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An Integrated Approach to the Appraisal of Investment Opportunities in Advanced Manufacturing Technology Using Expert System Techniques

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AN INTEGRATED APPROACH TO THE APPRAISAL OF INVESTMENT OPPORTUNITIES IN ADVANCED MANUFACTURING TECHNOLOGY USING EXPERT SYSTEM TECHNIQUES

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ABSTRACT

New and advanced manufacturing technologies now being developed offer greater scope for improved productivity and product quality. The analysis of the investment opportunities presented by these developments is of crucial importance to every manufacturing company. For any such analysis to be as complete and comprehensive as possible a range of complex factors needs to be considered.

However, investment appraisal methodologies employed by manufacturing companies have consistently fallen far short of the best available. This is probably mainly due to a lack of understanding of the various types of information needed in an investment appraisal, difficulty of access to that information and insufficient and/or incorrect use of available analytical tools such as forecasting and simulation. If discounted cash flow (DCF) techniques are to become more widely used then these potential problem areas need to be addressed.

This paper describes the progress made to date on the design and development of a computer system designed to provide a framework in which a more meaningful discounted cash flow analysis could be carried out. Possible solutions and their embodiment within a computer, using the tools and techniques of artificial intelligence where appropriate, is described. In particular , the role to the knowledge acquisition process is examined and the use of new rule induction algorithm, developed by the author described.

1. Introduction

New and advanced manufacturing technologies now being developed offer greater scope for improved productivity and product quality. The analysis of the investment opportunities presented by these developments is of crucial importance to every manufacturing company. For any such analysis to be as complete and comprehensive as possible, a range of complex factors need to be considered.

The implementation of AMT is of paramount importance if the lack of competitiveness of U.K. manufacturing industry against international competition, which has become obvious in recent years, is to be overcome. Approaches currently adopted to the financial justification of investment in AMT have consistently fallen short of the best available. But even if the current trend towards more widespread use of discounted cash flow (DCF) techniques continues, a number of crucial problems still remain.

2. Possible pitfalls in applying DCF techniques in manufacturing.

Most of these problems relate to accessibility to the various types of information needed in carrying out DCF analysis. So, even if a company is committed to such methods in principle, a number of possible pitfalls still exist.

1. What information is needed in carrying out a DCF investment appraisal in a manufacturing context?
2. How does one get access to this information?
3. What analytical tools are available in improving the reliability of this information?

3. What Information?

The information required falls into two basic categories:

1. Information needed in the compilation of cash flow profiles - this problem has been dealt with comprehensively and the IVAN software package provides a framework in which the cash flows associated with a proposed manufacturing project can be built up.

2. Information needed in the evaluation of a firm's cost of capital - in evaluating itscost and relative importance of the various sources of capital used to finance investments (equity, debt etc.) as well as an appropriate technique of transforming these into a discount rate which can be subsequently used in DCF analysis.

4. Access to the information

Meaningful access to the various types of information required can only be achieved by integration of the various data sources involved. These data sources could be manual, computer based or simply in someone's head.

As for estimation of the discount rate (above), the aim of this project is to provide managers in manufacturing with a computer based framework which integrates all data sources containing the information needed. The elimination of duplication could possibly be used as a measure of this integration. A soundly based system of structured analysis, which can be used for the logical representation of an existing information system, is essential if this objective is to be achieved.

5. Analytical tools

In the completion of cash flows, one is, by its very nature, making predictions with regard to future outcomes, none of which is known with certainty. In an attempt to overcome this element of uncertainty to some extent, scientific analytical tools should be used where possible. A number of distinct areas where such tools can be applied are as follows:

1. Forecasting of future demand
2. Manufacturing simulation
3. Costing

So it is envisaged that the output from these processes will be used as the input to a DCF financial justification system.

6. Other Points

It is intended that this system will be a complete working system, in its own rights, which could be used by companies appraising a proposed investment in AMT, thereby ensuring a more complete and integrated approach. In doing so, it would help in overcoming the lack of a strategic investment "culture", which is apparent at present in a a large number of companies.

The system will also act as a trainer and adviser for personnel involved in the capital budgeting decision making process, using the recently developed tools of artificial intelligence and computer aided learning, where appropriate.

7. Artificial Intelligence and Expert Systems

An expert system is a computer system which possesses a set of acts, heuristics or knowledge about a specific domain of human expertise and by manipulating these facts intelligently it is able to make useful inferences for the user of the system. These systems make use of rules of inference to draw conclusions or make decisions within defined areas. Their power comes from the presence of facts and procedures which have been identified by human experts as the key components in the problem solving process.

In recent years, developments in computer hardware and software have facilitated the use of expert systems in industry. A number of distinct types of possible expert system applications within investment appraisal can be identified [1].

1. The embodiment within a computer of knowledge which is essential if an investment appraisal is to be as complete and comprehensive as possible - Relevant detailsabout the corporate taxation system, the costs of the various sources of funding and the best available techniques are examples of such information.

2. The provision of check-lists - Such check-lists are very useful in preparing investment proposals due to the large number of possibly relevant factors which need to be considered. An expert system, in reliably posing all relevant questions, can act as a checklist, reminding the user or all the factors to be taken into account.

3. The provision of heuristic rules of "rules of thumb" - This involves the giving of advice based on procedural tips or incomplete methods of performing certain tasks. Thus, the expert intuitive judgement of management can be stored and re-used. The basis of decision making can be formally recorded and the decision making process made more consistent as a result.

To ensure that the tools and techniques of artificial intelligence and expert systems are used effectively it is essential that a detailed study of the main phased within the knowledge engineering process is undertaken.

This study takes the form of an examination of the relevant techniques of

1. Knowledge Acquisition
2. Knowledge Representation

7.1 Knowledge Acquisition

INTRODUCTION

The rule induction process involves the creation of a rule, which can subsequently be used in an expert system, form a set of examples. The information embodied in the examples is generalised to cover many cases not specified by that example set. The induced rule is usually a very compact representation of the information contained in the examples.

Rule induction can be a very valuable tool in the knowledge acquisition process as domain experts are often likely to be able to express their knowledge in the form of declarative examples rather than procedural rules. Two main families of systems based on the ID3 [2] and AQ (for example [3]) algorithms have had some success in areas as diverse as soya bean diagnosis thyroid diseased and chess end-games.

POSSIBLE PITFALLS

However, in most real world problems incomplete and noisy examples are a fact of life. This may be due to measurement errors, recording or transcription errors, mistakes made by the expert etc., or to an inadequate domain description language. Many methods, designed to the simple removal of erronious examples to complex rule trucation techniques.

In addition, experience has shown that existing algorithms are particularly unsuitable for use in the development of knowledge-based production management systems (KBPMS) for a variety of reasons [1], including the following:

1. Manufacturing systems are complex.
2. Planning necessarily involves predicting future outcomes, none of which is known with certainty.
3. Access to necessary information is often difficult.
4. A large number of ways of approaching problems often exist.

What is required, therefore , is an algorithm which takes these potential pitfalls into consideration, thereby providing knowledge engineers with a useful tool for the acquisition of production management knowledge.

THE ALGORITHM

INTRODUCTION

The algorithm presented here is a modification of the ID3 algorithm [2]. It is designed for use with large sets of examples. Essentially its structure is as follows:

- Select a subset (window) of examples at random
- Generates a rule for this window
- Find exceptions to this rule among the remaining examples
- Generate rule for window of examples plus exceptions

This basic process has been shown [2] in converge rapidly and allow correct rules to be induced in time linearly proportional to the number of examples.

Overview of System

The example set comes from the expert and represents an expression of his/her knowledge in the form of examples.

The factor (c), which represents the conclusion (or outcome) of the problem, has n possible values (c ..c_n). The outcome will depend on the values of m factors (or attributes). Each attribute can take on j possible values, a', ..a'j, where i is the number of the attribute.

The size of the initial subset (or window) of examples is determined by the knowledge engineer and will depend on many factors including the size of the original example set. This window will be an array, E, of similar structure to the original array.

The problem now, is to generate a rule for this window of examples and subsequently for the complete example set.

Rule Generation

The actual rule generation process consists of the following steps:

- Find the L< which has the lowest value
- Divide E into 1 arrays (E,..E_{1k}) where E contains all examples with attribute a
- FOR each array (E_1 ..$E_{1k,}$)

IF array is of dimension 1 x (m + 1)
OR all conclusions and all but one attribute in array are identical
THEN form rule
ELSE
REPEAT
Divide arrays further on the basis of the attribute with the lowest number of occurrences
UNTIL
Array is of dimension 1 X (m + 1)
OR all conclusions and all but one attribute in array are identical
OR an example is discarded due to a low certainty-weighting index

The above represents a simple form of rule induction with the addition of the idea of a certainty-weighting index [discussed in [4]. The assumption that each time a rule is formed a check for consistency between the newly formed rule and existing rules is carried out is implicit.

7.2 Knowledge Representation

There are several different approaches available to knowledge representation (frames, production rules etc.). Work is currently being undertaken to determine which, if any, of the approaches are appropriate to the investment appraisal problem domain. Current work suggest that a hybrid system based on a number of the standard systems might offer the best chance of success.

8. Forecasting

Accurate forecasting of product demand is essential if the management of a manufacturing system is to be as effective as possible. In virtually every production planning decision some kind of forecast needs to be considered. In recent years the greater uncertainty in economic and financial affairs, caused in part by the rapid rate often technological development, has sharpened the focus on the need for improved forecasting.

An expert system which recommends an appropriate forecasting technique has been developed (FOREX) using the CRYSTAL shell.

Sixteen commonly used forecasting techniques were considered (see TABLE 1). It was seen as important that knowledge about a range of both qualitative and quantitative methods be emobied in the expert system in order to ensure widespread applicability. With regard to quantitative techniques both time series and causal models were investigated. It can be seen form TABLE 1 that the methods considered varied from the very simple (e.g. using the demand figure for the previous periods) to the quite complex (e.g. econometric modelling).

Type of Technique	Technique
Qualitative	The Delph method
	Market Research
	Panel Concenus
	Visionary forecast
	Historical analogy
Time Series	Past Average
	Figure for Last Period
	Moving Average
	Exponential Smoothing
	Box-Jenkins
	X-11
	Trend Projection
Casual	Regression
	Econometric model
	Input-Output model
	Life Cycle analysis

TABLE 1 - Forecasting techniques considered in the study.

Many complex and often inter-related factors need to be considered in choosing an appropriate forecasting strategy. TABLE 2 outlines the general classification of those factors considered in this study, as well as describing in more detail what is meant by each one.

FACTOR	EXPLANATION
Accuracy of forecast	Is accuracy considered to be of importance?
Turning point identification	Is the identification of turning points considered to be of importance?
Ease of understanding	Is ease of understanding of the forecasting methodology and interpretation of the forecast considered to be of importance?

Time Span	What is the time span of the forecast? immediate term (hours) short term (days) medium term (weeks) long term (months)
Time horizon	What is the time horizon of the forecast? Short range (0-3 months) medium range (3 months - 2 years) long range (over 2 years)
Cost of forecast	What financial resources are available in making the forecast?
Availability of data	What relevant data are available? demand patterns for previous periods market research reports factors influencing demand patterns similar product information in-company product and service flows
Data characteristics	What characteristics are apparent in existing data? Secular trends Seasonal variations Cyclical variations irregularities

TABLE 2 - Factors influencing choice of forecasting technique

Once the factors influencing the choice of technique have been identified, the situations in which a particular technique is appropriate need to be established. The nature of any situation can be assessed by examining the status of the relevant influencing factors (TABLE 2).

To achieve this, each of the sixteen techniques under consideration (TABLE 1) were examined in turn. Each was examined in terms of the influencing factors with a view to establishing its appropriateness in a range of situations.

A number of knowledge representation schemes were evaluated in view of the nature and format of the acquired knowledge. These included production rules, frame-based representation and semantic nets. It was decided to use production rules primarily because the knowledge could be easily and accurately represented in this form.

9. Conclusions

The type of approach outlined in this paper provides a logical, structured and coherent approach to manufacturing investment appraisal.

The rule induction algorithm allows much knowledge which was previously unusable to be embodied in an expert system. The forecasting module demonstrates how a working system can be created and how it can be used.

The use of this approach should prove to be of major benefit to managers responsible for capital budgeting.

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