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# EVALUATING DECISION STRATEGIES FOR STOCK MARKET INVESTMENT

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**WORKING PAPER NO. 319**

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## ABSTRACT

In this paper we intend to investigate the nature of those rules which are shared among decision makers facing similar ill-structured decision environments. To study this phenomena, the decision rules of three security analysts were captured and implemented in the form of three expert systems. This enabled us to make sure that the underlying rules and processes are similar to those used by each of the three experts involved in the project. The reliability of each expert system and consequently the reliability of underlying rules was tested using real cases and comparing the resulting recommendations of the systems with those of the experts.

The specific nature of the rules used in the expert systems for each security analyst (subject) is not divulged in this report because of the proprietary nature of the decision rules.

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## Introduction

In a decision problem an ill-structured problem arises on account of one or more of the following factors [Beach & Mitchell, 1978; Payne, 1976; Simon, 1980; Wood, 1986]:

1) A large number of variables and causal relationships among them

2) A lack of adequate time to perform preliminary analysis of the problem

3) The dynamic (i.e., stochastic, volatile) nature of the variables and the causal relationships among them

The decision problem faced by oil security analysts is highly ill-structured. This is due to the fact that the security analysts have to deal with the following factors:

1) A large number of variables and causal relationships among them

2) A lack of adequate time to perform preliminary analysis of the problem

3) The dynamic (i.e., stochastic, volatile) nature of the variables and the causal relationships among them

The goal of this study is to investigate the nature of the decision rules used by the security analysts in their development of trading strategies for oil securities. A subgoal is the need firstly to elicit from these security analysts their set of decision rules and secondly to ensure that the elicited rules are indeed used by them in their daily work. To this end the decision rules of the three security analysts involved in this study was captured and implemented in the form of three "expert systems".

The term "expert system" refers to a computer program that applies a substantial knowledge of a specific area of expertise to a problem-solving process. "Knowledge engineering" will refer to the tools and methods used to support the development of expert systems. It is the process of capturing the decision rules of decision makers and implementing them in the form of a computer program.

In the remainder of this study, "knowledge acquisition" will refer to the tools and methods used to elicit the decision rules from the decision makers. The remainder of this report will proceed as follows. Section 1 contains a description of the knowledge engineering process. Section 2 presents a survey of the techniques used for knowledge acquisition. Section 3 describes the procedures used in the study. Section 4 gives the discussion of the results and Section 5 presents the conclusions that may be drawn from the study.

Knowledge Engineering

As stated above, knowledge engineering refers to the process of developing expert systems. Knowledge engineering is itself an ill-structured and complex task. Buchanan et al (1983), have stated that knowledge engineering is not understood well enough at present. It is therefore not possible to outline a standard sequence of steps for generating an effective system building process. With this caveat they have given a rough characterization of the knowledge engineering process. According to them, knowledge engineering consists of several stages, namely, problem identification, conceptualization, formalization, implementation and testing. This is shown in Figure 1.

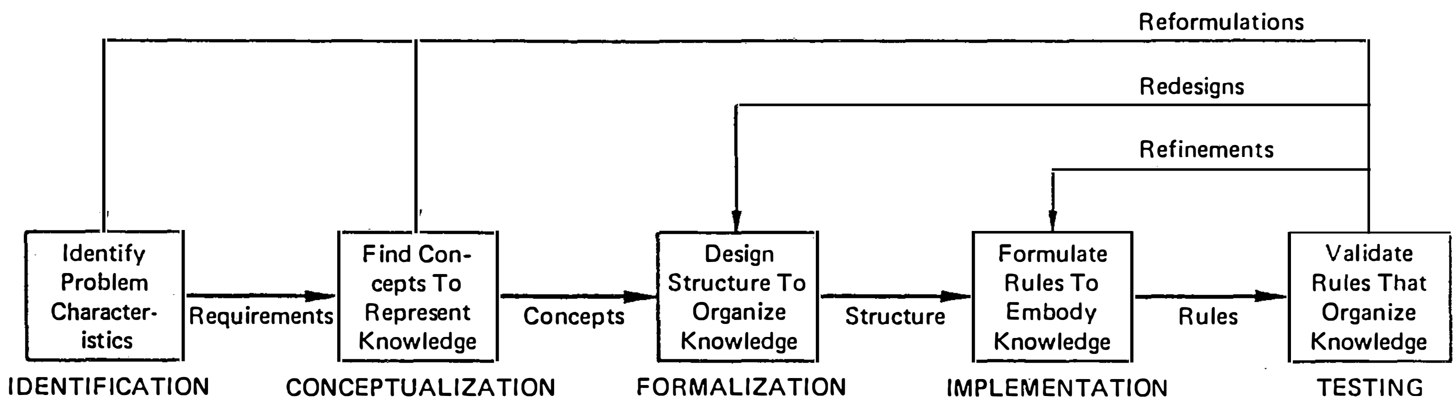


Figure 1. Conceptual Stages of Knowledge Engineering

The following description of each stage is provided by Buchanan et al (1983):

1) Identification

This stage is primarily concerned with characterizing the important aspects of the problem. This involves identifying the participants, problem characteristics, resources and goals.

Participant identification involves the selection of the knowledge engineers who are to develop the system as well as the experts willing to cooperate with the former in the development of the system.

The identification of the problem involves determination of :

1) What the problem is (e.g., deciding which stocks to trade).

2) What the subproblems are (e.g., forecasting the stock prices and determining the required return on the stocks).

3) What data are relevant to the decision making process (e.g., "potential added value over 2 years" and "projected 5 year cash flow growth").

4) What concepts are relevant to the decision making process (e.g., "future prospects" and "track record").

5) What a typical solution looks like (e.g., a list of stocks and the recommended trading strategy for each stock).

Resource identification involves the estimation of the time, money and computing facilities available for the development of the system. Note that time here also includes the amount of time that the experts can devote to the development of the system.

Finally, in the case of goals, Buchanan et al (1983), note that "examples of possible goals are formalizing an otherwise informal set of practices, distributing scarce expertise, helping experts solve problems better, and automating routine aspects of the expert's job".

2) Conceptualization

The key concepts and relations needed to solve the problem are made explicit during this stage. The interaction between the Knowledge Engineer (KE) and the domain expert during this stage leads to a more precise definition of the terms and concepts used by the expert. For example, suppose the decision problem is that of forecasting security prices. The KE may find out that in attempting to forecast the price of a company's security, the security analyst may consider the following factors: "potential added value over 2 years", "projected cash flow growth to the expected change in the oil price" and "projected 5 year cash flow growth". In making these concepts explicit, the KE has to find out precisely what the security analyst means when he refers to these concepts. For example, the security analyst may explain that by "potential added value over 2 years" he is referring to his expectations of a company's exploration efforts to be successful at finding oil. Next, in attempting to uncover the relations between these concepts, the KE may discover that the security analyst combines the above concepts in the following manner to provide an estimate of the company's future prospects :

```
FUTURE-PROSPECTS =   0.3 * POTENTIAL-ADDED-VALUE-OVER-2-YEARS
                   + 0.4 * PROJECTED-CASH-FLOW-GROWTH-TO
                           EXPECTED-CHANGE-IN-OIL-PRICE
                   + 0.3 * PROJECTED-5-YEAR-CASH-FLOW-GROWTH
```

3) Formalization

The formalization stage involves a mapping of the key concepts into a more formal representation suggested by the tool or language that is used to build the system. In other words, it involves the representation of the various concepts uncovered during the conceptualization stage in the form required by the system building tool. For example, the following is a formal representation of some concepts from our security-analysis domain as required by "Personal Consultant Plus", the tool used in our work :

```
IF   :: FUTURE-PROSPECTS = "VERY BAD"
THEN :: FORECASTED-PRICE = 0.7 * APPRAISED-VALUE

IF   :: FUTURE-PROSPECTS = "GOOD"
THEN :: FORECASTED-PRICE = 1.2 * APPRAISED-VALUE
```

4) Implementation

This stage involves the construction of the initial prototype of the system. Prototyping as an approach to systems development is relevant when :

> Neither user nor developer can specify functional requirements in advance. For instance, in unstructured or underspecified tasks, either there is a lack of knowledge to define the procedures and requirements, or a lack of procedures is intrinsic to the task [Spraque, 1982, p. 131]

In the context of the development of expert systems, prototyping is particularly relevant because :

> In the context of building an expert system, there is almost constant revision, which may involve reformulation of concepts, redesign of representations, or refinement of the implemented system. [Buchanan et al, 1983, p.148]

Moreover, prototyping leads to earlier detection of changes [Necco et al, 1987], as a result of tests [see below] performed on the prototype.

One other issue that needs to be resolved is we need to establish when to build the initial prototype. Buchanan et al (1983) suggests that development of the initial prototype should begin as early as possible with the limited scope of solving a small but meaningful subtask of the problem under consideration. For example, in order to decide which stocks to trade, the security analyst may take forecasting stock prices over a year as a meaningful subtask. Due to its limited scope, the initial prototype exhibits limited functional capabilities, low reliability and inefficient performance [Fairley, 1985]. Because of this the initial prototype must be iteratively refined. Each iteration will yield a successively improved version of the previous prototype in terms of increased functional capabilities, reliability and efficiency. For example, an iterative refinement on the initial prototype which forecasted stock prices, can yield a version which also includes the capability of determining the required return on the stocks. We are thus led to the issue of when to stop the iterative process of testing, refining and reimplementing a prototype. The iterative process is stopped when the developers and users feel that the costs of performing the next iteration outweighs the additional benefits that could be realized from further refining the system. [Keen, 1981; Money et al, 1988].

5) Testing

In this stage, the performance of the prototype is evaluated with the aid of the expert and user. Gaschnig et al (1983), suggest that the system should be evaluated on the following aspects :

a) The quality of the systems's decisions and advice

Expert systems tend to be built precisely for those domains in which the decisions of human experts are highly judgemental and nonstandardized. For such domains, lacking an objective standard of what constitutes a correct decision, Gaschnig et al, (1983) have suggested that the opinion of the human experts be considered the standard. The issue remains of what test cases to present to the system. Gaschnig et al (1983) suggest that the selection of tests should be random and preselected to range over a broad range of difficulty. This in turn suggests that the expert's help is required to determine what sample of tests provide the necessary breadth and depth. Finally, all test samples including those used to test the prototypes should be saved in a library. Each time a change is made to the existing prototype, all the tests in the library should again be presented to the system to verify that no unanticipated effects have been introduced as a result of the changes.

b) The quality of the human-system interface

The issues here are 1) choice of words used in questions by the system, 2) responses by the system, 3) ability of the system to explain the basis for its decisions and 4) ability of the system to assist users when they are confused about what is required of them.

c) The system's efficiency

This relates to the time required by the system to arrive at a decision. Lewis & Crews (1985) have discussed "workload modelling" as a means of assessing the speed performance of a hardware system. In the context of assessing the speed performance of a software system, "workload modelling" would involve the selection of test cases that are representative of the problems expected to be faced by the system. The average time required by the system to solve the cases could then be taken as indicative of the time required by the system to arrive at a decision.

If the developers and users feel that further improvement is needed, then the system might have to be reimplemented in lower level machine dependent language, which would then reduce the portability of the system. Thus the issues of speed on the one hand and portability on the other have to be faced.

d) The system's cost effectiveness

This is a measure of the benefits the system can provide in relation to the costs of developing the system. Keen (1981) and Money *et al* (1988) have discussed value analysis in relation to this factor. Value analysis used to assess the cost effectiveness of a system relies on the intuition of the decision makers. First of all, the decision makers determine the expected benefits that a prototype provides and then decide if they feel that the cost of building the prototype to obtain the benefits is acceptable. Secondly, once the prototype has demonstrated the feasibility of a full system, the decision makers need to determine the cost of the full system and then decide if the expected benefits are acceptable.

This concludes the description of the knowledge engineering process. The next section will describe the process of knowledge acquisition.

Knowledge Acquisition

It is generally believed that one of the major difficulties in the development cycle is the process of extracting knowledge from the expert. The process of knowledge acquisition is held to be the bottleneck in the development of expert systems. A major part of the difficulty is that human experts typically have difficulty in explaining their problem solving strategies. We now discuss some of the difficulties inherent in this process and present a survey of some of the various techniques that have been used to aid in the process of KNOWLEDGE ACQUISITION.

The techniques for eliciting knowledge from domain experts range from interviews and discussions (e.g., protocol analysis and other related methods) to the use of computer-assisted techniques. Essentially the techniques can be classified as :

1) interviewing the expert,
2) protocol analysis,
3) observational studies,
4) computer-assisted techniques.

A description of these techniques as summarized by Waterman (1986) on the basis of Clancey (1981) follows :

Interviewing the expert

Techniques for interviewing the expert include problem discussion and problem description.

In problem discussion, the knowledge engineer attempts to determine how the expert organizes knowledge about a problem, represents concepts and hypotheses and handles inconsistent, inaccurate or imprecise knowledge and data relating to the problem.

On the other hand problem description involves the expert being asked to describe a typical problem for each category of solution that could arise (e.g., "hard starting of car" could be a typical problem for the solution category "electrical fault"). The aim here is to aid the knowledge engineer to define a typical problem for each solution category so that a strategy or basic approach to solving the problem can be discovered. This can also suggest ways in which the expert's knowledge can be organized hierarchically. The difficulty with this technique is that of knowing what questions to ask in order to obtain the required information. More specifically, what are the questions to be asked and when during the interview should the questions be asked? Unfortunately, the interview process is still not understood well enough at present. Because of this there is no clear answer to the latter part of the problem.

LaFrance (1987) has suggested some question types that may be helpful during an interview. As described by LaFrance (1987) the types of questions are :

1) Grand Tour

These are questions of a general nature. They are meant to get the expert to paint a broad picture of the problem domain in order to understand the boundaries of the domain. They are also meant to obtain an overview of the expert's perspective, goals, organization and classifications. An example of such a question might be, "In estimating stock prices over a year, could you tell me what are the factors that you would need to consider ?"

2) Cataloging the categories

The goal of these questions are to determine if the data and concepts used by the expert can be classified into logical divisions. For example, it could be asked, "Earlier, you gave me a listing of some factors that you needed to consider, in order to estimate the stock prices over a year. Could you provide some logical classification of these factors ?" The expert may then state that the factors could be classified as either economic, industrial or company specific factors.

3) Ascertaining the attributes

These questions aim to discover the distinguishing features and range of possible values of the data used by the expert. Such a question might be, "We've discussed some factors that you considered in deciding on a trading strategy. Could you tell me what the possible values for each of these factors are ?"

4) Determining the interconnections

These questions are directed at uncovering the relations among the expressed concepts in the domain and thus in determining whether a cause-effect model is applicable to the domain. An example of such a question is, "You've mentioned that the appraised value is an important factor in the estimation of the stock price. Could you tell me why ?"

5) Seeking advice

These questions are designed to reveal the expert's recommendations and hence strategies for dealing with a variety of conditions. For example, "You've mentioned that the track record of a company is considered when you estimate the stock price. What if the company has been in existence for less than a year and hence does not have a track record ?"

6) Cross-checking

These questions are used to check on the consistency and accuracy of previously obtained information. These questions can be sub-classified into 5 types, namely, the Naive Question, Playing Devil's Advocate, Posing Hypothetical Situations, asking How Sure Are You ? and Seeking The Exception.

However, while these question types are helpful during the interview process, the interview process still poses difficulties because we do not yet know how to sequence the questions in order to generate an effective knowledge acquisition process.

Protocol analysis

In protocol analysis, on the other hand, the knowledge engineer gives the expert a series of problems to solve. As the expert solves each problem, he is required to describe the solution process aloud, giving as many intermediate steps as possible. Further, the knowledge engineer supplies the expert with any additional information or data needed to solve the problem. This problem solving session is recorded so that the knowledge engineer can then review it at any time. During the review, the knowledge engineer examines each step to determine the rationale behind it, including hypotheses generated, strategies used to generate hypotheses and goals pursued for strategy selection. Any questions can then be put to the expert at the next interview. As noted by Cooke & McDonald (1987), one of the main difficulties with protocol analysis is that

> Much expert knowledge is not available to conscious introspection (i.e., it is automatic or compiled) and consequently, experts may give erroneous or incomplete accounts of their knowledge [Nisbett & Wilson]. Indeed, Ericsson and Simon (1984) contend that information must be in the focus of attention (i.e., short term memory) in order to be verbalized.

In addition, Nisbett and Wilson (1977) have cautioned researchers about the pitfalls of protocol analysis. They list removal in time, a priori theories (correctly or incorrectly formed), mechanics of judgement, context, non-events and discrepancy between the magnitude of cause and effect as factors which affect the availability and representativeness of events and stimuli in individuals. These, in turn, affect the consistency and accuracy of the resulting verbal reports. Moreover, Ericsson and Simon (1984) list timing of verbalizations, directedness and content of verbalizations and amount of intermediate processing required as factors that affect the consistency and completeness of verbal reports.

Notwithstanding the above difficulties several techniques have been derived on the basis of protocol analysis. Boose (1986) gives the examples listed below.

1) Grover's (1983) 3-phase methodology.

   Here the knowledge engineer first defines the domain, then reviews several types of problems with the expert in order to acquire sufficient knowledge to implement the first prototype, and, finally, iteratively refines the prototype.

2) Delphi technique [Jaganathan & Elmaghraby, 1985].

   The knowledge engineer derives information from experts, then presents his results to the experts for re-evaluating; the process is repeated until a degree of consensus on decisions is reached.

3) Crawford Slip Method [Crawford, 1983].

Here the knowledge engineer queries groups of individuals who respond on slips of paper in a certain format within a specified amount of time and the responses are then organized and classified.

4) Smith & Baker's Approach [Smith & Baker, 1983].

In this approach to helping experts verbalize their knowledge, the knowledge engineer presents them with novel problems and then records the problem solving process.

Observational studies

As in protocol analysis, observational studies involve the solution of problems by the expert, although here the expert is observed while solving problems on the job, and not the contrived ones used for protocol analysis. he aim here is to gain some insight into the complexity of the problem. For example, in protocol analysis, the security analyst might be presented with past data on a company. These data might include his past assessments of the company's management and strategy. The analyst is then required to verbalize his problem solving as he analyses the company. In observational studies, on the other hand, the analyst is observed while solving problems during the course of his daily work. This might include observing the analyst as he forms a perception of a company's strategy and management during a discussion of the company's strategy with its management.

Computer-assisted techniques

Some examples of systems which are used to aid in the automation of the knowledge acquisition process are KITTEN [Shaw & Gaines, 1987], AQUINAS [Boose & Bradshaw, 1987], SALT [Marcus, 1987], MOLE [Eshelman et al, 1987], KRITON [Diederich et al, 1987] and TEST [Kahn et al, 1987].

KITTEN and AQUINAS both use techniques based on Kelly's (1955), personal construct theory and incorporate the use of a "repertory grid". The repertory grid is "a two-way classification of data in which events are interlaced with abstractions in such a way as to express part of a person's system of cross-references between his personal observations or experiences of the world (elements), and his personal constructs or classifications of that experience" [Shaw & Gaines, 1987]. Essentially, the repertory grid can be thought of as a two-dimensional table with the elements, that is problem solutions, along the top of the table and the attributes or traits of these solutions down the side of the table. The knowledge acquisition process then reduces to the problem of determining the elements, attributes and values for the entries of the table. The values are essentially scales which rate the extent to which an element possesses a given attribute. For example, in the domain of analysis of oil securities, a security may possess an attribute "future prospects". This attribute may then be scaled to take on values from 1 to 5, representing "very bad", "bad", "average", "good" and "very good" respectively.

Once the grid has been obtained, it can be analysed to establish if there are any relationships between attributes. Examples of techniques for such analysis include cluster analysis and entailment analysis. FOCUS [Shaw, 1980] provides an example of cluster analysis while ENTAIL [Gaines & Shaw, 1981] provides an example of entailment analysis.

Boose and Bradshaw (1987), have noted that some limitations of the repertory grid technique are that :

> First, a single rating grid can represent only "flat" relations between single solutions and traits. No deep knowledge, causal knowledge, or relationship chains can be shown. A second limitation was that only solutions or traits at the same level of abstraction could be used comfortably in a single grid. Finally, large single grids were often difficult to manipulate and comprehend. [Boose & Bradshaw, 1987, p. 6]

In AQUINAS, Boose and Bradshaw (1987) have attempted to overcome these limitations by hierarchically ordering solutions and traits which are at the same level of abstraction. Further they extended the grid to four dimensions by forming 2 additional hierarchies to represent multiple sources of knowledge and classes of problems. However, even with their extensions, they admit that difficulties still arise. In particular they state that :

> Personal construct psychology methods provide no guarantee that a sufficient set of knowledge will be found to solve a given problem.

Further, they state that at present, AQUINAS works best on problems whose solutions can be easily enumerated, for example analytic or structured selection problems such as classification or diagnosis. This could be taken to be a limitation of elicitation procedures based on personal construct psychology. For other problems, such as synthetic or constructive problems which involve the construction of solutions from components, for example, configuration and planning problems, they believe the approach used in SALT is particularly promising.

SALT [Marcus, 1987] is described as a knowledge acquisition tool for generating expert systems that use a propose-and-revise problem solving strategy. That is, SALT incrementally constructs an initial design by proposing values for design parameters, identifying constraints on design parameters as the design develops and revising design decisions in response to detection of constraint violations in the proposal. Basically, SALT assumes that 3 basic kinds of knowledge make up a propose-and-revise system. These 3 kinds of knowledge are :

1) procedures for proposing values for the pieces of the design the system will output. The procedures involve either computations or a database lookup. In the case of a computation, the value of a piece of the design is computed from the values of other pieces of the design. In the case of a database lookup, a SALT generated expert system consults its database of equipment specifications to select an appropriate item.

2) identification of constraints on design parameters. SALT attempts to determine constraints on the values of the design parameters, if any.

3) suggestions for ways of revising the design, if the constraints are not met. This involves the use of procedures for revising the value of some piece of the design to ensure that the constraints are met. The procedures are supplied by the user. In some cases, it is possible that there is more than one procedure for revising the design. To allow for this possibility, the user has the choice of which procedure to use.

The elicitation process in SALT then focuses on obtaining the various kinds of knowledge outlined above until a solution is found or it is determined that the problem is over-constrained and no solution is possible. As a final note it should be noted that trouble spots exist in SALT. This involves the possibility of infinite loops in the system. These infinite loops can occur when SALT attempts to revise the value of some piece of the design which then causes a constraint violation in some other piece. The revision process then gets into an indefinite loop. However in their paper describing SALT [Marcus, 1987], the authors state that they eventually hope to have an automated means of correcting this problem.

Finally, another approach, not based on personal construct theory, is that of MOLE [Eshelman et al, 1987]. MOLE was designed primarily for use in acquiring knowledge for expert systems that do heuristic classification, that is, the selection of some conclusion from a set of pre-enumerable conclusions. Examples of these are systems that conclude some fault or disease on the basis of weighted considerations of some set of observables. Thus, the approach used by MOLE essentially consists of determining what hypotheses will account for these symptoms, what sub-symptoms will aid in differentiating hypotheses that are probable explanations for some particular symptom and, finally, select the best combination of viable hypotheses that are consistent with all symptoms.

This concludes the survey on the techniques used for knowledge acquisition. The next section presents a report on the methodology used for this study.

## RESEARCH METHODOLOGY

A 5-phase knowledge engineering methodology was used to capture the decision rules of the 3 security analysts involved in the study, and to implement the rules in the form of 3 expert systems.

### Identification phase

The goal of this phase is to determine the concepts and data relevant to the task of analysing oil securities. This goal was achieved through interviewing a security analyst. To start with, the security analyst was asked to name the elements (i.e., data and concepts) which he deemed to be relevant to the analysis of oil securities. It was explained to the analyst that the elements may include both hard data (eg., rate of change in world GNP) and soft data (eg., assessment of a company's management). The security analyst was then interviewed after he had had a week to review the relevant elements. This list was then discussed with him to determine the possible values and the unit of measure for each element. A five point Likert-scale was used to measure "soft" elements, with 1 being the lowest and 5 the highest point on the scale. The five points, from 1 to 5 were then taken to represent "VERY BAD", "BAD", "AVERAGE", "GOOD" or "VERY GOOD", respectively. For the "hard" elements, the analyst was asked to state the range of possible values and the unit of measure for each element (eg. the MARKET CAPITALIZATION can vary from 0 to 800 measured in terms of millions of dollars). Further, for the "hard" elements, the analyst was asked what range of values he would consider to be "VERY BAD", "BAD", "AVERAGE", "GOOD" or

"VERY GOOD" respectively. This information enabled the "hard" elements to be mapped to a point on the Likert-scale and allowed a uniform representation for both the "hard" and "soft" elements.

Conceptualization phase

The goals of this phase were to :

a) obtain more precise definitions for each element identified during the foregoing phase

b) obtain brief explanations with respect to why an element was identified as being relevant to the task of analysing oil securities

c) make explicit the relations between the elements.

The goals were achieved through the use of protocol analysis. Taped recordings were made during discussions with the security analyst. During the discussions, the analyst was asked to provide definitions for each of the elements identified and to explain briefly why he had identified an element as being relevant to the analysis of oil securities (eg., "Potential added value refers to the expectation of a company's exploration efforts to be successful at finding oil. This is relevant because if the perception is that they will be successful, then investors will pay a higher price for the company's share"). After this, the recording tapes were transcribed and written reports were prepared listing the elements, their definitions, and explanations. The security analyst was then given these reports and asked to comment on them and provide recommendations for any changes that should be made. The reports were revised on the basis of his recommendations. After revision of the reports, the relations between the elements were made explicit. As a start, it was explained to the security analyst that an "input" element is an element that he did not derive from either a qualitative or a quantitative assessment of some combination of elements. An "output" element is an element that he did derive through an assessment of some other elements. Next, it was explained to the analyst that relations were to be developed between the input and output elements. It was explained that the relations include both "hard" relations (eg., MARKET-CAPITALIZATION = TOTAL-NUMBER-OF-SHARES * SHARE-PRICE) and "soft" relations (eg., FUTURE-PROSPECTS is a weighted assessment of POTENTIAL-ADDED-VALUE, PROJECTED-CASH-FLOW-GROWTH and the ratio of PROJECTED-CASH-FLOW-GROWTH to the EXPECTED-CHANGE-IN-OIL-PRICE). The relations were then put into a written report which was later given to the analyst for verifications and revisions.

Formalization phase

During the previous phases, the security analyst had identified a number of input elements which influenced the output element "PERCENTAGE DISCOUNT". The goals of this phase were

a) to determine if the factors identified during the identification and conceptualization phases are in fact binding on the decision process of the security analyst.

b) to determine the weights attached by the security analyst to each of the factors in order to derive the underlying linear model.

c) to determine the correctness of the identified linear model

The goals were achieved as follows :

1) The security analyst was given a copy of FORM 1 (see Appendix A). FORM 1 contains a list of factors identified by the security analyst during the first 2 phases.

2) For each factor on the form the security analyst was asked to identify those factors relevant to his estimation of the PERCENTAGE DISCOUNT. He was to do this by marking the corresponding boxes under the title "USED".

3) The security analyst was then asked to rank the factors marked in this manner in ascending order of importance.

4) The security analyst was then told to assume that the least important factor had a weight of 1 and that he was to weigh the other factors relative to the former factor.

5) The factors were then normalized to values ranging from 1 to 5 on the Likert scale. Starting with 1, the values represented qualitative judgements of "VERY BAD", "BAD", "AVERAGE", "GOOD" and "VERY GOOD"

respectively (eg., if ASSESSMENT-OF-COMPANY-STRATEGY = 4 then this meant that the company's strategy was judged to be good).

6) The security analyst was asked how he would group (cluster) these factors to show which of them were related. For example, the three factors

[ (ASSESSMENT OF COMPANY STRATEGY)
(ASSESSMENT OF COMPANY MANAGEMENT)
(ASSESSMENT OF COMPANY REPORTING) ]

constitute one cluster, which can be called QUALITATIVE-FACTORS. The clusters obtained in this manner are shown in TABLE 1.

TABLE 1 : CLUSTERS OF FACTORS USED BY ONE OF THE SUBJECTS

```
QUALITATIVE-FACTORS : [ (ASSESSMENT OF COMPANY STRATEGY)
                        (ASSESSMENT OF COMPANY MANAGEMENT)
                        (ASSESSMENT OF COMPANY REPORTING) ]

CURRENT-FUNDAMENTALS : [ (BREAK EVEN COSTS PER BARREL)
                         (OPERATING COSTS PER BARREL)
                         (INTEREST AND PREFERRED DIVIDEND)
                         (DEBT/CAPITAL) ]

TRACK-RECORD : [ (HISTORICAL CASH FLOW GROWTH PER SHARE)
                 (FINDING COSTS PER BARREL) ]

FUTURE-PROSPECTS : [ (POTENTIAL ADDED VALUE)
                     (PROJECTED 5 YEAR CASH FLOW GROWTH/
                      EXPECTED CHANGE IN OIL PRICE)
                     (PROJECTED 5 YEAR CASH FLOW GROWTH) ]

MARKET-FLOAT : [ (MARKET FLOAT) ]

DISCOUNT-FACTOR (*) : [ (QUALITATIVE-FACTORS)
                        (CURRENT-FUNDAMENTALS)
                        (TRACK-RECORD)
                        (FUTURE-PROSPECTS)
                        (MARKET-FLOAT) ]


DISCOUNT-FACTOR (**) : [ (QUALITATIVE-FACTORS)
                         (CURRENT-FUNDAMENTALS)
                         (FUTURE-PROSPECTS)
                         (MARKET-FLOAT) ]
```

NOTE :

In estimating the DISCOUNT FACTOR, the TRACK RECORD of the company is considered only if the company has a track record of at least 3 years, otherwise the track record is considered insufficient and will not be considered. Thus,

(*) indicates that the TRACK RECORD is sufficient
(**) indicates that the TRACK RECORD is insufficient

7) The weights assigned by the analyst were then normalized so that their total combined weight is 1. This ensures that a linear combination of factors using the normalized weights yields a value on the Likert scale. For example, we have

```
QUALITATIVE-FACTORS =
    0.2 * ASSESSMENT-OF-COMPANY-STRATEGY
  + 0.5 * ASSESSMENT-OF-COMPANY-MANAGEMENT
  + 0.3 * ASSESSMENT-OF-COMPANY-REPORTING
```

Protocol analysis was used to determine the correctness of the identified linear model. A sample of the previous work performed by the security analyst for the organization was obtained. This work consists of an estimation of the percentage discount for each of 16 companies which the security analyst has dealt with. In addition, reports for each company were obtained from the security analyst . These reports contained information which the security analyst used in estimating the percentage discount for the sample of work he provided. The following steps were then performed :

1) The security analyst was given reports on each of the 16 different companies which he normally dealt with. These reports contain information regarding the factors included in the identified linear model. The names of the companies were not disclosed in the reports in order to avoid bias.

2) The security analyst was asked to estimate the percentage discount for

each of the companies on the basis of the reports. The security analyst took approximately an hour to do this. An example of the outcome of this process for one of the subjects is shown in Table 2.

<u>Implementation phase</u>

"Personal Consultant Plus" was used to implement a prototype of the linear model identified.

TABLE 2 : RESULTS OF TEST

| NO. | APPRAISED | DISC TEST % | DISC PREV % | DISC SYSTEM % | TEST TARGET | PREVIOUS TARGET | SYSTEM TARGET |
|---|---|---|---|---|---|---|---|
| 1 | 57.26 | 95 | 96 | 100 | 54.40 | 55.00 | 57.12 |
| 2 | 28.96 | 90 | 92.5 | 93 | 26.05 | 26.80 | 27.05 |
| 3 | 11.75 | 100 | 102.5 | 103 | 11.75 | 12.00 | 12.16 |
| 4 | 30.22 | 90 | 82.1 | 97 | 27.20 | 24.80 | 29.24 |
| 5 | 26.56 | 90 | 93.2 | 95 | 23.90 | 24.75 | 25.14 |
| 6 | 18.00 | 90 | 88.9 | 96 | 16.20 | 16.00 | 17.29 |
| 7 | 33.82 | 80 | 81.3 | 94 | 27.05 | 27.50 | 31.79 |
| 8 | 68.15 | 95 | 96.8 | 100 | 64.75 | 66.00 | 68.01 |
| 9 | 21.47 | 90 | 92.2 | 95 | 19.30 | 19.80 | 20.49 |
| 10 | 18.00 | 95 | 111.1 | 97 | 17.10 | 20.00 | 17.49 |
| 11 | 19.00 | 90 | 100.0 | 92 | 17.10 | 19.00 | 17.55 |
| 12 | 37.91 | 90 | 92.3 | 90 | 34.10 | 35.00 | 34.10 |
| 13 | 12.81 | 95 | 109.3 | 100 | 12.15 | 14.00 | 12.87 |
| 14 | 7.07 | 90 | 95.5 | 93 | 6.35 | 6.75 | 6.57 |
| 15 | 9.82 | 95 | 97.8 | 99 | 9.30 | 9.60 | 9.71 |
| 16 | 3.84 | 95 | 104.2 | 93 | 3.65 | 4.00 | 3.55 |

NOTE :

1) "No." refers to the serial numbers used to identify the companies during TEST 2.

2) "DISC TEST" referS to the estimates of the DISCOUNT FACTOR obtained from TEST 2.

3) "DISC PREVIOUS" refers to the estimates of the DISCOUNT FACTOR obtained from a sample of the analyst's previous work.

4) "DISC SYSTEM %" refers to the estimates of the DISCOUNT FACTOR obtained from the system.

Testing phase

The current prototype developed during the preceding phase was then tested. As the goal is to establish the correctness of the implemented linear model, the emphasis of testing was on the quality of the system's recommendations. Specifically, the security analyst was asked to comment on the system's performance in this regard. As the analyst evaluated the system in this manner, he was led to question the relevance of some data.

In addition, the analyst identified several more elements that should be included in the model. This led to the next iterative refinement of the current prototype.

This concludes the description of the methodology used to develop the expert systems for the three subjects involved in the study. The next section will describe the methodology used to validate each of the three expert systems developed as well as the method used to determine the degree of similarity among the sets of decision rules used by the three subjects involved in this study.

## ANALYSIS

The methodology, in the form of three expert systems, obtained from the three subjects involved in this study, used to implement the decision rules has already been discussed in the previous section (see Research Methodology). In this chapter the objective is a description of the methodology used to validate the models, as well to determine the degree of similarity between the decision strategies of the three subjects. The analysis will consist of two phases. These phases are described next.

### Validation phase

The objective of this phase is to determine the degree of correlation between the decisions of each expert (subject) with his expert system. Before proceeding with the description of the validation methodology, we give an overview of the decision strategy of the subjects. This overview clarifies the rationale for the validation methodology used.

The "target" price of a stock refers to the security analyst's 12-month forecast of the price of a stock. For example, a target price of $12.00 for a stock reflects the analyst's belief that the stock would be traded at $12.00 for some period of time within the next 12 months. The subjects adopt the following strategy in determining the target price for a stock :

1) Assess a list of factors $X_1$, $X_2$, $X_3$,....., $X_i$ for the stock in question (e.g., see FORM 1)

2) Form an overall assessment of the stock, based on an assessment of the

factors X in terms of whether the stock is "very bad", "bad", "average", "good" or "very good". In deciding on the overall assessment, however, the subjects tend to place greater emphasis (weight) on some factors than others. This decision process is best described as a weighted assessment of factors, with the outcome of the process being an overall assessment of the stock. This overall assessment of the stock is termed "discount factor" (D). In the systems developed, D is represented as a point on a 5-point Likert scale, with 1 representing "very bad" and 5 representing "very good". With this representation, the weighted assessment of factors can be described mathematically as :

$$D = \sum W_i * X_i \qquad \text{(E1)}$$

where the W 's represent weights for the corresponding factors. The method of obtaining these weights has already been discussed (see Research Methodology). Recall that the method involved the subjects being asked to assign relative weights to the factors.

3) After the discount factor, D, is determined, the subjects translate this qualitative evaluation of a stock into a quantitative value termed a percentage discount, P. For example, P is given as :

$$P = 0.6 + (D - 1) * 0.1 \qquad \text{(E2)}$$

Note that the numbers used here have been modified to protect the confidentiality of the subjects.

4) Finally, the subjects set the target price as the percentage discount (P) from the value of a factor A (e.g., A can be the appraised value per share or projected 1 year cash flow). Note that the subjects differ in their choice of this factor. This difference will be discussed later (see Cluster Analysis). The target price (T) is given as :

$$T = P * A \qquad (E3)$$

For example, suppose A is the appraised value per share. If a stock has an appraised value per share of $10.00 and the analyst has decided that an appropriate value for P is 0.9, then the target price of the stock is $9.00.

It should be noted that since A is a value supplied to the systems directly by the subjects and E2 and E3 are actual formulas used by the subjects, any discrepancies of the decisions of the subjects from the decisions of their respective expert systems can be attributed to D. This should be clear, given that El models the decision process of the subjects making a qualitative decision. Thus, in order to validate the model it is necessary to determine the degree of correlation between the discount factors D arrived at by the systems, with the discount factors D found by their respective subjects. Before the analysis could proceed, samples of past work performed by the subjects had to be obtained. The subjects were requested to provide samples of their past work which give information on the factors they use in determining the discount factor as well as the values of the discount factors they found on the basis of a weighted assessment of those factors. The subjects were also told that their samples had to satisfy the following requirements :

1) The samples should be from the preceding year. This requirement was needed because the decision strategies of the subjects may change over periods of longer than a year. This may give rise to changes in the factors they use or even in the weights assigned to the factors.

2) The samples should be of relatively normal trading activity, to avoid any major perturbation that can affect the decisions of the subjects. This means that the samples could not cover the 12 months surrounding the October 1987 market crash.

The samples from the subjects were received a week later. They represented 30 weeks of work, with 10 weeks covering the period from 16 Jan 1987 to 17 Jun 1987 and the remaining 20 weeks covering the period from 15 Apr 1988 to 26 Aug 1988. It should be noted that one of the subjects supplied data for the latter period only as he was not involved in trading during 1987. The subjects were only able to provide samples containing information on the factors and the target prices they had arrived at, because, as they explained, discount factors were routinely recorded on any documents. Thus, it is necessary to derive discount factors from the target prices, as follows; Equations El, E2 and E3 yield

$$D = ( (T / A) - 0.8 ) / 0.075 + 1 \qquad (E4)$$

However, the derivations reveal some irregularities with discount factors. It was observed that some of the values could not be mapped onto a point on the 5 point Likert scale being used. That is, the values did not lie in the interval [1, 5]. At this point the subjects were individually asked if they could provide explainations for these irregularities. The subjects agreed among themselves that the decision strategy (ie., weighted assessment of factors) they had reported was used to set a target price based on the "fundamental factors" $X_i$. However, in response to certain exigencies which occur, it was sometimes necessary to adjust target prices. This adjustment could be made independently of the fundamental factors. The subjects stated that exigencies could be

1) the possibility of a company being taken over

2) the possibility of a company being restructured

3) the possibility of a new exploration find

These factors are a part of what the subjects term market "psychological factors". The subjects believe that these events or rather the possibility of the occurrence of these events affect the decisions of investors and ultimately, this can influence stock prices.

The foregoing being the case, it was assumed, at first, that the magnitude of these adjustments could be determined. A subtraction of the known adjustment from the target price yields the target price actually obtained using discount factors. Again there was a consensus amongst the subjects. The subjects stated that the adjustments were made on an ad hoc basis, but they could not recall what adjustments actually had been made. The problem was compounded by the fact that these adjustments were done on an informal basis, so that no documentation was available. Another reason for this lack of documentation was the fact that the subjects were not required by their organizations to state such "psychological factors" in their reports on the target prices they had set.

Thus, the only alternative left was the determination of the discount factors from protocol analysis. Information relating to the inputs required by the expert systems to compute discount factors were obtained from the samples of past work provided by the subjects. This information was then presented to the subjects. The subjects were asked to estimate the discount factors based on the information presented to them. The subjects took approximately 2 hours to do this.

The preceding paragraph should have made clear our intention to determine the degree of correlation between the discount factors from the test and the discount factors computed by the subjects' respective expert systems. However the major goal of the subjects, in estimating the discount factors, is to decide on the "rankings" to be assigned to the stocks. The ranking of a stock in the oil industry is a number on a 5 point Likert scale which represents the stock's potential to outperform other stocks in the oil industry. On the scale, the best ranking is 1 and the worst is 5. An average stock would have a ranking of 3. The rankings reflect the subjects' decisions on which stocks should be bought or sold. More specifically, stocks ranked 1 or 2 should be bought, stocks ranked 4 or 5 should be sold and no action should be taken on stocks ranked 3. The rankings of the subjects were obtained from the samples of past work that the subjects had provided. From the discussion of this paragraph, it should be clear that we intend to determine the degree of concordance between the rankings arrived at by the subjects with the rankings arrived at by their systems. Recall that this is in addition to our previously stated intention to determine the degree of correlation between the discount factors of the subjects and their systems.

Based on the preceding discussion of this section the rationale for the validation methodology to be described as well as the method of data collection for the analysis should be evident. The validation methodology consisted of 2 stages. These are described next.

1) Subjective evaluation by subjects

In this stage, the subjects were requested to use their expert systems over a period of four weeks. Two of the subjects (A and B) had access to microcomputers with enough random access memory to run their expert systems. The third subject (subject C) did not have access to the required hardware to run his expert system. He was given a hard copy of his expert system's recommendations of the stock rankings and discount factors based on a series of cases provided by the subject. At the end of the period the subjects were asked to evaluate the performance of their systems. Specifically, they were asked to take note of the discount factors and rankings arrived at by their systems and to assess the performance of their systems with regards to these outputs. The subjects said that they found their systems to be performing satisfactorily.

2) Objective assessment

In this stage, the objectives were

a) to determine the degree of correlation between the discount factors of the subjects $D_a$ with those of their respective expert systems $D_s$.

b) to determine the degree of agreement between the rankings of the subjects $R_a$ with those of their respective expert systems $R_s$.

In the former case, Pearson's coefficient of correlation was used as a measure of the correlation between $D_a$ and $D_s$. In the latter case, Kendall's coefficient of concordance was used as a measure of the agreement between $R_a$ and $R_s$. The coefficients of the respective comparisons for the three subjects are shown in Tables 3 and 4.

The results for the three subjects seem similar in one respect. Discount factors showed better agreement than rankings. A possible reason for this is the difference between the methods used to collect data for $D_a$ and $R_a$. It should be recalled that the data for $D_a$ was obtained through the use of a written test given to the subjects. In the case of $R_a$, the data was obtained from samples of past work that the subjects had performed for their organizations.

Table 3

Discount Factors Of Subjects From A Written Test ($D_a$)

Versus

Discount Factors From Their Respective Expert Systems ($D_s$)

| | Lowest | Highest | Average |
|---|---|---|---|
| Subject A | 0.733 (0.02) | 0.7508 (0.01) | 0.7417 *** |
| Subject C | 0.7719 (0.00) | 0.8259 (0.00) | 0.815 *** |
| Subject B | 1.0000 (0.00) | 1.0000 (0.00) | 1.0000 *** |

Notes :

Lowest - lowest value for the coefficients over the 30 weeks tested
Highest - Highest value for the coefficients over the 30 weeks tested
Average - Average value for the coefficients over the 30 weeks tested

* - Pearson's coefficient of correlation
(significance probability of Pearson's coefficient)

*** - Significant probabilities are not given for the average values as the probabilities would not be meaningful.

Table 4

Rankings Of Subjects Obtained From Samples Of Their Past Work ($R_a$)

Versus

Rankings From Their Respective Expert Systems ($R_s$)

| | Lowest | Highest | Average |
|---|---|---|---|
| Subject A | 0.2162<br>(0.44) | 1.0000<br>(0.00) | 0.6234<br>*** |
| Subject C | -0.0793<br>(0.73) | 0.4887<br>(0.03) | 0.3545<br>*** |
| Subject B | 0.35<br>(0.31) | 0.6999<br>(0.04) | 0.5327<br>*** |

Notes :

Lowest - lowest value for the coefficients over the 30 weeks tested
Highest - Highest value for the coefficients over the 30 weeks tested
Average - Average value for the coefficients over the 30 weeks tested

** - Kendall's coefficient of concordance
(significance probability of Kendall's coefficient)

*** - Significant probabilities are not given for the average values as the probabilities would not be meaningful.

The point is that there were differences between decision environments in which the subjects made their decisions concerning $D_a$ and $R_a$. The difference was that the decision environment for the test was a contrived environment, whereas the decision environment from which the samples were obtained was the usual environment in which the subjects performed their daily work. Because of this, it was possible that factors present in the usual environment of the subjects were not present in the test environment. Examples of such factors listed before are the possibility that a company would be taken over, that it would be restructured, or that it would make a new exploration find. These factors constitute a perturbation imposed on the data. $D_a$ would be expected to be relatively perturbation-free compared to $R_a$. Therefore, a comparison of the discount factors is expected to yield better results than a comparison of rankings.

A further observation made on the basis of these results is that the perturbation seems to have less influence on the rankings obtained by subject A, than those obtained for by the other subjects, C and B. For example, suppose $X_i$ is the average coefficient obtained for a comparison of $D_a$ versus $D_s$ and that $Y_i$ is the average coefficient obtained for a comparison of $R_a$ versus $R_s$ for subject i. Let $Z_i$ be the difference between $X_i$ and $Y_i$ (ie., $Z_i = X_i - Y_i$). Then from the results shown in the tables above, we have

$$Z_A = X_A - Y_A = 0.7417 - 0.6234 = 0.1183$$

$$Z_C = X_C - Y_C = 0.815 - 0.3545 = 0.4605$$

$$Z_B = X_B - Y_B = 1 - 0.5327 = 0.4673$$

It will be noted that the difference Z for subject A is lower than that for either C or B. In addition, there seems to be little difference between $Z_B$ and $Z_C$. Before we can give a reason for this, we must understand the relationship between the discount factor and the ranking. It should be recalled that the discount factor D is used to determine a discount percentage P. The discount percentage P is then used to determine the target price T. The "potential capital gain" G of a stock is the percentage difference between the target price of a stock and the current price C of the stock, that is, G is given by

$$G = \frac{T - C}{C} * 100 \qquad \text{(E5)}$$

As the subjects use G to determine the rankings, any errors affecting subjects' determination of the target prices T affect their computations of G and ultimately their determination of rankings. A discussion of the effect (of errors) on a comparison of rankings will be facilitated if the following notation is introduced: Let $R_a$ denote the rankings of the subjects, $R_s$ denote the rankings from the expert systems, $G_a$ the capital gains computed by the subjects and $G_s$ the capital gains computed by the expert systems. Further, let r denote the difference between $R_a$ and $R_s$ and let g denote the difference between $G_a$ and $G_s$, i.e.,

$$r = R_a - R_s \qquad (E6)$$

$$g = G_a - G_s \qquad (E7)$$

Let us now consider the decision strategy used by the subjects to determine rankings. Both subjects C and B use a weighted assessment of factors in determining the rankings. The decision strategy of subject A is however different from the other two subjects. Let us now proceed to discuss the decision strategies of subjects B and C, before we discuss the decision strategy of subject A.

In the case of subjects B and C, the factors that they assess in order to determine the rankings include asset mix, operating costs and capital gain. For the purpose of this discussion, it will be sufficient to list the factors used as capital gain (G) and "other factors". Let $X_i$ represent "other factors" and let $W_i$ represent the corresponding weight of factor $X_i$. Let $W_g$ represent the weight of the capital gain G. The ranking R can now be written as:

$$R = (\sum (W_i * X_i)) + W_g * G \qquad (E8)$$

Now from E6, E7 and E8 it will be noted that :

$$r = W_g * g \qquad (E9)$$

Equation E4 shows that a positive relationship exists between the effects of errors on the target prices and that of the value of g. Thus, equation E9 implies that a positive relationship exists between r and the effect of error in the target prices. It should be recalled that r measures the difference between the ranking found by the subjects and the ranking found by their expert systems. Any error affecting the target prices would directly reduce the value of Kendall's coefficient obtained for a comparison of the rankings of a subject and his expert system.

The foregoing concludes the discussion for subjects B and C. Now consider the decision strategy of subject A. Subject A uses the following procedure to assign rankings to the stocks :

1) Determine the number of stocks (N) being ranked

2) Let R , R , R , R and R represent the number of stocks that will be ranked as 1, 2, 3, 4 and 5 respectively. Compute $R_1$, $R_2$, $R_3$, $R_4$ and $R_5$ as follows :

$$R_1 + R_2 + R_3 + R_4 + R_5 = N$$

$$R_1 = 0.1 * N$$

$$R_2 = 0.2 * N$$

$$R_3 = 0.4 * N$$

$R_4 = 0.2 * N$

$R_5 = 0.1 * N$

3) List the stocks in descending order based on their potential capital gain (G).

4) Rank the first R stocks on the list as 1's

5) Rank the next R stocks on the list as 2's

6) Rank the next R stocks on the list as 3's

7) Rank the next R stocks on the list as 4's

8) Rank the next R stocks on the list as 5's

For example, let us suppose that we have

1) N = 10

2) $R = 0.1 * N = 1$

$R = 0.2 * N = 2$

$R = 0.4 * N = 4$

R = 0.2 * N = 2

R = 0.1 * N = 1

3) Stocks $S_1$, $S_2$, $S_3$, $S_4$, $S_5$, $S_6$, $S_7$, $S_8$, $S_9$ and $S_{10}$ with potential capital 60%, 50%, 90%, 55%, 80%, 65%, 85%, 70%, 75%, and 45% respectively. Then in descending order of potential capital gains the stocks would be listed as $S_3$, $S_7$, $S_5$, $S_9$, $S_8$, $S_6$, $S_1$, $S_4$, $S_2$, $S_{10}$.

4) Rank the first (since R = 1) stock on the list (ie., $S_3$) as a 1

5) Rank the next 2 (since R = 2) stocks on the list (ie., $S_7$ and $S_5$) as 2's

6) Rank the next 4 (since R = 4) stocks on the list (ie., $S_9$, $S_8$, $S_6$ and $S_1$) as 3's

7) Rank the next 2 (since R = 2) stocks on the list (ie., $S_4$ and $S_2$) as 4's

8) Rank the next (since R = 1) stock on the list (ie., $S_{10}$) as a 5

Thus the stocks $S_3$, $S_7$, $S_5$, $S_9$, $S_8$, $S_6$, $S_1$, $S_4$, $S_2$, $S_{10}$ would be ranked 1, 2, 2, 3, 3, 3, 3, 4, 4 and 5 respectively.

Let us suppose that due to errors, the potential capital gains computed by the expert system were 35%, 15%, 50%, 10%, 45%, 30%, 40%, 25%, 20% and 5% respectively for the stocks $S_1$, $S_2$, $S_3$, $S_4$, $S_5$, $S_6$, $S_7$, $S_8$, $S_9$, $S_{10}$. Thus, the system would have listed the stocks in descending order of potential capital gains as $S_3$, $S_5$, $S_7$, $S_1$, $S_6$, $S_8$, $S_9$, $S_2$, $S_4$, $S_{10}$ with corresponding ranks of 1, 2, 2, 3, 3, 3, 3, 4, 4 and 5.

It should be noted that in this case, the rankings arrived at by the system would match perfectly with the rankings arrived at by subject V. Further it should be noted that this perfect match was achieved in spite of the fact that :

1) the capital gains arrived at by the subject was significantly different from that of the system.

2) the listing of the stocks in descending order by the subject and the system were significantly different.

Thus, for subject A, it would be expected that any noise affecting his determination of the target prices would have little or no effect on a comparison between the rankings of the subject and that of the system. As such this would be a reason for the fact that the difference between the average coefficient obtained from a comparison of discount factors and that obtained from a comparison of rankings was lower for subject A than for either subject C or subject B.

On the basis of the results obtained, and the above discussion, we can conclude that disregarding errors, the expert systems developed are reasonably valid models of the decision strategies of their respective subjects. This concludes the analysis for this section. In the next section, the degree of similarity of the decision strategies of the subjects will be discussed.

Cluster Analysis

In order to determine the degree of similarity between the subjects with respect to their use of these elements, cluster analysis was performed between the choice of elements used by each subject. A "match" occurs between two subjects for an element if that element is either used or not used by both subjects. The matching score (N) (i.e., number of matches) as a percentage of the maximum possible matching score (M) was then taken as the measure of similarity between the subjects' use of elements. For example, the measure of similarity (S) is computed as :

$$S = \frac{N}{M} * 100$$

This similarity measure was computed for the following clusters of elements:

1) Quantitative Inputs

This refers to the "hard" data supplied to the system, for example, debt or capital.

2) Quantitative Outputs

This refers to results of computations on the quantitative inputs, for example, the debt/capital ratio of a company.

3) Qualitative Inputs

This refers to the "soft" data supplied to the system, for example, assessment of management.

4) Qualitative Outputs

This refers to the system's assessment of "hard" data in qualitative terms, for example, assessing the debt/capital ratio as either "good" or "bad".

5) All Elements Used

This refers to the union of all the elements in (1) to (4).

For each of these clusters, two tables are shown below. Tables 5a, 6a, 7a, 8a and 9a show the matching scores between subjects with the maximum possible score for the cluster being shown in the upper left corner of the tables. Tables 5b, 6b, 7b, 8b and 9b express the matching scores as percentages of the maximum possible scores. For example, in table 5a, subjects A and C have a matching score of 9. The maximum possible score for this cluster is 44. Therefore, their matching scores expressed as a percentage of the maximum possible score is 9/44 which is approximately 20% .

MATCHING SCORES FOR QUANTITATIVE INPUTS

| 44 | A | C | B |
|---|---|---|---|
| A | * | 9 | 21 |
| C | 9 | * | 24 |
| B | 21 | 24 | * |

Table 5a

| | A | C | B |
|---|---|---|---|
| A | * | 20% | 48% |
| C | 20% | * | 55% |
| B | 48% | 55% | * |

Table 5b

MATCHING SCORES FOR QUANTITATIVE OUTPUTS

| 28 | A | C | B |
|---|---|---|---|
| A | * | 8 | 8 |
| C | 8 | * | 20 |
| B | 8 | 20 | * |

Table 6a

| | A | C | B |
|---|---|---|---|
| A | * | 29% | 29% |
| C | 29% | * | 71% |
| B | 29% | 71% | * |

Table 6b

MATCHING SCORES FOR QUALITATIVE INPUTS

| 6 | A | C | B |
|---|---|---|---|
| A | * | 2 | 3 |
| C | 2 | * | 3 |
| B | 3 | 3 | * |

Table 7a

| | A | C | B |
|---|---|---|---|
| A | * | 33% | 50% |
| C | 33% | * | 50% |
| B | 50% | 50% | * |

Table 7b

MATCHING SCORES FOR QUALITATIVE OUTPUTS

| 9 | A | C | B |
|---|---|---|---|
| A | * | 2 | 2 |
| C | 2 | * | 9 |
| B | 2 | 9 | * |

Table 8a

| | A | C | B |
|---|---|---|---|
| A | * | 22% | 22% |
| C | 22% | * | 100% |
| B | 22% | 100% | * |

Table 8b

OVERALL MATCHING SCORES

| 87 | A | C | B |
| --- | --- | --- | --- |
| A | * | 20 | 34 |
| C | 20 | * | 54 |
| B | 34 | 54 | * |

Table 9a

| | A | C | B |
| --- | --- | --- | --- |
| A | * | 23% | 39% |
| C | 23% | * | 62% |
| B | 39% | 62% | * |

Table 9b

As Tables 5a, 5b, 6a and 6b show, the greatest degree of similarity, with respect to use of inputs, occurs between subjects B and C. However, it should be noted that a comparison of the inputs may not necessarily be a good indicator of the similarity of the decision processes between two subjects. For example, consider the inputs, "price of a stock", "appraised value" and "projected cash flow", where the inputs may simply be used as means to an end and not as ends in themselves. For example, for one subject, the ends may be the ratios, "price/appraised" and "price/projected cash flow" while for another subject it may be "price/appraised", "appraised/projected cash flow". Thus, comparison of the inputs alone would be misleading in this case, considering that the comparison would yield a matching percentage score of 100% while in actual fact, the decision strategies of the subjects are similar only to the extent that both the subjects use the output "price/appraised". Comparison of the outputs in this case yields a matching percentage score of only 50%. This demonstrates how a simple comparison of inputs can be misleading as an indicator of decision processes.

Given the weakness of comparison of inputs as an indicator of decision processes, the alternative is to compare the outputs used by the subjects. Using this method, Tables 6a, 6b, 8a and 8b show that the greatest degree of similarity occurs between subjects B and C. However, this method is not without disadvantage. The disadvantage lies in the fact that different formulas may be used to compute the same output. For example, consider the output "historical cash flow growth", which is the average growth rate over past years. The problem here is that one of the subjects bases this average over the last five years whereas another subject bases the average over the last three years. Conceptually, the subjects are similar in that they are both attempting to make projections about future events based on past events. However, the difference lies in the number of years of historical data used to make those projections. Thus, it becomes a subjective decision as to whether the subjects can be considered similar in their use of the output.

The disadvantages of the previous methods however do not negate their utility. The methods still provide some perspective on the similarity between the decision processes of two subjects, although it becomes necessary to determine the reasons for the dissimilarity between the subjects with respect to particular inputs and outputs that were not used. With this objective, three lists were prepared, one for each subject. The subjects were then asked, for each element on their respective lists, why they did not use the element. In general, the reasons given by the subjects were as follows:

1) Redundancy

Some other element that the subject had used, provided the same information as the element which he did not use. For example, one subject indicated that he did not use "appraised/debt" because it basically provided the same information as "appraised value per share".

2) Subsumption by another element

The element that was not used was already covered by an element that was used. For example, "assessment of reporting" was not considered as an element in itself but as part of "assessment of management".

3) Irrelevance

The element was not used because the subject considered it to be irrelevant to the analysis of oil securities.

## CONCLUDING REMARKS

It is stated in the introduction to this report that the objectives of this empirical study were to investigate the nature of the decision rules used by oil security analysts in their development of trading strategies for oil securities.

The goal of the study is met through the development of three expert systems which incorporate the decision strategies of the three subjects. Implementation of the decision strategies in the form of expert systems has made explicit the nature of the decision rules used by the subjects.

The conclusion of this study is that a degree of similarity does exist between the decision strategies of the subjects. Further, it is found that part of the differences in the decision strategies of the subjects is due to the subsumption of elements by the subjects. It should be recalled that this means, for example, that whereas one subject considers "assessment of reporting" and "assessment of management" as separate elements, another subject considers "assessment of reporting" as part of "assessment of management".

Finally, a logical extension of this study would be to determine the nature of the decision rules used by security analysts in other industries, for example, real estate securities.

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## APPENDIX A

FORM 1 : Factors Identified By One Of The Subjects During The First 3 Phases Of Knowledge Acquisition For Estimating The DISCOUNT FACTOR

| | USED | RANK | WEIGHT |
|---|---|---|---|
| A) PROJECTED 5 YEAR CASH FLOW GROWTH / EXPECTED CHANGE IN OIL PRICE | [ ] | (_____) | [____] |
| B) PROJECTED 5 YEAR CASH FLOW GROWTH | [ ] | (_____) | [____] |
| C) INTEREST AND PREFERRED DIVIDEND | [ ] | (_____) | [____] |
| D) DEBT / CAPITAL | [ ] | (_____) | [____] |
| E) ASSESSMENT OF COMPANY STRATEGY | [ ] | (_____) | [____] |
| F) ASSESSMENT OF COMPANY MANAGEMENT | [ ] | (_____) | [____] |
| G) RELATIVE PRICE/APPRAISED | [ ] | (_____) | [____] |
| H) COMPANY PRICE/APPRAISED | [ ] | (_____) | [____] |
| I) RELATIVE IMPUTED VALUE | [ ] | (_____) | [____] |
| J) COMPANY IMPUTED VALUE / INDUSTRY RULE OF THUMB VALUE | [ ] | (_____) | [____] |
| K) SHARE PRICE / PROJECTED 1 YEAR CASH FLOW | [ ] | (_____) | [____] |
| L) NORMALIZED CASH FLOW | [ ] | (_____) | [____] |
| M) POTENTIAL ADDED VALUE | [ ] | (_____) | [____] |
| N) MARKET FLOAT | [ ] | (_____) | [____] |
| O) HISTORICAL CASH FLOW GROWTH PER SHARE | [ ] | (_____) | [____] |
| P) EXPECTED DIVIDEND YIELD IN 1 YEAR | [ ] | (_____) | [____] |
| Q) ASSESSMENT OF COMPANY'S REPORTING | [ ] | (_____) | [____] |
| R) SHARE VOLATILITY | [ ] | (_____) | [____] |
| S) FINDING COSTS PER BARREL | [ ] | (_____) | [____] |
| T) OPERATING COSTS PER BARREL | [ ] | (_____) | [____] |
| U) BREAK EVEN COSTS PER BARREL | [ ] | (_____) | [____] |

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