move back to the E.M.I.S. there will obviously be a need to maintain and enhance it. There will have to be an ability to change the rules of the expert system if the portfolio policy is changed, and as the rules of lending are refined in the light of greater experienced gained in lending.

One way in which the expert system could be used is as a coarse filter on propositions. The client would interact with the system in an initial probe of his proposition, without the lender being involved. Only clients that pass this initial screening would be seen by the lender. In this way, the lender would be spared the necessity of dealing with hopeless cases. Indeed it is in this area that credit scoring models - offering an index of the risk involved in the lending - could be used as effective policy screens. The portfolio manager specifying to the system the level of risk exposure he is prepared to accept.

Systems which are able to adapt and 'learn by their mistakes' are only currently in the research stage. Rule induction packages can be made to update their rules as new information is gathered. However it is extremely difficult, even in very simple situations, to produce an expert system that can automatically change its rule base without outside intervention.
Technology is changing rapidly and procedures are on the horizon which look like being able to allow for such automatic updating. However these developments are unlikely to nullify the value of developing non-automatic expert systems. Thus there is no requirement to wait upon such developments before proceeding with the development of an expert management information system (EMIS) for the evaluation of individual corporate bank lending propositions. Indeed, it might be suggested that to wait would remove the competitive advantage of using the systems, and may even place a bank at a disadvantage if other banks do begin using them successfully.

A WAY FORWARD.

The role of MIS and DSS in bank decision-making is by no means clear-cut. It is confused by the lack any comprehensive IT strategy by most UK clearers. Both the proposed strategic decision types and the lending decision-making process present a demanding challenge for systems developers. With the wide ranging differences between the types of decision-making involved in strategy formulation and in the evaluation of individual lending propositions, it is unlikely that the greatest gains will come from an attempt to create an all embracing IT system that supports both types of decision-making. At this stage in the development of IT support in banking, the preferred approach would seem to be to move ahead with the development of the thinking behind each type of support tool, implementing prototype systems to aid in this development process. These developments can readily proceed in parallel, but with each aware of the interactions between them. Once prototype systems have been evaluated, a reappraisal of the overall approach should be undertaken.

The EMIS needs to be developed from current lending practices so that the wealth of knowledge held by lending officers can be effectively used. In addition to trapping overt current practice, any new systems must also be tested on past lending cases. Additionally the rule base built into the EMIS must be fully tested in the field, to obtain feedback from the lenders themselves, and to uncover any covert rules of lending that are either deliberately concealed in the public statements made about lending, or which are not revealed because they are subconsciously carried out.

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## APPENDIX FOUR - THE QUESTIONNAIRES PRODUCED

### THE QUESTIONNAIRES

The results used in the development of the expert system were only those complied from the first column in the questionnaire (i.e. the factors considered for borrowing under £100,000).

The format of the questionnaire used to establish the factors considered by lenders when evaluating a lending proposition is shown below. Also included is the introductory information sent with each questionnaire:

THE FACTORS INVOLVED

WHEN EVALUATING LENDING

PROPOSITIONS

- A BANKING QUESTIONNAIRE

Dear Sir,

Please find enclosed a questionnaire relating to the factors used by managers when lending to businesses. This questionnaire has been produced to find out those criteria which are seen as important by the lending banker.

The results from the questionnaire are forming a part of research into the use of Decision Support Systems by bank managers, and the aggregated responses will go towards the production of a computerised advisor for lenders.

It would be appreciated if all answers to the questions could be made with reference to actual lending proposals considered by yourself over the past three months. The replies need not be "text book" responses as it has been found that these can be different from those used in the "Real World", where often elements are incorporated or even missing. All answers are in the form of a weighting given out of ten. The questionnaire covers six pages and should only take about fifteen minutes to complete.

You may find that assessing the elements used when evaluating a lending proposition is of use to you for reference in the future, for example when consulting new propositions. If this is the case please feel free to take copies of the questionnaire for your own use. Any comments in relation to the value of this would be appreciated and can be made on the last sheet.

Thank you for your assistance in this research.

Gareth J. Forsey,

Loughborough University 1986.

THE LENDING TYPE UNDER EVALUATION

The lending has been split into four sections to see whether there are any differences in the factors considered when different amounts are lent. If you do not lend above any one of the amounts shown please complete only the relevant columns. The lending can be to any type of firm and for any purpose, however it should not include any lending done on a venture capital basis.

Please work through each of the sections placing a weighting based on the scale below for each factor. Please place a weighting by every factor and weight each item independently from the others. (i.e. All of the factors can be given the same score if this is necessary). If you use any other factors in evaluating lending propositions which have not been included please add these at the end in the space provided, and then attach a weighting to these as well.

If you feel that any item can refer to more than one thing please weight it according to the most used reference and then please place the other meaning in the blank section at the end of the questionnaire.

THE WEIGHTING SCALE

| | | | |
|---|---|---|---|
| | 0 | | Not Used. |
| 1 | 2 | 3 | Not Necessary but used occasionally. |
| 4 | 5 | 6 | Desirable/Important. |
| 7 | 8 | 9 | Highly Desirable/Important. |
| | 10 | | Essential. |

| | WEIGHTING GIVEN |
|---|---|
| | <£100k <£500k <£1m <£5m |

SECTION ONE

GENERAL FACTORS

| | |
|---|---|
| The Business: | I.....I.....I.....I.....I |
| Cross Selling Capabilities: | I.....I.....I.....I.....I |
| The Customer: | I.....I.....I.....I.....I |
| The Financial Accounts: | I.....I.....I.....I.....I |
| The Management Accounts: | I.....I.....I.....I.....I |
| Prediction of Failure Models: | I.....I.....I.....I.....I |
| The Proposition: | I.....I.....I.....I.....I |
| The Repaymemt Structure: | I.....I.....I.....I.....I |
| The Repayment Ability: | I.....I.....I.....I.....I |
| The Security: | I.....I.....I.....I.....I |
| The Proprietor's Stake: | I.....I.....I.....I.....I |

SECTION TWO

THE BUSINESS

| | |
|---|---|
| The Business Viability: | I.....I.....I.....I.....I |
| Competition: | I.....I.....I.....I.....I |
| Marketability of Product: | I.....I.....I.....I.....I |
| Economic Considerations: | I.....I.....I.....I.....I |
| Record of Past Borrowing: | I.....I.....I.....I.....I |
| The Sector Viability: | I.....I.....I.....I.....I |
| The Trade Type: | I.....I.....I.....I.....I |

| | WEIGHTING GIVEN |
|---|---|
| | <£100k <£500k <£1m <£5m |
| **THE CUSTOMER** | |
| Age: | I....I....I....I....I |
| Bank Record: | I....I....I....I....I |
| Business Acumen: | I....I....I....I....I |
| Experience: | I....I....I....I....I |
| Honesty: | I....I....I....I....I |
| Need For The Loan: | I....I....I....I....I |
| Personal Commitments: | I....I....I....I....I |
| Reliability: | I....I....I....I....I |
| **THE FINANCIAL ACCOUNTS** | |
| The Account Ratios: | I....I....I....I....I |
| The Balance Sheet: | I....I....I....I....I |
| The Bank Account: | I....I....I....I....I |
| The Notes To The Accounts: | I....I....I....I....I |
| The Profit and Loss Account: | I....I....I....I....I |
| The Tax returns: | I....I....I....I....I |

| | WEIGHTING GIVEN<br><£100k <£500k <£1m <£5m |
|---|---|
| **THE MANAGEMENT ACCOUNTS** | |
| Aged Creditor Lists: | I.....I.....I.....I.....I |
| Aged Debtor Lists: | I.....I.....I.....I.....I |
| Break Even Analysis: | I.....I.....I.....I.....I |
| Budgets: | I.....I.....I.....I.....I |
| The Business Plan: | I.....I.....I.....I.....I |
| The Cashflow Forecast: | I.....I.....I.....I.....I |
| Sensitivity Analysis: | I.....I.....I.....I.....I |
| Source & Application of Funds: | I.....I.....I.....I.....I |
| Talks With Company Auditors: | I.....I.....I.....I.....I |

## SECTION THREE

| | |
|---|---|
| **THE ACCOUNT RATIOS** | |
| Efficiency: | I.....I.....I.....I.....I |
| Liquidity: | I.....I.....I.....I.....I |
| Profitability: | I.....I.....I.....I.....I |
| Stability: | I.....I.....I.....I.....I |

| | WEIGHTING GIVEN<br><£100k <£500k <£1m <£5m |
|---|---|
| **THE BALANCE SHEET** | |
| Current Asset Type: | I.....I.....I.....I.....I |
| Fixed Asset Type: | I.....I.....I.....I.....I |
| Liability Type: | I.....I.....I.....I.....I |
| Overall Size of Balance Sheet: | I.....I.....I.....I.....I |
| **THE BANK ACCOUNT** | |
| Excesses: | I.....I.....I.....I.....I |
| Hardcore Development: | I.....I.....I.....I.....I |
| Maximum & Minimum Figures: | I.....I.....I.....I.....I |
| Seasonal Trends: | I.....I.....I.....I.....I |
| **THE PROFIT AND LOSS ACCOUNT** | |
| The Cost Of Sales: | I.....I.....I.....I.....I |
| The Direct Costs: | I.....I.....I.....I.....I |
| The Overheads: | I.....I.....I.....I.....I |
| The Sales Level: | I.....I.....I.....I.....I |
| Depreciation: | I.....I.....I.....I.....I |

| | WEIGHTING GIVEN<br><£100k <£500k <£1m <£5m |
|---|---|
| **SECTION FOUR** | |
| **EFFICIENCY** | |
| Credit Given Period: | I.....I.....I.....I.....I |
| Credit Taken Period: | I.....I.....I.....I.....I |
| Stock Turnover: | I.....I.....I.....I.....I |
| **LIQUIDITY** | |
| "Quick Ratio": | I.....I.....I.....I.....I |
| Current Ratio: | I.....I.....I.....I.....I |
| **PROFITABILITY** | |
| Gross Profit Margin: | I.....I.....I.....I.....I |
| Net Profit Margin: | I.....I.....I.....I.....I |
| Return On Investment:<br>(Taxed Profit/Net Cap. Res.) | I.....I.....I.....I.....I |
| **STABILITY** | |
| Debt/Equity Ratio: | I.....I.....I.....I.....I |
| Gearing:<br>(Borrowing/Net Cap. Res.) | I.....I.....I.....I.....I |
| Interest Cover:<br>(EBIT/Interest Paid) | I.....I.....I.....I.....I |
| Leverage:<br>(Total Liab./Net Cap. Res.) | I.....I.....I.....I.....I |

WEIGHTING GIVEN

<£100k <£500k <£1m <£5m

OTHER FACTORS WHEN EVALUATING A LENDING PROPOSITION.

THE FACTORS

| | |
|---|---|
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |
| .............................: | I....I....I....I....I |

COMMENTS ON THE QUESTIONNAIRE

..........................................................................

..........................................................................

..........................................................................

..........................................................................

..........................................................................

## APPENDIX FIVE - THE QUESTIONNAIRE RESULTS

### THE QUESTIONNAIRE RESULTS

The results to the questionnaires are shown below. The are given in a sort by mode and standard deviation. This is because the ordinal nature of the data means that the arithmetic mean cannot be relied upon to give an accurate representation. The standard deviation has been used to show the spread of the data about the mean which is also shown for reference purposes.

The range of the results is also shown. The last column entitled "NUMBER" is simply the question number of the factor on the original questionnaire.

| ' NAME | NAME | MEAN | MODE | S.D. | RANGE | NUMBER |
|---|---|---|---|---|---|---|
| 'ab | THE REPAYMENT ABILITY | 9.40 | 10 | 1.07 | 4 | 9 |
| .ns | MAXIMUM AND MINIMUM FIGURES | 8.86 | 10 | 1.20 | 5 | 52 |
| .ab | BUSINESS VIABILITY | 9.16 | 10 | 1.41 | 9 | 12 |
| ıon | CUSTOMER HONESTY | 8.95 | 10 | 1.50 | 8 | 23 |
| ;t | PROPRIETOR'S STAKE | 8.10 | 10 | 1.50 | 5 | 11 |
| ıce | THE FINANCIAL ACCOUNTS | 8.25 | 10 | 1.60 | 6 | 4 |
| ׀t | THE BALANCE SHEET | 8.20 | 10 | 1.60 | 6 | 28 |
| | THE CUSTOMER | 8.32 | 10 | 1.67 | 6 | 3 |
| 'el | CUSTOMER RELIABILITY | 8.50 | 10 | 1.70 | 10 | 26 |
| ıcc | THE BANK ACCOUNT | 8.20 | 10 | 1.70 | 6 | 29 |
| tls | THE PROFIT AND LOSS ACCOUNT | 8.30 | 10 | 1.80 | 9 | 31 |
| | THE PROPOSITION | 8.16 | 10 | 1.87 | 10 | 7 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ıtab | PROFITABILITY RATIOS | 8 | 10 | 1.90 | 10 | 44 |
| ıeed | NEED FOR THE LOAN | 6.87 | 10 | 2.30 | 10 | 24 |
| :low | THE CASHFLOW FORECAST | 7.50 | 9 | 1.60 | 6 | 38 |
| ıcu | CUSTOMER BUSINESS ACUMEN | 8.10 | 8 | 1.36 | 6 | 21 |
| ıng | BORROWING/NET CAPITAL RESOURCES | 7.87 | 8 | 1.40 | 7 | 68 |
| ls | BANK ACCOUNT SEASONAL TRENDS | 7.50 | 8 | 1.50 | 6 | 53 |
| ıts | BUDGETS | 7 | 8 | 1.50 | 8 | 36 |
| :ity | THE SECURITY | 6.97 | 8 | 1.50 | 7 | 10 |
| :t | NET PROFIT MARGIN | 7.85 | 8 | 1.52 | 7 | 65 |
| ;pft | GROSS PROFIT MARGIN | 7.85 | 8 | 1.53 | 7 | 64 |
| ıt | MARKETABILITY OF PRODUCT | 8.04 | 8 | 1.66 | 7 | 14 |
| :ore | BANK ACCOUNT HARDCORE | 7.80 | 8 | 1.70 | 7 | 51 |
| ;ses | BANK ACCOUNT EXCESSES | 7.60 | 8 | 1.70 | 7 | 50 |
| | COMPETITION | 6.26 | 8 | 1.72 | 8 | 13 |
| :ec | CUSTOMER BANK RECORD | 7.30 | 8 | 1.80 | 7 | 20 |
| | THE BUSINESS PLAN | 7.30 | 8 | 1.80 | 8 | 37 |
| :d | PAST BORROWING RECORD | 7.39 | 8 | 1.85 | 8 | 16 |
| ıead | COST OF OVERHEADS | 7.30 | 8 | 1.85 | 8 | 56 |
| ›sts | DIRECT COSTS | 7.01 | 8 | 1.87 | 8 | 55 |
| ; | THE SALES LEVEL | 7.40 | 8 | 1.90 | 8 | 57 |
| | STABILITY RATIOS | 7.10 | 8 | 1.90 | 10 | 45 |
| ›r | SECTOR VIABILITY | 6.27 | 8 | 1.93 | 8 | 17 |
| .lit | LIABILITY TYPE | 6.93 | 8 | 1.97 | 10 | 48 |
| l | FIXED ASSET TYPE | 6.67 | 8 | 1.98 | 10 | 47 |
| ; | THE NOTES TO THE ACCOUNTS | 7.10 | 8 | 2 | 9 | 30 |
| ıtio | CURRENT RATIO | 6.90 | 8 | 2 | 9 | 63 |
| | THE MANAGEMENT ACCOUNTS | 6.90 | 8 | 2.14 | 10 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| t | STOCK TURNOVER | 6.80 | 8 | 2.15 | 10 | 61 |
| er | PERSONAL COMMITMENTS | 7.10 | 8 | 2.20 | 10 | 25 |
| .tt | CREDIT TAKEN PERIOD | 6.75 | 8 | 2.20 | 10 | 60 |
| .tg | CREDIT GIVEN PERIOD | 6.70 | 8 | 2.20 | 10 | 59 |
| r | QUICK RATIO (ACID TEST) | 6.50 | 8 | 2.20 | 10 | 62 |
| rs | AGED DEBTOR LISTS | 6.50 | 8 | 2.30 | 10 | 34 |
| .tor | AGED CREDITOR LISTS | 6.40 | 8 | 2.30 | 10 | 33 |
| evn | BREAK EVEN ANALYSIS | 5.90 | 8 | 2.30 | 10 | 35 |
| y | EFFICIENCY RATIOS | 6.20 | 8 | 2.60 | 10 | 42 |
| xp | CUSTOMER EXPERIENCE | 7 | 7 | 1.50 | 7 | 22 |
| .dy | LIQUIDITY RATIOS | 7.60 | 7 | 1.90 | 10 | 43 |
| nt | CURRENT ASSET TYPE | 6.89 | 7 | 1.98 | 10 | 46 |
| | COST OF SALES | 6.81 | 7 | 2.18 | 10 | 54 |
| q | DEBT/EQUITY RATIO | 6.32 | 7 | 2.18 | 10 | 67 |
| age | TOTAL LIABILITIES/NET CAP RES. | 5.78 | 7 | 2.60 | 10 | 70 |
| r | EBIT/INTEREST PAID | 5.75 | 7 | 2.70 | 10 | 69 |
| | ECONOMIC CONSIDERATIONS | 6.12 | 6 | 1.73 | 9 | 15 |
| c | DEPRECIATION | 5.98 | 6 | 1.80 | 8 | 58 |
| | TRADE TYPE | 5.62 | 6 | 1.85 | 9 | 18 |
| tio | THE ACCOUNT RATIOS | 6.50 | 6 | 1.90 | 8 | 27 |
| st | THE REPAYMENT STRUCTURE | 7.32 | 6 | 1.92 | 7 | 8 |
| n | RETURN ON INVESTMENT | 5.95 | 6 | 2.30 | 10 | 66 |
| e | SOURCE AND APPLICATION OF FUNDS | 4.75 | 6 | 2.60 | 10 | 40 |
| | OVERALL SIZE OF BALANCE SHEET | 5.90 | 5 | 2.30 | 10 | 49 |
| ess | THE BUSINESS | 6.54 | 5 | 2.34 | 10 | 1 |
| | CROSS SELLING CAPABILITIES | 3.60 | 3 | 1.90 | 8 | 2 |
| .ge | AGE OF CUSTOMER | 4.60 | 3 | 2.07 | 9 | 19 |

| | | | | | | |
|---|---|---|---|---|---|---|
| tors | TALKS WITH COMPANY AUDITORS | 4.16 | 3 | 2.10 | 9 | 41 |
| et | THE TAX RETURNS | 3.30 | 0 | 2.90 | 10 | 32 |
| | PREDICTION OF FAILURE MODELS | 2.35 | 0 | 2.90 | 10 | 6 |
| itiv | SENSITIVITY ANALYSIS | 3.50 | 0 | 3.10 | 10 | 39 |

# APPENDIX SIX - EXPERT SYSTEM SHELLS AVAILABLE

A sample of the more common expert system shells which are currently available (September 1988) are listed below. The shells are described according to hardware requirements, functions, user interface, and price. (The list includes shells which were not available at the start of the research).

## LEONARDO

Introduction:

Leonardo has been available for approximately 1 year. It is produced by Creative Logic Ltd who, prior to Leonardo offered a system called Reveal in the USA.

Hardware Requirement:

Standard PC (8086/88, 286, or 386) with a hard disk.

VAX Mini Computer

Apollo Work Station

IBM PS/2 (with OS/2 available 2nd Qtr 1989)

Sun Work Station (available 2nd Qtr 1989)

IBM Mainframe (available 3rd Qtr 1989)

Functions:

Knowledge Representation:

Production Rules

Frames

Procedural Language

Inference Engine:

- Class Structures
- Backward Chaining
- Forward Chaining
- Meta Control
- Uncertainty Management - Bayes
  - Probabilistic
  - Certainty Factors
  - Multi Valued
- Object Orientation
- Hypothetical Reasoning
- Mathematical Functions
- Statistical Functions
- Commercial Functions
- External Database/Spreadsheet Interfacing
- Extermal Code Interfacing
- Embedded Applications
- Pattern Matching

User Interface:

- User Defined Screen Designer
- Forms
- Single/Multiple Choice Questionning
- Uncertain Responses
- Graphics - Character
  - User Defined

Business Graphics

Active Images

Reporting System

How?

Why?

What If?

Costs:

£2,000 for the basic full version.

XI PLUS

Introduction:

Xi Plus is produced by Expertech Ltd. It was originally available as Xi and has been on the market for about two years. Many commercial developments have been produced in Xi Plus, however they are mainly of a simplistic nature running on single site, stand alone PCs.

Hardware Requirement:

Standard PC (8086/88, 286, or 386) with a hard disk.

VAX Mini Computer (2nd Qtr 1989)

Functions:

Knowledge Representation:

Production Rules

Inference Engine:

- Backward Chaining
- Forward Chaining
- Meta Control (using floating variables)
- Mathematical Functions
- Pattern Matching
- External Interfaces to languages & packages
- Database & Graphics Interfaces (to external packages)
- Screen Grabber
- Rule Induction

User Interface:

- Forms
- Single/Multiple Choice Questionning
- Reporting System
- Why?
- What If?
- Multiple Solutions

Costs:

£2,000 for the basic full version.

## CRYSTAL

Introduction:

Crystal is produced by Intelligent Environments Ltd. It has been available for approximately three years and is a first generation expert system. It is an good tool to use for learning about expert systems as much of the hierarchical structure used in backward chaining is set up by Crystal and cannot be changed.

Hardware Requirement:

Standard PC (8088/86, 286, or 386) with a hard disk.

Functions:

Knowledge Representation:

Production Rules

Inference Engine:

Backward Chaining

Mathematical Functions

Pattern Matching

Rule Induction

External interfacing to programs and packages

External interfacing to databases

User Interface:

Forms

Single/Multiple Choice Questionning

Reporting System

Why?

What If?

Costs:

£1,000 for the full version.

## PC PLUS

Introduction:

PC Plus (Personal Consultant Plus) has been available in the USA for approximately three years. It is sold by Texas Instruments and is the biggest selling expert system shell in the USA. It is largely unsupported in the UK and all technical queries are diverted to Italy first and then to the US.

Hardware Requirement:

Standard PC (286 or 386) with a hard disk.

TI Explorer

Functions:

Knowledge Representation:

- Production Rules

Inference Engine:

- Backward Chaining
- Forward Chaining
- Meta Control
- Rule Priorities
- Uncertainty Management - Certainty Factorss
  - Probabilistic
  - Multi Valued
- Mathematical Functions
- Statistical Functions

Pattern Matching

User Interface:

User Defined Screen Designer

Forms

Single/Multiple Choice Questionning

Uncertain Responses

Graphics - Screen Grabber

Active Images

Reporting System

How?

Why?

What If?

Costs:

£2,000 for the full version.

## ESE

Introduction:

ESE is IBM's expert system for main frame applications. It is a first generation expert system (production rules) and is based on the Emycin method of expert system development. It is written in Pascal.

Hardware Requirement:

IBM Mainframe Computer

Standard PC (286 or 386) with a hard disk for RUNTIME only (available 3rd Qtr 1989)

Functions:

Knowledge Representation:

- Production Rules

Inference Engine:

- Backward Chaining
- Forward Chaining
- Meta Control
- Uncertainty Management - Certainty Factors
  - Probabilistic
  - Multi Valued
- Mathematical Functions
- Statistical Functions
- Pattern Matching

User Interface:

- Single/Multiple Choice Questionning
- Uncertain Responses
- Reporting System
- How?
- Why?
- What If?

Costs:

£30,000 for the minimum full version. Cost of system is dependent on hardware platform selected.

## GOLDWORKS

Introduction:

Goldworks is an American LISP based expert system shell/ environment. It is produced by Gold Hill and is distributed by Artificial Intelligence Ltd in the UK. It is a very powerful expert system development tool based largely on object orientated programming techniques.

Hardware Requirement:

Standard PC (386) with a hard disk and minimum of 8 mb ram.

Sun Work Station

Apple Macintosh Work Station

Functions:

Knowledge Representation:

Production Rules

Frames

Object Orientated Programming

Inference Engine:

Class Structures

Backward Chaining

Forward Chaining

Meta Control

Agendas

Rule Priorities

Checkpoints

Sponsors

Multiple Inheritance

Multiple architecture representation

Uncertainty Management - Bayes

Probabilistic

Certainty Factors

Multi Valued

Object Orientation

Hypothetical Reasoning

Mathematical Functions

Statistical Functions

Pattern Matching

User Interface:

Full Overlaid Windowing

User Defined Screen Designer

Forms

Single/Multiple Choice Questionning

Uncertain Responses

Graphics - Character

User Defined

Graphical Kb Layout & Browser

Real Time Active Images

Reporting System

How?

Why?

What If?

Costs:

£5,000 for the minimum full version.

## APPLICATION EXPERT

Introduction:

Application Expert is marketed in the United Kingdom by Cullinet Software Inc. It is an EMYCIN type expert system shell (based on production rules and using certainty factors to cope with uncertain knowledge). The system was written in Cobol and Assembler and was released approximately 6 months ago.

Hardware Requirement:

IBM Mainframe Computer

VAX Mini Computer

Functions:

Knowledge Representation:

Production Rules

Inference Engine:

Backward Chaining

Forward Chaining (limited)

Uncertainty Management - Certainty Factors

Multi Valued

Mathematical Functions

User Interface:

Single/Multiple Choice Questionning

Forms Design

Uncertain Responses

Reporting System

How?

Why?

What If?

Costs:

Est. £30,000 for the minimum full version. Cost of system is dependent on hardware platform selected.

# APPENDIX SEVEN - THE LENDING CASE STUDY

The case study used in the interviews with lending bankers was taken from an actual company with the names changes to avoid the lenders recognising the company and so possibly having an advantage. There was no direct solution to the case study other than the successful discovery of the pointers in the information towards success or failure. For interest purposes only the company collapsed a year after the end of the case study. The case study was put through the expert system prototype which suggested that no more lending should be granted to the company.

The case study was given to the lenders in two parts, a borrowing request being made after the first part. The second part was designed to identify how much information the lender required before he became wary of the lending he had agreed/refused at the end of the first part. Information was only offered to the lender as it was requested by him.

FULTON CONSTRUCTION COMPANY LIMITED

PART ONE

THE BANKING PROPOSAL:

In October 1971 Fulton Construction Company Limited requested longer term financing of current operations. This was to be arranged by:

1) The issue of £1m of 25 year debenture stock.
2) A £500k medium term loan.

The proposition as above needs to be considered in the light of the information presented.

THE BACKGROUND:

Fulton Construction grew from a department within Fulton Engineering to an international construction Group during the 1960's. This was largely due through emphasis on public, competitively tendered work to the exclusion of private sector negotiated contracts. The work undertaken has included the following:

A series of Scottish hydro-electric schemes (the last being in Fawley in 1966); Cement Works; A radio telescope; A G.P.O. switching centre; Reservoirs; Pipelines and sewerage works; Office buildings; Schools and hospitals.

More recently the Group has bid for the Anchor project at Scunthorpe. It bid the lowest tender at £28m but lost the contract to Sir Robert McAlpine.

A less important bid led to a contract with the Zambian government to produce a hydro-electric power station at Kariba on the Zambian bank of the Zambesi. The tender submitted was for £11m.

EARNINGS RECORD £'000s:

| | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|
| TURNOVER | 24,000 | 32,000 | 29,300 | 30,300 |
| E.B.I.T. | 918 | 1,098 | 1,251 | 1,469 |
| Short Term Loan Int. | 140 | 188 | 167 | 264 |
| | 778 | 910 | 1,084 | 1,205 |
| Taxation | 288 | 354 | 530 | 467 |
| Profit After Tax | 490 | 556 | 554 | 738 |
| Preference Dividends | 67 | 53 | 43 | 38 |
| Ordinary Dividends | 186 | 203 | 269 | 288 |
| | 237 | 300 | 242 | 412 |
| Chairman's Div. Waiver | 14 | 21 | - | - |
| RETAINED EARNINGS | 251 | 321 | 242 | 412 |

BALANCE SHEETS:

| | | 1970 | | 1969 |
|---|---|---|---|---|
| CAPITAL EMPLOYED £'000s | | | | |
| Share Capital: Ordinary Shares | | 961 | | 961 |
| Preference Shares | | 500 | | 500 |
| | | 1,461 | | 1,461 |
| Reserves | | 2,869 | | 2,470 |
| Outside Interest | | 30 | | 41 |
| Loans | | 183 | | 227 |
| | | 4,543 | | 4,199 |
| REPRESENTED BY: | | | | |
| Fixed Assets | | 2,982 | | 2,728 |
| Investment | | 159 | | 434 |
| Current Assets: | | | | |
| Work In Progress | 9,328 | | 8,610 | |
| Debtors | 3,137 | | 2,018 | |
| Cash | 155 | | 464 | |
| | 12,620 | | 11,092 | |
| Less Current Liabilities: | | | | |
| Creditors | 7,578 | | 7,414 | |
| Taxation | 915 | | 945 | |
| Bank Overdraft | 2,419 | | 1,409 | |
| Proposed Dividend | 306 | | 287 | |
| | 11,218 | 1,402 | 10,055 | 1,037 |
| | | 4,543 | | 4,199 |

FUNDS FLOW STATEMENT FOR YEAR ENDED DEC 31 1970

| | £'000s |
|---|---|
| SOURCES | |
| Retained Earnings | 412 |
| Depreciation | 517 |
| Increase in Minority Funds | (11) |
| Trade Investments | 275 |
| Investment and Development Grants | 92 |
| Share and Loan Capital Reserves | 29 |
| Increase in Creditors | 152 |
| Increase in O/D and Cash Reduction | 1,319 |
| Short Term Loans | 6 |
| | 2,791 |
| APPLICATIONS | |
| Fixed Assets | 863 |
| W.I.P. Stocks and Debtors | 1,836 |
| Acquisition of Minority Interests | 42 |
| Repayment of Loans and Cash Increase | 50 |
| | 2,791 |

SHARE DATA:

| | 1967 | 1968 | 1969 | 1970 |
|---|---|---|---|---|
| E.P.S. (ordinary) | 11.4p | 13.3p | 13.3p | 18.2p |
| Divs Per Share | 5.00p | 5.37p | 7.00p | 7.50p |
| Share Price: | | | | |
| High | 140p | 203p | 173p | 202p |
| Low | 75p | 107p | 133p | 135p |
| Capital Employed at Start of Year (inc. Overdraft) | £4,618m | £5,910m | £5,784m | £5,608m |

REPORT FROM BANK ECONOMICS DEPARTMENT:

a) Profitability.

The company appears to be pretty successful. However it is important to remember that profits arise on the completion of projects, and so represent historic, rather than present, activity.

b) Liquidity.

The type of the current assets underlies the questionable liquidity situation.

Debtors - Payments from the public sector are commonly late in receipt. Nevertheless the period does not seem to be excessive.

Stock and Work in Progress - If work is certified there should not normally be more than one month's construction work on hand at any one time. Even allowing for extra materials on site, and stocks of manufactured goods in the hands of companies within the Group, the figures seem to be extremely high.

Cash - The use of cash to finance a fairly illiquid asset is bound to put a strain on operations.

c) Payments For Work Done.

The company operates a monthly payment system to contractors. This allows working capital to be kept to a minimum. However, if payments are delayed or deferred for any reason, then the costs of financing a contract can increase many times, creating obvious liquidity problems. Delays in the public sector are nothing untoward. The blockage is usually blamed on the double check of final accounts by the audit department.

PRESS REPORT - THE ECONOMIST JUNE 27 1970.

No one will be surprised if questions are soon to be asked in the Commons about the Anchor Works, the first stage of the British Steel Corporation's projected steel works at Scunthorpe. The main civil engineering contract will be awarded in about a fortnight. Within the industry it is already an open secret that the contract will go to Sir Robert McAlpine.

There is, however, a rising volume of complaint, which is now erupting in the trade press, notably in Construction News, to the effect that McAlpine's tender for the Anchor Works was £29,555,000 compared with slightly higher figures for George Wimpey, Taylor Woodrow, and Costain & Mowlem; - but an appreciably lower tender from Fulton Construction of £28,145,000. Fulton is considerably smaller than the other four contractors, but it is growing fast and trying to break into the big time. Apparently McAlpine, at least initially was allowing over 6 per cent, as margin on total cost, to cover head office overheads, while other contractors used figures around 3 per cent.

The BSC may have had its eye on Fulton's labour relations, its size, the terms of its tender, or its capability to handle the job; none of these can be expressed in terms of price but they count heavily when big contracts are at stake. A £30m contract is just about equal to Fulton's annual turnover, while the other contractors are three to six times as big. The BSC says, however, it was satisfied on all these accounts. So why did Fulton lose the contract? And will it be asked to tender next time?

FULTON CONSTRUCTION COMPANY LIMITED

PART TWO

FINANCIAL INFORMATION 1971.

The basis of valuing stock is at cost, less provision for possible losses. Turnover is based on work certified during the year, plus the invoiced sales of manufactured products.

SHARE DATA FOR 1971.

The share price reached an all time high of 313p during 1971.

THE KARIBA PROJECT.

The project was to produce a hydro-electric power station. This had to include: an intake structure, and outfall structure, a switching station, a transformer compound, a control and administrative building, housing and ancillary works.

The machine hall was designed to accommodate 4,150 megawatt turbines and was 130 metres long, 124 metres wide and 36 metres high.

Work was to start on 1 April 1971 and to be completed for June 1975. During 1971 rock falls killed two men indicating possible problems with rock conditions.

The tender submitted was for £11m. This was £2m lower then the next lowest tender, and £5m lower than Balfour Beatty's tender.

KARIBA PROJECT GEOLOGICAL REPORTS.

1) Zambesian Department of Geology Report.

This differed dramatically from the information given to the tenderers. i.e. the rock condition was far worse than stated.

2) & 3) Reports by the Geological Survey Department of Zambia.

Identified gross inaccuracies in the original report to the tenderers and challenged the authenticity of the original geological survey on exploration work for the second stage of the power station.

4) Report by Consulting Engineers.

This report decided that conditions were in fact more difficult than could reasonably have been foreseen at the time of the tender.

THE MARTLESHAM HEATH P.O. RESEARCH ESTABLISHMENT.

a) Awarded in 1969.

b) By Dec 1972 £1.5m still outstanding because of non-availability of detailed design at contract award stage.

c) Total disruption since work began with Fulton only being allowed access to the site on an irregular basis.

ROYAL ARMY ORDINANCE CORPS.

a) Contract for £2.5m awarded to build new facilities at Blackdown.

b) £1.3m still outstanding in Dec 1972.

c) A report by independent quantity surveyors exceeded 11,000 pages with an estimated 45,000 items.

d) Second contract awarded to reconstruct training centre. This was let for £1.6m.

e) £204,000 still outstanding in Dec 1972 because of contract variations and other delays.

OTHER OUTSTANDING CONTRACTS.

1) Four contracts for RN base at Faslane. £149,000 outstanding.

2) Medical and Dental block built. £23,000 outstanding.

3) RN contract at Rosyth. £285,000 outstanding.

4) Reception centre in Leeds. £60,000 outstanding.

5) DoE roadworks, 2 contracts. £1.2m outstanding.

6) Other public sector contracts. £5.5m outstanding.

Of the £5.5m, £2.6m was for contracts completed by 1965.

CHAIRMAN INTERIM REPORT AND EFFECTS.

Report issued on 31 January 1972.

Interim figures for half year to June 1971 showed a profit of £60,608 compared with a profit of £484,000 for the previous half year. Final profits in excess of £1m were predicted for the full year. The share price fell 50p overnight at the news.

PROFITS FOR YEAR ENDED 31 DEC 1971

| | £'000s |
|---|---|
| TURNOVER | 40,600 |
| E.B.I.T. | 1,301 |
| Less: Bank Interest, Debenture Interest, & Short Run Loan Int. | 260 |
| Profit Before Tax | 1,041 |
| Less Taxation | 498 |
| | 543 |
| Less: Minority interests, debenture issue expenses, & pref. dividends | 73 |
| Ordinary Dividends | 288 |
| | 182 |
| Chairman's waiver of dividends | 29 |
| | 211 |
| Earnings per ordinary share | 12.2p |
| Earnings per preference share | 7.5p |

CONSOLIDATED BALANCE SHEET 31 DEC 1971

| | £'000s | £'000s |
|---|---|---|
| CAPITAL EMPLOYED | | |
| Share capital | | 1,461 |
| Reserves | | 3,972 |
| | | ------ |
| | | 5,433 |
| 9.5% Debenture Stock 1989/96 | | 1,000 |
| Outside Shareholders interest | | 64 |
| Loans | | 263 |
| Tax Equalisation | | 733 |
| | | ------ |
| | | 7,493 |
| | | ====== |
| REPRESENTED BY: | | |
| Fixed Assets | | 4,526 |
| Investments | | 10 |
| Current Assets: | | |
| Work in Progress | 13,156 | |
| Debtors | 3,183 | |
| Cash | 333 | |
| | ------ | |
| | 16,672 | |
| Less Current Liabilities: | | |
| Creditors | 10,138 | |
| Taxation | 551 | |
| Bank Overdrafts | 2,749 | |
| Proposed Dividends | 277 | |
| | ------ | |
| | 13,715 | |
| | ------ | 2,957 |
| | | ------ |
| | | 7,493 |
| | | ====== |

FUNDS FLOW STATEMENT FOR YEAR ENDED 31 DEC 1971.

| | £'000s |
|---|---|
| SOURCES | |
| Retained Earnings | 211 |
| Tax Equalisation | 370 |
| Depreciation | 521 |
| Increase in Minority Funds | 34 |
| Increase in Creditors | 2,167 |
| Overseas Trade Investments | 149 |
| O/D Increase and Cash Decrease | 329 |
| Short Term Loans | 184 |
| Additional Share/Loan Capital & Reserves | 931 |
| | 4,896 |
| APPLICATION OF FUNDS | |
| Fixed Assets | 741 |
| W.I.P., Stock and Debtors | 3,874 |
| Repayment of Loans & Cash Increases | 281 |
| | 4,896 |

NOTES TO 1971 ACCOUNTS.

| Note 1: Share Capital. | AUTHORISED | ISSUED |
|---|---|---|
| 500,000 7% cumulative preference shares of £1 | £500,000 | £500,000 |
| Ordinary Shares of 25p | £1,500,000 | £961,282 |
| | £2,000,000 | £1,461,282 |

Note 2: Reserves.

Major improvements in reserves were £10,000 discount on issue of debenture stock written off share premium account, and surpluses of £1.3m on property valuation, less £363,000 corporation tax on potential capital gains.

Note 3: Debenture Stock.

£1m 9.5% Debenture Stock 1989/96 was issued on 28 October 1971 at £99. £25 was paid on acceptance, the balance of £740,000 being due on April 14 1972. The debtors and overdraft on the balance sheet have been adjusted to reflect the position as if all the cash due has now been received.

Note 4: Since 31 Dec 1971 £500,000 of bank overdraft has been converted into a medium term loan.

Note 5: A professional revaluation of properties resulted in a surplus of £1.3m which has been included in the books.

Note 6: Tax Equalisation.

The provision of recent legislation regarding depreciation have resulted in virtually no tax being paid on U.K. profits for the year. An equivalent amount that would have been payable, together with probable corporation tax on the revaluation of property, have been transferred to the tax equalisation account.

BANK ECONOMICS DEPARTMENT REPORT ON 1971 FIGURES.

1) Profitability.

A substantial decrease in return on capital employed. Also in absolute profit, four year average, and earnings per share. The decrease was probably expected after the interim figures. Several factors seem to have contributed to this:

a) Kariba Project - Stock valuation at cost method used. The project is said by the chairman to be at a standstill.

b) Fewer competitions or lower margins - Lower profits could have come from the former, while the latter could reflect managerial/tendering deficiencies. BUT: The very size of the profit figure is alarming. Why was there such a dramatic turn around in the figures between the half year figures and the year end figures? Were there several large completions in the period or was some form of "window-dressing" applied. The financial press thought that the former was true. Turnover increased by 30% on the 1970 figure. This is based on work certified and need not vary in direct relationship to profits. (Note opposite trend in 1969).

2) Net Current Assets.

Current ratio up to 1.2:1. A marginal increase, but to be expected after the "capitalisation" of £1m overdraft by the issue of debentures. Acid test has failed again. Increase in current assets seems to have been due entirely due to greater stocks and W.I.P.

Debtors: Collection period is now less than one month. The proper position for a company paid on the basis of a monthly certification.

Stocks and Work In Progress: The financing of the increase in these items is obviously creating a strain on financial resources. This is blamed by the chairman on delays in payments from the public sector. It is impossible to say whether this is true or whether the situation has arisen from disputes over work completed. If this latter point is true then serious doubt must be cast over the realisation of all the £13.1m work in progress.

Cash: The cash figure has considerably worsened indicating in effect that the debenture issue has been little more than a holding exercise, merely preventing a large increase in the overdraft. The funds flow statement shows that the issue and the increase in creditors are the basic sources of funds for the £3.8m increase in W.I.P. Given the question of the realisability of the latter, this use of funds seems extremely dangerous.

3) Gearing.

The gearing has changed from 0.18 to 0.3 between 1970 and 1971. These figures are fairly low and so should not have much effect on the share price or the return on equity. The interest for the year of £95,000 will easily be accommodated within the Group's present profitability.

EXTRACTS FROM THE CHAIRMAN'S REPORT ON 1971 ACCOUNTS.

In January this year, shareholders were informed that the profit for 1971 would be not less than £1m. The final profit before taxation is £1.04m.

The up-dated four year moving average which I always include in my statement is:

1964-1967 : £ 595,000 1965-1968 : £ 703,000

1966-1969 : £ 842,000 1967-1970 : £ 994,000

1968-1971 : £1,060,000

The directors are naturally disappointed that for the first time since the company went public in 1963 there has been a setback in the steady climb of profits. This disappointment is only partially offset by our having raised our average profits for a four year period above the £1m mark.

Having regard to all circumstances, the directors are proposing a payment to ordinary shareholders of 30% for the year, which is the same as last year. An interim payment of 10% has already been paid and a final payment of 20% will be recommended to shareholders at the AGM on 20 July 1973.

Turnover has increased significantly and the proportion of work executed abroad has increased from 34% to 47%. This has been partly due to the contract for the production of an underground power station on the Zambian bank of Lake Kariba.

In common with other contractors, we are still experiencing considerable frustration in getting timely payments from our work in the public sector. It is hoped that this situation will ease in the near future, and as a measure to place financing of current operations on a longer term basis, we issued £1m of 25 year debenture stock and a £500,000 medium term bank loan.

The changes in depreciation legislation have benefited the Group to the extent that there will be virtually no tax payable on profits earned in the U.K. in 1971. However, we have set aside, for the first time, a tax equalisation reserve equivalent to the amount that would have been payable.

ORDERS: During the latter part of 1971 there was evidence of an improvement in the amount of civil engineering work coming out to tender in the U.K., particularly in Scotland. We have secured a fair proportion of this work, and have also secured substantial work abroad. By Jan 1972 we have now got a record level of orders on our books.

THE FUTURE: In the past I have stressed the importance of the four year moving average as a yardstick against which to measure the performance of a company such as ours which is engaged on long term projects. Basic to this has been the belief that transient and non-recurring things do not affect a single year's profits, but affect over a period. While this has been true in normal circumstances, it is the case in our industry we have had a very long period of difficult trading conditions. This situation has been aggravated because of the processes of payment in the public sector have become progressively more slow and due to the incidence of inflation the money when it is received has depreciated in value and does not provide adequate return on the initial outlay. Delays in payment also have another bad effect in that they deprive management of one of its essential tools - the ability to forecast with any certainty cash flow within the industry.

Against this background, we are currently making a reappraisal of our activities, as a result of which we may well consider it necessary to restrict the amount of our competitive work in the public sector and to deploy resources in other fields. In this we would be following the example of other major contractors. I cannot think that this trend is a good thing for the public sector or for the longer term interests of the industry and it is a sad thing for those of us who have grown up in an atmosphere of challenge which we have always enjoyed. It is too soon to predict the outcome of such a change but I would hope that in the short term there would be no major disappointments for the shareholders and in the long term the moves will reflect to their advantage.

THE KARIBA PROJECT PART TWO.

a) During the last part of 1972 the project was losing £300,000 per month.

b) The rock condition caused massive delays and were subject to four reports.

c) Financial settlement of £5.5m put forward for the work done on the project. Far less than Fulton anticipated and indeed believed that they were entitled to. This was agreed in Feb 1973.

FINAL REPORT AND RESULTS.

During the second half of 1972 it became apparent that the problems at Kariba were at least as serious as had been feared. Differences of opinion between Fultons and Sir Alexander Gibb and Partners over the validity of the Geological Survey on which the tender was based were known to exist. Meanwhile the power station construction got further and further behind. - 12 months by Jan 1973.

Problems of contract variations, and delays in payments were continuing - by Jan 1973 there were eight outstanding arbitration cases to be heard, including one in Peterborough for £1m for work dating back to 1967.

During this period the share price fell to 140p.

On 31 January 1973 the Board of Directors of Fulton Construction Holdings Limited released the following statement:

"The Board of Fulton Construction Holdings Limited announce with regret that they have today requested the Midland Bank and the Trustees of the Company's £1m debenture stock to appoint a receiver.

The Group's problems at Kariba, in regard to its contract to build an underground power station for the Zambian Government, have been referred to in the past. The Group has had every reason to expect that these problems would be satisfactorily

resolved. Unfortunately it has proved impossible to negotiate a satisfactory settlement, let alone in the time available. This situation, coupled with difficulties experienced elsewhere in the Group, has produced an unbearable strain on the Group's resources. Accordingly, the Board found themselves no other alternative but to request the appointment of a Receiver.
The Board have also asked the Council of the Stock Exchange to suspend dealings in the Company's share and loan Capital."

The Holding Company and its various subsidiaries were found to be inextricably bound up and, as a result, it was initially decided to sell off the assets of the company. The majority of the assets were purchased by Tarmac Construction Ltd., however the main co-ordinating construction company of the Group was liquidated on May 7 1973.

# APPENDIX EIGHT - DISK OF EXPERT SYSTEM

A diskette of the expert system has been lodged with the Management Studies Department of Loughborough University of Technology. The system can be run on any IBM compatible Personal Computer provided a copy of the XI Plus Expert System Shell is present.