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**Integration of Decision Support Systems and Expert Systems in Finance:
Common Design Issues and
the Case of Money Market Preferred Share Bidding**

**by
Douglas A. Macklem, BCS (Honours)**

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements of
Master of Management Studies

Carleton University
School of Business

April 20, 1990

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INTEGRATION OF DECISION SUPPORT SYSTEMS AND
EXPERT SYSTEMS IN FINANCE:
COMMON DESIGN ISSUES AND THE CASE OF MONEY MARKET
PREFERRED SHARE BIDDING

Submitted by Douglas Macklem, B.C.S.
in partial fulfillment of the requirements for
the degree of Master of Management Studies.

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Abstract

This study examines the integration of decision support system (DSS) and expert system (ES) technologies to support financial decision making from a two levelled perspective. First, the assessment of common dimensions for DSS/ES design in financial decision making provides generality encompassing multiple applications. Secondly, an in depth examination of a particular financial problem, namely Money Market Preferred (MMP) stock bidding, facilitates the design and development of a DSS/ES computer-based prototype to support the bidding decision. This investigation involves the detailed examination of issues concerning the integration of the two technologies. The chosen problem of MMP bidding encompasses all salient characteristics of a typical financial decision faced by an investment or money manager.

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Part 1 Research Overview

1. 1 Introduction

“As the world grows more complex, we must use our energy, food and human resources wisely; we must have high quality help from computers to do it. Computers must help, not only by doing ordinary computing, but also by doing computing that exhibits intelligence” (Harmon and King, 1985). In today's ever-changing world, society is faced with problem-solving and decision-making based on incomplete, uncertain and even contradictory information; ‘intelligent computing’ or Artificial Intelligence (AI) and Decision Support Systems (DSS) offers the promise to harvest remarkable developments of computer science and computers to make all of us more efficient.

Decision Support System (DSS) and Expert System (ES) technologies represent an exciting, computer-based development with potential applications to financial decision-making. The complexity, time pressures, knowledge requirements and the overall importance of many of these financial decisions provide motivation and justification for an investigation of the effective applicability of DSS/ES technologies to these domains. An evaluation of conceptual commonalities among these applications will provide guidance in the development and design of DSS/ES systems for financial decision making. Specifically, the development of new innovative financial instruments often require specialized decision-making approaches or expertise; the introduction of ‘Money Market Preferred’ stock (MMPs)¹ with the associated ‘Dutch-Auction’ set dividend rate serves as a prime example of such an innovation.

The specific area of MMP bidding was selected due to the overall decision complexity on one hand and the existence of models and modelling requirements on the other. DSS, in general, provide processed and prepared information enabling model creation, testing and verification. ES technology often has models/theories incorporated within the system, combined with the necessary verification which enable these systems to deal with complexities inherent in a particular problem domain. Thus, a thorough examination of issues involved in the application of DSS/ES technology to MMPs presents the opportunity to investigate the integration of DSS/ES technology to this specific problem in an attempt to design effective computer-based support for the MMP bidding decision.

1.2 Research Decomposition

This research is comprised of two components.

First, the research assesses and attempts to define some overall commonality for DSS/ES system design for financial decision making problems. Cases gleaned from financial literature and existing commercial software packages form the basis for this component of the research. This element attempts to address the following research question: What common dimensions form a framework for DSS/ES system design addressing financial decision making problems?

Secondly, the research examines the feasibility, support features and modelling requirements necessary to support the MMP bidding process. This evaluation results in the development of a computer-based prototype; the main goal being to examine the integration of DSS/ES technologies while attempting to model a realistic financial decision-making problem. The development phase of the prototype design provides an assessment of difficulties and barriers inherent in effective design implementation of integrated DSS/ES systems for a financial decision making environment. This development allows the research to address further questions: a) Where does the MMP problem fit along the common dimensions developed in the first component of the research? b) What features must be incorporated in an effective DSS/ES system design for the MMP bidding problem? c) What barriers or difficulties exist to restrict the implementation of an effective integrated DSS/ES system design for such a problem, and consequently for other financial decision-making problems of similar nature?

Part 2 DSS/ES Design Dimensions

The examination of commonalities in DSS/ES design for financial decision making requires a step-by-step progression of analysis to facilitate the proper development of design principles. First, a general understanding of issues surrounding both DSS and ES technologies and the integration of the two, must be provided as a basis. Secondly, an overview of DSS/ES developments in the financial industry lends perspective to application areas. Thirdly, a discussion of fundamental system dimensions serves as a foundation for analysis of commonalities between individual applications within financial industry sectors and among cross-sector applications. The final stage utilizes these system dimensions to position financial DSS/ES cases and industry sectors to derive commonalities and differences in design.

2.1 DSS/ES Technologies: Fundamentals and Integration

The technologies of DSS and ES have evolved along parallel but largely independent paths. Although both focus on the activity of human decision making, each has fundamentally different approaches to computer-based support: DSSs operate as support devices to decision makers, while ESs function largely independently as a consultant, adviser or replacement for the decision maker. The commonality of purpose and the differentiating characteristics of these two technologies provide the potential for a synergistic combination of DSS/ES (Turban, 1988).

2.1.1 Decision Support Systems

A variety of definitions exist for DSS with no consensus among practitioners in the field as to the accepted meaning of the term. In the 1970s, the early definitions focused on the input to the process, while the more recent definitions have incorporated the output of the process, specifically the quality of decisions through recommendations, analysis and evaluation. Due to the lack of consensus of an accepted definition of DSS and the fact that practitioners from varying backgrounds view DSS differently, the technology is often defined in terms of its overall characteristics. However, there is obviously no agreement as to the exact capabilities of DSS.

The definition which will serve as a basis for this research is provided by Efrain Turban (1988), quote: "a DSS is an interactive computer based information system that utilizes decision rules and models, coupled with a comprehensive database and the decision makers own insights, lead-

ing to specific implementable decisions in solving problems that would not be amenable to management science, optimization models per se.”

Turban (1988) also outlines an ideal set of DSS capabilities as: a) provides support for decision making in semi-structured and unstructured situations through the combination of interactive human judgement and computerized systems, b) allows multi-level managerial decision making support, c) supports all phases of the problem solving process: intelligence (problem search), design (alternative generation) and choice (appropriate action), d) is easy to use: user interface issues are of increasing importance if management is to use these tools , e) enables effectiveness, not efficiency: the important function is to facilitate a correct decision rather than a quick yet faulty approach, f) allows the human to remain in control of the machine and g) is adaptable and flexible as defined on several basis: the ability to support both group and individual decisions, support of evolutionary usage where the system is expanded and improved over time, support of several decision styles and interdependent or sequential decisions. Most DSSs do not possess all of these characteristics, but outlining these potential capabilities of DSS gives background and perspective for the technical aspects to follow.

An effective DSS is comprised of three major components: *data management*, *model management* and *dialog management* . Figure one presents this conceptual schema of a DSS from a software component stand-point (Turban, 1988). Table 1 provides an overview of the purpose and functionality of each of the components.

Conceptual Model of Decision Support System

Figure 1

Building Decision Support Systems

The capabilities incorporated in DSS require a differing development methodology to that employed in traditional electronic data processing (EDP) or management information systems (MIS). The decision making focus combined with changing information requirements, lend DSS to be developed in an iterative, adaptive or evolutionary manner. "Small iterative systems should be built, used and modified as needed" (Hogue & Watson, 1984). A variety of factors influence the development approach along the continuum of system development methodologies: at one extreme is the System Development Life Cycle (SDLC) approach traditionally advocated for computerized systems, while at the other extreme is the purely evolutionary approach of prototyping recommended for DSS development. Organizational, environmental and technical factors all fundamentally influence the choice of DSS development method. Table 2 presents a summary of influential factors on development methodology, including a direction of influence.

2.1.2 Artificial Intelligence and Expert Systems

AI and ES represent another approach to computer-based decision making. DSS perform supportive and interactive functions as a component of human decision making; ES function primarily in an advisory role in an attempt to replicate the human decision making capabilities.

Artificial Intelligence is defined by Chithelen (1987) as: "the capability of a machine to perform tasks associated with human intelligence and reasoning." Winston (1984) views AI as: "the study of ideas that enable computers to be intelligent." Intelligence implies the ability to acquire and apply knowledge, to reason, to manipulate objects in the physical world, along with an amalgam of information-representation and information-processing talents. In an attempt to understand the principles that make intelligence possible, the field of AI has been subdivided into three relatively independent research areas: natural language processing, robotics and expert systems. (See figure 2).

Fields of Artificial Intelligence

Figure 2

For this paper, the area of focus within AI is ES. Feigenbaum of Stanford University (Harmon & King 1985) sees an *expert system* as: "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. Knowledge necessary to perform at such a level, plus the inference procedures used, can be thought of as a model of the expertise of the best practitioners of the field." These programs can be viewed as performing tasks that would be considered intelligent if executed by a human expert.

The term 'expert systems' was coined by AI researchers when they developed the first large systems, which were truly intended to function like human experts; thus the implication of 'expert'

is appropriate. However, knowledge engineers realized that one could build small, useful systems that were not modelled on human experts and thus did not contain the knowledge of an expert. The terminology adopted for these systems is *knowledge systems* to avoid the implication that such systems always capture the expertise of an expert.

Components of an Expert System

If a computer is to emulate human experts, it must perform tasks associated with expertise: the ability to consult with others, to ask questions, to explain reasoning, to justify their conclusions in an understandable language and be able to function with incomplete and uncertain data (Harmon and King 1985). In attempting to simulate human behaviour, AI researchers have developed a general ES architecture which serves to partition the expert system. ES has three major components: a) the *knowledge base*, b) *inference engine* or *control mechanism* and c) the *user interface*. (See figure 3, Shane 1987). Each component will be discussed briefly below.

Components of an Expert System

Figure 3

Knowledge Base: The knowledge base is the heart of every expert system, the long-term memory containing the facts and heuristics that embody the expert's knowledge. The *facts* constitute a body of information generally agreed upon by experts in the field. The *heuristics* are "little-known rules of good judgement, of plausible reasoning and good guessing, that characterize expert level decision making in the field" (Chithelen 1987). The performance of an expert system is largely a function of the size and quality of its knowledge base. *Working memory* is 'short-term memory': that part of long-term memory that is currently active; for ES applications it contains facts pertaining to a current problem situation.

Representation of the knowledge within the knowledge base is a key concern in ES design. To represent knowledge, one must communicate descriptions or pictures that correspond, in some pertinent way, to the state of the environment. In AI, the concern is to generate descriptions in such a way that an intelligent machine could come to new conclusions about its state of the world by formally manipulating these descriptions (Brachman and Levesque, 1985). Several alternative knowledge-representation schemes have been proposed and implemented by AI researchers. Some prevalent schemes for knowledge-representation include: production rules, semantic networks, object-attribute-value triplets, frames, logic-based notation and functional representation. For description and detail of these approaches, refer to Harmon and King (1985), Winston (1984), Holsapple (1987) and Brachman and Levesque (1985). Regardless of representation, each scheme involves rules in some form at some level.

Several representations have been developed by AI researchers; none of which is a 'perfect' knowledge representation scheme. All schemes have advantages and disadvantages. Perhaps the best scheme is a combination of two or more methods.

Inference Engine and Control Strategies: Human experts perform a great deal of reasoning and draw from strong inferential capabilities when solving problems in their field of expertise; for an expert system the inference engine component performs these duties. In fulfilling these responsibilities, the tasks of an inference engine can be separated into two distinct areas (Harmon and King, 1985): a) the examination of facts and heuristics of the current problem in working memory attempts to draw new conclusions towards a solution and b) determines the ordering of inferences and hence structures the consultation with the user to obtain necessary information. "An impor-

tant component of knowledge-based systems is a knowledge explanation facility. User acceptance is enhanced if the system is able to describe the applied reasoning processes. This facility can provide direction on how to use the analysis models and proper interpretation of results" (Duchessi et al, 1988).

Several key issues must be dealt with to ensure the greatest possible efficiency and effectiveness of the inference engine as it performs its tasks in a particular domain. Table 3 examines relevant issues involving inference engine design.

User Interface: The third and most widely varying component of an expert system is that element most visible to system users: namely, the user interface (UI). The UI is concerned with acquiring information from sources external to the expert system (i.e. the expert or financial reports) for further interpretation by other internal components of the expert system. Fundamental issues in this area include: user-friendliness, mouse-driven versus key-board driven input, and menu-based versus command-line based systems. For an expert system, the concern is not only for the original knowledge structure on which the system was built, but also the steady stream of new information needed to keep the system current and growing (Silverman, 1987).

Customarily, advanced ES user interfaces evolve around the AI field of *natural language processing*. These language-understanding components of the ES facilitate communication between the user and the system at a level readily comprehensible by humans. With these interfaces, the maintenance of the knowledge level of an expert system requires frequent, time-consuming human interaction; this seems unrealistic in today's vastly complex, fast-paced, resource-constrained environment. The knowledge-acquisition process can be a limiting factor for ES development. Other than direct human input, access to data can be provided through *database* information, *human-readable* information (i.e. printed reports) and *networking* with other computer resources (Reference: Silverman, 1987).

Building Expert Systems

The complexity incorporated in ES technology requires that specialized techniques, software tools and languages be available for their feasible development. The development techniques and building blocks can be viewed in a layered form; an examination of the different layers of

computer software provides a perspective from which to examine ES development. See figure 4 (Harmon and King, 1985) below.

Levels of Software Between Human Problems & Computer Hardware

Figure 4

The three lowest levels of *computer hardware*, *machine language* and *operating system* are far too primitive for the development of knowledge-based systems. The *high-level languages* plateau provides the first practical instrument for ES development.

Programming Languages : Even at the fourth level of high-level programming languages, significant programming effort by an experienced programmer would be required, depended upon the implementation language. *Traditional* problem-oriented programming languages such as Pascal, Ada and C, are not suited for expert system development. Conversely, the *symbolic manipulation languages* of Lisp and Prolog have constructs which simplify the manipulation of symbols, and as such are more appropriate for ES systems (References: Harmon and King, 1985; Winston and Horn, 1984; Shafer, 1988). Both are based on predicate calculus logic. These programming languages provide the ultimate in flexibility to customize programs to their exact needs. However, their representation of knowledge and knowledge-based accessing methods leave much to be desired. Thus, the next levels of *knowledge-engineering environments* and *tools* evolved to simplify the complex task of ES development, commonly classified as ES tools.

ES Building Tools : Just below the actual knowledge-based expert system lie the two highest levels of development software: *knowledge-engineering environments* and *tools*. Both of these layers provide facilities which enhance expert system building capabilities. In the case of *environments*, there is provision for a knowledge-engineering language, together with a set of predefined routines to aid the developer. *Tools* have these features and also provide knowledge-representation and reasoning strategies internally.

These two types of knowledge-engineering instruments can be further classified into two categories: *skeletal systems* and *general purpose systems* (Smith, 1987). *Skeletal systems*, coined expert system 'shells', are systems which are stripped of all domain-specific knowledge, leaving only the knowledge-engineering building blocks of the inference engine and support facilities. These lack flexibility and generality, but facilitate faster and easier development. Conversely, *general purpose systems* provide more control over data access, searching and input/output mechanisms. Often, editors and specialized routines are provided. Various knowledge-representations and control structures may be supported.

The tools and environments can be differentiated along other dimensions: namely, the *consultation paradigm(s)* supported, and the *scale (size) of development* project for which the 'tool' is intended (For detail see: Smith, 1987; Chithelen, 1987; Holsapple, 1987; Harmon and King, 1985). Tables 4, 5 & 6 present a brief overview of representative development system alternatives categorized along the size dimension.

When is Expert System Technology Applicable?

With every new and exciting technological development comes the over-riding optimism for applicability and success; caution must be exercised to assess if and where the new technology might be fruitfully applied. This is also true regarding expert systems.

Silverman (1987) provides a filtering mechanism for ES applicability, outlining four criteria for the appropriate application of ES technology: *relevancy, feasibility, optimality and success-orientation*; table 7 provides a summary of Silverman's appropriateness perspective.

2.1.3 Integration of DSS/ES

Several fundamental differences between DSS and ES technologies could lend great potential to their integration. The contrast between the two technologies extends from basic underlying objectives to functionality provided by them (Turban, 1988). Some of the differences follow.

a) The objectives of DSS are to support the decision maker, while the ES seeks to replicate the human adviser. b) The problem area attacked by DSS is broad and complex; in contrast, ES is restricted (in the short-run) to a more structured and narrow domain; the result being that DSS deals with ad hoc, unique situations, while ES provides advice on a repetitive problem area. c) The database of DSS contains facts; while the counterpart for an ES, the knowledge base, has not only factual elements but also procedures for approaching the problem. d) An ES, by definition, has reasoning capabilities; this characteristic is not inherent in a DSS. A related issue is the powerful explanation facility provided by an ES; DSS has only limited explanation capabilities. e) When a DSS is involved, the user has full control over system operation; in contrast, an ES directs the consultation and queries the user to acquire necessary factual information. f) ES has an inherent closed system assumption implying that the problem domain is circumscribed within the system and functions are confined within these boundaries. Conversely, a DSS is an open environment to provide flexibility and adaptability to the evolving needs of the user. The final and most fundamental difference lies in the analysis' strengths incorporated in the two technologies; the model base and database structure of DSS is best suited for quantitative modelling whereas the inferential capability inherent in the structure of ES lends itself well to qualitative reasoning or symbolic processing.

DSS and ES both have distinct advantages in problem solving for certain domains which can produce synergistic results when combined; the joint effort of a combination could produce better results than either approach independently (Turban, 1988, Jelassi et al. 1987). DSS typically gives full control to the decision maker in all aspects of the decision making process and therefore is susceptible to human biases evidenced in psychological literature; an ES is free of many of these biases if the system is designed properly. Each component of the overall structure of such a system would draw benefits from both technologies. A survey of the benefits accrued from an amalgamated system is presented as follows:

a) *Database and Database Management System (DBMS) Improvements*: The construction, operation and maintenance of the DBMS is enhanced, along with the provision for access to large databases through the attributes of ES technology. The DSS provides a database directly accessible to the ES. b) *Models and Model Base Management System (MBMS)* : For this component, DSS technology contributes standard models and an initial problem structure ; the potential exists for the storage of specialized models constructed by experts. The direction provided by ES can improve the model selection and add judgemental elements to these models. Sensitivity analysis, alternative generation and simulation building, together with an incrementally modifiable problem structure, all benefit from the addition of the ES technology. c) *Interface Considerations* : The addition of natural language processing offered by AI technology, often incorporated within ES, enables the user to interact with the system in a user friendly manner through common language commands. The extensive explanation capability of ES further improves user/machine interaction. The DSS allows alternative presentations to suit individual cognitive styles.

All fundamental components of an amalgamated system benefit as a result of the integration. The ability of the synthesized system to incorporate strong quantitative modelling capabilities through the DSS component, and qualitative or symbolic reasoning provided by the ES, lends powerful extensions to both technologies. Recent developments have indicated the increased interest in DSS/ES integration. Expert databases (Kerschberg, 1986, 1987) and integrated technology tools such as Guru serve as prime examples.

Current Alternative Strategies for the DSS/ES Combination

Several strategies have been proposed toward the integration of ES/DSS; these approaches involve supplementing the ability of one technology with the other. The fundamental approaches involve the addition of ES technology to a traditional DSS.

Two basic alternatives have been outlined by Turban (1988). The first alternative proposes the addition of an ES component to each of the four DSS components: database, model base, interface and user; this approach expands the system capabilities as described in the previous section. The second paradigm views an ES as a totally separate component of the DSS; output or input is directed to the appropriate component. In this way, the DSS can support an ES or vice versa, facilitating the

partitioning of the decision making process. The evolution toward integration of the two technologies will lead to a more active and consulting role for the traditional DSS (Jelassi et. al. 1987).

2.2 Financial Applications: A Current Overview and Desirable Extensions

Financial industry analysts see great potential for DSS/ES technologies as the industry abounds with judgemental decisions based on heuristics. Actual demand has been sluggish: as of 1986, only 7% of expenditure on AI technology stemmed from the financial industry (Chithelen, 1987). However, as of June 1987, the financial industry had advanced expenditures to become second only to the aerospace industry. The relatively slow spread of ES throughout the financial community seems odd considering that insurance, banking and brokerage houses were among the first to computerize on a massive scale (Lovett, 1987). Part of the explanation lies in the fact that IBM machines overwhelmingly dominate the community, and until recently IBM has been hesitant to offer many AI products. Consequently, many potential users have been deterred by the incompatibility and cost concerns of a largely, untested technology (Chithelen, 1987).

A survey of current DSS/ES development projects within the financial industry will serve as a foundation for an analysis of strengths, weaknesses and commonalities in approaches to financial problems employing DSS/ES technology. Potential commonalities will permit positioning of specific problems in the context of financial decision making characteristics, and will be used to characterize the MMP bidding problem detailed in the second component of this thesis. This section utilizes a progressive derivation approach toward the development of DSS/ES design dimensions for financial decision making. First, overall DSS/ES development efforts within the *banking, investments, corporate finance, accounting and insurance sectors* will provide a generic overview of the area under study. The stepwise derivation will continue through a detailed case-based analysis of DSS/ES design within these sectors. This second stage of analysis will permit the formulation of intra-sector and cross-sector commonalities and differences in effective DSS/ES design.

Banking : Two notable development projects within the area of credit assessment warrant discussion: Loan Analysis Support System (LASS), and Authorizer Assistant. LASS is an application of ES technology to support commercial loan analysis (Duchessi and Belardo, 1987). The analysis process involves the identification and evaluation of the forces and types of risks to which the lend-

ing institution is exposed, thus requiring an in depth understanding of the five C's of credit: character, capital, capacity, collateral and conditions, as well as knowledge regarding the applicability of financial modelling techniques. *Authorizer Assistant* is a successful expert system currently in use at the American Express Company (AMEX). The system analyses credit data to fine tune the customer selection process (Lovett, 1987; Friedland, 1988), and assists credit officers in accessing as many as thirteen different databases before a decision regarding credit approval is rendered (Chithelen, 1987).

Investments: The key disciplines of portfolio management/optimization and financial planning lend themselves to ES technology; these areas require substantial judgement and specialized expertise in rendering appropriate decisions.

a) The *portfolio management/optimization discipline* has several prime applications: Folio is the best known. Portfolio Management Investment Decision Support System (PMIDSS) and Personal Financial Decision Support System (PFDSS) present extensions to the customary approach. *Folio* is a traditional rule-based system, which extracts client information from an interview and records these preferences; the system then makes recommendations regarding the optimal portfolio that meets the client's objectives (Smith, 1987). *PMIDSS* supports the interactive decision-process for an investment adviser interviewing a prospective investor. Financial areas covered by this expert system include stocks, bonds, real estate and cash equivalents, each of which incorporate a different knowledge-representation scheme. *PFDSS* advances new ideas for the use of expert systems for portfolio management (Shane, Fry and Toro, 1987). This system employs two expert systems which share data in order to provide a flexible approach. One expert system has knowledge regarding external environment conditions and their effects on the appropriate investment opportunities. This knowledge base modifies the rules of a second expert systems which pertains to the client specific information.

b) *Financial Planning* developments centre around 'PlanPower', an expert system that attempts to model decisions in the intricate environment. The system takes comprehensive client information, analyses the circumstances and produces written documentation for the recommended financial course of action. Several prototypes were part of the iterative development process, with the resulting system taking an object-oriented approach with backward chaining.

Corporate Finance: Capital budgeting is the sole application in the literature surveyed. *Decmark*, developed in 1983 (Silverman, 1987) uses rules elicited from the perspective user and then applies these rules to a class of projects to arrive at a recommendation regarding that project. Myers (1988) discusses a recent development in this area where the system functions in a consultative paradigm.

Accounting: The two areas within accounting which have received considerable attention from AI researchers are *auditing* and *tax accounting*. Most of the ES applications within the accounting field are still confined to the prototype stage. *TaxAdvisor* is the only accounting ES application currently in commercial use employed to assist attorneys with tax and estate planning for clients with large estates (Smith, 1987). *Auditor* is a prototype accounting ES application, intended for use in determining 'bad debt' allowances (Smith, 1987; Silverman, 1987).

Insurance: Equitable Co. has developed an underwriting ES application to aid inexperienced employees in this complex area (Lovett, 1987). There were interesting side benefits for the experts themselves: in the compilation of rules, the ES project helped the underwriting experts to crystallize their thinking and made them aware of inconsistencies in their approaches. Table 8(a) and 8(b) presents a survey of representative ES development projects encompassing the five fields of finance surveyed.

Many financial decisions require flexible quantitative modelling well suited to the capabilities of DSS, while dealing with complex qualitative reasoning, a strength of ES technology. Often quantitative model results guide the qualitative reasoning process. Hence the discipline of finance is an excellent context in which to examine the integration of the two technologies.

2.2.1 DSS/ES Design Motivations, Significance and Methodology

"ES is about to transform the financial industry ... , they are blossoming out of the prototype phase and will soon have a major impact on the profits of insurance companies, commercial banks and brokerage firms" (Friedland, 1988). However, to date each development seems to have been taken as a special case. There has been little focus by practitioners and/or academics on the possible commonalities in design of such DSS/ES systems within broader areas. A motivation for the design component of this research is to investigate the possibility of employing a more generic approach to DSS/ES design within the area of interest: financial decision making. This integra-

tion/synthesis is necessary for the proper application of DSS/ES technology to a wide variety of financial problems. Moreover, the development of common dimensions for financial applications has the potential to aid managers in the industry to understand the fundamental components of DSS/ES system design for financial problems and requirements necessary to develop a DSS/ES. Design commonalities will also assist in the positioning and characterization of specific problems; this ability is important to the study of the MMP bidding problem constituting the second component of the thesis. These criteria could also guide the software selection process and the choice of developmental methodology (internal versus external development).

The evaluation of common dimensions relevant to DSS/ES design for financial problems is drawn from two fundamental sources: a) a survey of available pertinent financial literature involving DSS/ES system design and development efforts and b) an analysis of commonalities and differences gleaned from a limited number of software packages from the security selection domain. The former source involves an in depth analysis of existing financial applications discussed in financial literature: a case-oriented analysis for similarities and differences in design. In the completion of the latter component, a letter was sent to seven software vendors who sell products in the stock/option selection area, requesting design information and possible demo material. (See appendix 1 for copy of letter). The companies chosen for this sample, with the applicable products, are shown in appendix 2; examples of areas covered include portfolio management, stock selection and option selection. The software package information elicited from the vendors were evaluated to determine overall similarities and differences in design (e.g. the data requirements and communication ability), facilitating analysis of common generic dimensions.

2.2.2 Design Dimension Results: Cases and Software Package Analysis

2.2.2.1 Financial System Dimensions: A Basis for Analysis

An examination of the fundamental components and corresponding characteristics of the financial decision making process will provide an overview of important issues to be considered for DSS/ES applications in this area. The decision making process could potentially be decomposed into characteristics or dimensions of analysis to provide perspective for proper design. The derivation of potential common dimensions will serve to provide a level of generality in the application of DSS/ES technologies to financial decision making problems.

The complexity and diversity of financial decision making problems require consideration of characteristics which can be viewed in terms of continua allowing more flexibility to encompass a wider range of problem situations. Several key characteristics of financial problems can be analyzed from this perspective and present the opportunity for comparative/commonality analysis. A discussion of the elements involved in these continua will be provided below. Dominant classification dimensions include: a) data dimension, b) knowledge dimension, c) evaluation/analysis dimension, d) output dimension and e) DSS/ES emphasis.

a) *Data Dimension*

Every decision must have 'raw material' data which are the fundamental elements for making a decision. This data dimension parameterizes relevant characteristics with respect to information requirements for successful decision making within the financial domain. Several components warrant consideration within this element; each can be scrutinized along continua which together characterize the attributes of essential data. Four fundamental continua will be discussed, namely: source, volume, complexity and longevity of data.

The *source of data* involves the location of relevant information for making the decision before entry into a computer-based DSS/ES. Extremes along this continuum are: direct-user input and external database access. A combination of these two styles is feasible and prevalent.

The *volume of data* necessary to reach a successful decision is an essential concern with respect to hardware requirements and processing difficulties. Financial problems present a diversity of data sets: from small structured data sets, through mid-sized requirements, to large, broad databases necessary for some selection decisions (ie: stock selection).

The *complexity* associated with the essential data incorporated in the decision is a basic design consideration for computer-based DSS/ESs. Financial decisions range from solely accounting-based financial numeric input, to numeric and textual scales, and finally to free form qualitative alphanumeric elements.

The *longevity* attributes associated with data with a decision making system encompasses two distinct issues: the update cycle and the relevancy time frame of decision data. The *update cycle* concerns the frequency arrival of and change to relevant data; this continuum varies from real-

time applications, through point-of-use updates to static periodic updates. The *relevancy time frame* of data relates to length of time that data is considered as influential in the decision process. Points along this continuum include: the continuous augmentation of system data for more in depth analysis and the replacement of past data with more current, timely values.

b) Knowledge Dimension

The knowledge dimension delineates pertinent characteristics with respect to the techniques and inferencing procedures necessary for proper problem solution. Hence, knowledge for the purpose of this study can be defined as, 'the ability to apply relevant techniques and the associated inferencing and reasoning attributes to solve a particular problem'. With this perspective, an overall description of the knowledge dimension can be studied employing two continuum variables: knowledge state and knowledge structure.

The continuum of *knowledge state* pertains to the degree of variability associated with successful problem solution in the financial decision making domain. Static knowledge, which involves generally accepted solution techniques and inferencing patterns, lies at one end of the continuum. An intermediate knowledge status involves the incorporation of company specific heuristics (ie: threshold levels and indicators), and periodic updating of knowledge through inductive procedures. At the opposite end of the continuum lies dynamic knowledge structure characterized by evolving knowledge where changing, individualistic solution approaches dominate the problem domain.

The *knowledge structure* dimension characterizes the overall solution approach prevalent in a particular financial decision making domain. This continuum varies from component synthesis, where separate problem elements are combined to achieve a solution, to sequential stage analysis involving a linear progression or stepwise approach towards a final solution, and finally to symmetric alternative solution processing where similar processing is performed for alternative problem solutions to achieve the best overall solution.

c) Evaluation/Analysis Dimension

Raw data seldom represents solutions to diverse complex problems. The processing style and requirements necessary to transform initial data into an overall solution is an essential characteristic that should be examined across problem areas to suggest plausible commonalities.

Characterizing processing from the straightforward analysis to the most complex, in depth analysis serves as a excellent guideline for this examination.

A single continuum can represent alternative processing styles and/or requirements for a variety of problem domains. Several points can be envisioned along this evaluation/analysis dimension. At the straightforward end of the spectrum lies *mathematical computational model processing*, where fundamental mathematical formulae are employed to obtain the appropriate solution. Following these basic techniques, the *comparative analysis of cross industry and historical trend analysis*, common to many business applications, is positioned. At the next point along this continuum, *the screen/pruning processing style* filters alternative solutions to eliminate unsuitable contenders, thus reducing the size of the overall solution set. Next, *parameter variation analysis* performs systematic changes to problem parameters to estimate the total effect on the problem situation. At the complex end of the spectrum, *drill-down analysis* analyses a particular problem component in greater detail and at a more in depth level than initially required; this style is frequently employed for causal estimation.

d) Output Dimension

The result of a decision making process must be represented in design requirements appropriate for any computer-based system to facilitate business decisions. This output dimension outlines the broad alternative output schemes available for such systems. Three distinct approaches are feasible; *text/report generation*, where alphanumeric text is produced, describes system interaction; *graphics output* relays concise information from a visual context; *intermediate input for a larger system* involves system output serving only as a single component of a larger process and could necessitate a degree of communication between separate components.

e) DSS/ES Emphasis

DSS/ES technologies have contrasting capabilities and attributes which impact the appropriate combination of the two technologies for an effective problem solution. A perspective with respect to a suitable emphasis of these two technologies in a variety of problems has the potential to guide effective development efforts.

Two dimensions delineate significant factors for the determination of relative DSS versus ES emphasis for problems under study: automated versus human control, and knowledge dimension

coupling. *Automated versus human control* concerns the consultation control issue. A traditional DSS performs actions on the basis of human control; in contrast, a problem solved under a solely ES paradigm incorporates an automated control sequence. *Knowledge dimension coupling* describes the influence of the knowledge dimension on other problem dimensions. The knowledge inferencing and reasoning capability is encompassed within ES technology; DSS concentrates on the analysis evaluation dimension. A strong influence of the knowledge dimension on data, analysis and output structure indicates a strong ES component in problem solution; in contrast, independence of data, analysis and output components from the knowledge dimension signals DSS style construction.

A summary of the dimension-based analysis is shown in Figure 5. The connections between the knowledge dimension and the dimensions of data, evaluation/analysis and output, may vary in strength dependent upon knowledge control versus dimension independence.

Financial DSS/ES Dimension Schema

Figure 5

2.2.2.2 Financial Cases: A Detailed Decomposition

An in depth examination of DSS/ES application efforts within the financial domain serves to verify or suggest modifications to the fundamental financial system dimensions described above. To furnish further insight into commonalities for broader classes of financial decision making problems, the relevant cases from the financial literature and available software materials are segmented into the five pertinent financial industry areas previously outlined: *a) banking, b) investments, c) corporate finance, d) accounting and e) insurance*. The main focus of case examination is on the first two areas: banking and investments; synthesis of cases within these sectors are presented. Cases from the latter three sectors serve to provide some understanding of decision making in these domains.

A) Banking: The banking industry represents a fertile application area for DSS/ES technologies. High speed transactions, judgemental interactions and overall importance of corporate financial transactions are all factors which have lead the banking sector to investigate the advantages of computer-based DSS/ES technologies. In particular, the areas of focus have been credit and loan assessment and training applications; six application examples will be analyzed in detail.

Case One

CAEL: Credit / Bankruptcy Assessment

(P. Elmer and D. Borowski, 1988)

The ES system coined CAEL analyses a traditional 'savings and loans' (S&L) company on the basis of four broad components: *Capital, Assets, Earnings and Liquidity*. It then combines the evaluation in these four areas to achieve a weighted score as an indicator of overall financial strength of the company under study. The system employs financial data to compute 27 financial ratios/indicators of financial health attempting to predict bankruptcy possibilities of S&L companies. Thresholds must be set for score levels to provide some idea of the relative financial health. Measures of overall strength are derived on the basis of fixed standard comparison or peer group comparison by asset-size class.

Production rules are used as the knowledge representation scheme, accommodating extreme ratio value situations and combinations of variable values which may serve as warning indicators of pending financial distress. Non-traditional S&Ls, such as mortgage bankers, are analyzed on a case-by-case basis by a human analyst. On the basis of test results, CAEL out-performs traditional

logit methods in long-range prediction of bankruptcy; the system's accuracy is superior to the traditional approaches in the range of seven to twelve and thirteen to eighteen months prior to bankruptcy.

A key advantage of Cael's ES technology framework is its flexibility and almost limitless potential for extendibility and development. One feasible extension could be the use of historic score levels as a basis for inductive knowledge refinement.

Dimensions for Case One

CAEL

A Credit/Bankruptcy Analysis

Data Dimension:

Source of data: The system relies on external access to financial databases to receive relevant source input.

Volume of data: For the purpose of a single consultation, the financial data associated with a single firm must enter the system. This data set represents a small and structured information source in the form of conventional financial statements.

Complexity of data: The sole information being processed by this system is numeric financial data. Hence, for a financial application, the data required is of the least complex form.

Longevity: The update cycle associated with financial statement data follows conventional, static, periodic update; all accomplished in the order of quarter or annual fiscal periods. Financial statement data may have a static relevancy life span within the system (say five years), while the generated CAEL scores could remain for a longer time span for the purpose of trend analysis.

Knowledge Dimension

Knowledge state: The CAEL application has an intermediate knowledge status. The overall structure (ie: capital asset, earnings and liability) is predominantly static; the weightings, financial indicators and CAEL score thresholds are all subject to corporate specific adjustments; inductive knowledge refinement, if instituted, would further lean towards the dynamic end of the continuum.

Knowledge structure: To endorse recommendations regarding financial health, CAEL incorporates four fundamental components: capital, assets, earnings and liquidity. The synthesis of these components results in a score as a measure of overall financial health, clearly, an example of component synthesis knowledge.

Evaluation/Analysis Dimension

The processing approach incorporated in CAEL is the comparative/cross industry/ historic analysis style. Company statistics are compared with peer group figures or static standards in the process of evaluating the strength associated with each system component.

Output Dimension

The output associated with CAEL is a numeric rating score in combination with the corresponding rating of financial health.

DSS/ES Emphasis

Automated versus human control: The system operates under automated control for score generation and financial health recommendations. However, the final action taken as a result of the consultation is subject to human scrutiny.

Knowledge dimension coupling: The knowledge dimension dictates the data utilized throughout the consultation, analysis procedures followed and the resultant recommendation output; hence, knowledge influence is significant. From these considerations, the CAEL application can be viewed as a predominantly ES approach.

Case Two**MARBLE Credit Assessment/Loan Evaluation (M. Shaw & J. Gentry, 1988)**

The expert system MARBLE (managing and recommending business loan evaluations) evaluates business loan applications on the basis of relevant quantitative financial information and qualitative assessment characteristics. The system computes a credit-worthiness score of a perspective client and then compares this score against past examples to determine acceptance or rejection of the loan application. Upon acceptance, the system recommends the appropriate repayment provisions. Rules for the appropriate classification of loan applications are developed through inductive training cases: past credit cases with important determinant variables and the corresponding credit evaluation. The system is then capable of deriving rules which encompass the correct classification of all example cases. The knowledge in the system is also refined by such an inductive process. In general, inductive learning is the process of inferring the description of a class from the description of individual objects of the class.

Production rules are the basis of MARBLE architecture. Rules are categorized into different context types for which they are invoked. For example, rules are segmented into components of evaluation, feasibility, credit, utilization, return, profitability, repayment and collateral. During a consultation session, these context rule types are organized hierarchically as a context tree allowing large amounts of information to be structured into logical units. "The context tree lends structure to the loan evaluation process; each context solves one part of the lending problem and provides important information needed to solve the total loan evaluation problem". A written report summarizing the procedure followed in evaluating the loan application and the corresponding credit-worthiness score with recommendations is generated for future reference.

Dimensions for Case Two**MARBLE****Credit Assessment/Loan Evaluation****Data Dimension**

Source of data: MARBLE combines external database access for fundamental financial data with user-entered responses to incorporate qualitative assessments.

Volume of data: The system requires multiple sources of data: numeric, accounting, financial information is a necessity which must be synthesized with qualitative assessments, such as managerial expertise and external credit ratings. These requirements result in a mid-range data volume evaluation.

Complexity of data: The requirements of the business loan evaluation process necessitates both numeric, financial data and scaling procedures; this combination increases the complexity associated with the interpretation of necessary data.

Longevity: The MARBLE system must incorporate various data maintenance characteristics to accommodate the different aspects. Financial data is subject to the customary static periodic updates (quarterly or annually); in contrast, qualitative assessments are characterized by a point-of-use update cycle.

The relevancy time-frame of data is also divided along qualitative and quantitative boundaries. Numeric financial data is maintained in the system for a fixed time frame (say five years), at which time information is replaced in the typical first-in first-out (FIFO) manner. Documents describing previous loan applications will be used to guide future evaluations for the same customer, and will become a data element in the inductive knowledge refinement process.

Knowledge Dimension

Knowledge state: Business loan evaluation knowledge can be viewed in terms of an intermediate knowledge status. Heuristics employed within the basic structure of MARBLE could potentially be proprietary corporate guidelines. Once these evaluation heuristics/levels have been defined, knowledge is refined through example case induction.

Knowledge structure: The knowledge embedded in MARBLE is segmented into nine distinct areas, when combined result in system recommendations and overall credit-worthiness score. With the synthesis of distinct components, this system clearly adopts a component synthesis approach.

Evaluation/Analysis Dimension

MARBLE utilizes comparative/cross industry/historic trend analysis style to establish the relative strengths or weaknesses of system component attributes; this is the heart of the system's purpose and operation.

Output Dimension

The output dimension involves textual report generation summarizing the loan evaluation process and the resultant recommendations, in combination with the derived credit-worthiness score.

DSS/ES Dimension

Automated versus human control: MARBLE takes an active role in the evaluation of the business loan; inquiries are based on system action, in contrast to user initiation. The automated control sequence is characteristic of a fundamental ES approach: the user makes inquiries of the system based on the sequence of operation controlled by knowledge embodied in the system.

Knowledge dimension coupling: System knowledge shapes the consultation path, requests relevant data for analysis and produces the appropriate output in response. The controlling role played

by the system knowledge with respect to other system components, indicates a strong ES component.

Case Three

LASS Credit/ Loan Analysis (P. Duchessi, s. Belardo, 1987)

LASS (Lending Analysis Support System) is a knowledge enhanced DSS requiring "that the basic features of a DSS be combined with the power of a knowledge-based system....., a knowledge explanation facility and specially designed interfaces are required to promote user acceptance and support more sophisticated modelling activities." LASS employs this architecture to guide loan officers through the analysis process necessary to approve commercial loan applications. The system analyses the five C's of credit: character, capital, collateral, capacity and economic conditions.

The analysis of problem components proceeds through a four stage process: problem description, analysis of loan application and financial data, further suggested analysis and detailed analysis based on weaknesses. The system utilizes a hybrid knowledge representation employing both networks and production rules: the networks provide a convenient mechanism for representing problem structure, while production rules direct processing to appropriate components of the problem.

Dimensions for Case Three

LASS

Credit Analysis

Data Dimension

Source of data: In the acquisition of necessary data, LASS facilitates the integration of external financial database access and user entered responses.

Volume of data: The system functions on the basis of a five year financial data component. Industry statistics are synthesized with individual corporation statistics; relevant qualitative estimates are also maintained. These factors contribute to the mid-range data volume estimate for LASS.

Complexity of data: System data is predominantly numeric, financial data. However, the incorporation of some qualitative alphanumeric responses increases data complexity towards mid-range on the continuum.

Longevity: The financial data incorporated in LASS is updated on a static quarterly or annual basis with a five year total information set; data is replaced in the FIFO manner. Some qualitative elements necessitate point-of-use updating.

Knowledge Dimension

Knowledge state: At a fundamental level, the knowledge embedded in the system is static. However, the heuristics/indicators utilized in the analysis of the components are potentially subject to corporate modification. Upon establishment of appropriate indicators and associated levels, the knowledge dimension would remain predominantly unchanged.

Knowledge structure: The components of loan analysis (character, capital, collateral, capacity and conditions) are analyzed through a phased process. Thus, LASS is a combination of component synthesis and sequential stage analysis.

Evaluation/Analysis Dimension

LASS synthesizes two analysis approaches: comparative/cross industry/historical trend analysis and drill-down. The comparative analysis indicates relative financial strength with respect to industry average or fixed standards. The drill-down analysis is employed to suggest potential causes for evident weaknesses; detailed analysis is spawned on the basis of these weaknesses.

Output Dimension

The output is primarily text describing the analysis procedure, usage of models and the associated 'help' facility.

DSS/ES Emphasis

Automated versus human control: The system recommends analysis to be performed for problem solution. It allows the user to exit the knowledge-based components to perform this analysis, and then to re-enter the knowledge base with this new detailed analysis to receive more guidance from the system. This flexibility tends towards the DSS end of the spectrum. The ability to leave to the knowledge-base component to perform independent analysis differentiates LASS from a completely ES paradigm.

Knowledge dimension coupling: The knowledge dimension provides guidance and direction for data and analysis. The independent analysis capability provides a degree of separation between the knowledge and other system dimensions: a characteristic prominent in traditional DSS. LASS is truly a knowledge-enhanced DSS.

Case Four**CLASS Credit/Loan Analysis (P. Duchessi, H. Shawky & J. Seagle, 1988)**

CLASS (Commercial Loan Analysis Support System) is an ES designed to evaluate a company's financial posture, recommend commercial loan decisions and pertinent covenants, and document the loan analysis. The system performs two levels of analysis: 1) general trend analysis which graphically superimposes the company's trend line over the corresponding industry trend, asking the user to classify or judge the extent of the trend and 2) detailed analysis of four C's of lending: credit, collateral, capital and capacity. Character evaluation is left to the loan officer to incorporate into the overall decision. The detailed analysis pin-points the weakness of the applicant and attempts to isolate potential causes for these weaknesses; it generates a documented report summarizing the analysis.

CLASS is highly modularized: seventy rule groupings govern separate aspects of the loan analysis decision.

There is a significant similarity between CLASS and the system of LASS discussed previously. Both have a common author: P. Duchessi. My personal view is that CLASS represents a progression in the implementation of the ideas embodied in LASS. Differences evidenced involve the realization of the complexity and difficulty inherent in a full implementation of the loan analysis system; simplification of several components (ie: data source, character evaluation) are evident.

Dimensions for Case**CLASS****Credit/Loan Analysis**

Data Dimension

Source of data: Fundamentally, the system relies on user input; financial facts about the borrower are recorded by using standard spreadsheet interfaces. The logical capabilities associated with spreadsheets are then used to convert numeric data into symbolic evaluations which are read by the ES.

Volume of data: Five years of corporate and industry financial data are maintained as a basis for evaluation of loan requests. These requirements facilitate a mid-range volume evaluation.

Complexity of data: The numeric financial data is processed into numerous financial ratios, percentages and trends. Low complexity is associated with standard financial data processing.

Longevity: Financial data maintains periodic updates. The relevancy time frame is a five year scope cycled on a FIFO basis.

Knowledge Dimension

Knowledge state: The knowledge state of CLASS is consistent with LASS. At a fundamental level, the knowledge embedded in the system is static. However, the heuristics/indicators utilized in the analysis of the components are potentially subject to corporate modification. Upon establishment of appropriate indicators and associated levels, the knowledge dimension would remain predominantly unchanged.

Knowledge structure: CLASS synthesizes evaluations from the four C's of lending to achieve an overall evaluation: component synthesis.

Evaluation/Analysis Dimension

CLASS evaluation /analysis is also consistent with LASS synthesizing two analysis approaches: comparative/cross industry/historical trend analysis and drill-down. The comparative analysis indicates relative financial strength with respect to industry average or fixed standards. The drill-down analysis is employed to suggest potential causes for evident weaknesses; detailed analysis is spawned on the basis of these weaknesses.

Output Dimension

A fully documented report including graphics provides full documentation of the loan decision structured by CLASS.

DSS/ES Dimension

Automated versus human control: A consultation with CLASS proceeds under the guidance of knowledge inferencing. The loan officer is a passive data entrant in the process, requesting explanation from the system when necessary. The automated control is characteristic of an ES.

Knowledge dimension coupling: The knowledge embedded in CLASS requests the relevant information, performs the appropriate analysis and produces a corresponding report; these features characterize extremely tight knowledge coupling supporting an ES based approach.

Case Five

Participating Company (PC) Corporate Credit Management (V. Srinivasan & Y. Kim, 1988)

The system under study attempts to replicate the credit granting procedure of a participating corporation; the identity is withheld due to proprietary considerations. It addresses two phases of the process: assessing credit-worthiness and the determination of a credit limit.

For assessing *credit-worthiness*, the system examines various components: financial strength, customer background, repayment record, business potential/frequency and geographic location. The analysis proceeds hierarchically through each of the components of credit evaluation. Past credit cases are used as a benchmark for judging overall credit-worthiness.

To determine *credit limit*, an Analytical Hierarchical Process (AHP) model score is computed to determine a credit limit for the corporation. The AHP structures the problem hierarchically and then establishes priorities at each level. Individual company characteristics are factored into the AHP score at a lower level of the hierarchy; the bottom level represents alternative solution answers (ie: probability of default vs. probability of repayment). Loans are subdivided according to the amount of the loan. The AHP score that must be achieved to receive credit for each class of loan is corporate specific. The credit limit is established by multiplying the expected cash flows in the case of acceptance or of default by the corresponding probabilities weighted by the level of the AHP score.

Inductive rule generation is used to derive heuristics for various classes of loans. An extensive database structure is maintained as a basis for inductive processing.

Dimensions for Case Five
PC Corporate Credit Management

Data Dimension

Source of data: Both extensive database and user entered responses feed the necessary data to the credit management system.

Volume of data: Data volume requirements are mid-range. Large financial and historical case databases form basic system components. For a single consultation, only a small portion of this data would be utilized.

Complexity of data: This system relies predominantly on numeric, accounting, financial data; fundamentally simple data. The possibility exists for the integration of alphanumeric information in qualitative assessments which would increase data complexity.

Longevity: The update characteristics of system data are static and periodic; financial data and external qualitative ratings (ie: Dun and Bradstreet) are updated on a quarterly or annual basis. The life-span of the data is fixed and replaced on a FIFO basis. Referral to past cases provides a knowledge refinement mechanism.

Knowledge Dimension

Knowledge state: PC is classified as static in nature with the incorporation of company heuristics.

Knowledge structure: A consultation proceeds hierarchically through each aspect of loan evaluation. The components at each level combine to achieve an overall evaluation: clearly component synthesis.

Evaluation/Analysis Dimension

The comparative/cross industry/historical trend analysis style allows an assessment of relative measurement for alternative loan applications: a basis for acceptance or rejection of a loan.

Output Dimension

A textual report summarizing the loan analysis procedure represents the output dimension.

DSS/ES Dimension

Automated versus human control: The knowledge dimension stipulates the data required and the analysis procedures to be followed.

Knowledge dimension coupling: The linkage between knowledge, data and analysis dimensions is strong, tending towards an ES approach.

Case Six**Assessing Credit Card Applications Credit Assessment****(C. Carter et al, 1987)**

This system involves credit card applicant reliability and profitability. It utilizes a credit scoring method and an inductive process from correct example decisions to form rule-based solution procedure.

Two components are the basis of the credit scoring methodology: a scoring table and a repayment probability table. The *scoring table* allots points to attribute values which are deemed important decision criteria. Score points are summed across attributes to achieve a final overall score. If

this score is above a upper threshold, the request is routinely accepted; if the score is below a lower threshold, the request is rejected; intermediate values are subject to further investigation. The *repayment probability table* relates the overall score levels to the probability of repayment, providing guidelines for acceptable score levels corresponding to acceptable repayment characteristics.

Past examples are employed as a basis for inductive processes to generate decision rules for acceptance/rejection recommendations. Decision trees were initially developed in this paradigm. However, design adjustments have increased the system performance; class probability trees increase the flexibility of the decision criteria. At the leaf nodes, these trees indicate the probability of such cases belonging to each loan class through a vector of probabilities. Adjustments to acceptance/rejection thresholds can be made by changing the probability of default level associated with an accepted/rejected application.

Other technical features enhance the reliability of predictions associated with the system. For example, scores levels which reside close to the acceptance/rejection threshold require special consideration.

Dimensions for Case Six

Assessing Credit Card Applications

Data Dimension

Source of data: A combination of user input of application form data and database access for external credit reports accommodates system data requirements.

Volume of data: An individual credit card applicant session requires only a small, structured amount of application data. If necessity, external reports provide more in depth data.

Complexity of data: Financial application information is a simple, basic form of data on which the system operates. Qualitative references increase the complexity.

Longevity: The life-span of credit card assessment data is extremely short, requiring point-of-use updating. Future use is limited, used only as a data element in an inductive knowledge refinement process.

Knowledge Dimension

Knowledge state: The knowledge is static by nature. Determination of factors important to inductive rule generation stabilizes system knowledge. Rules based on these factors may be periodically updated to embody more recent cases.

Knowledge structure: Component synthesis is incorporated at a lower level. Key factors are determined as input to the inductive process. The derived rules can then be grouped by classification area.

Evaluation/Analysis Dimension

It emphasizes a screening/pruning analysis paradigm to recommend credit card decisions.

Output Dimension

The output is comprised of text recommendations regarding credit granting decisions and the corresponding explanations.

DSS/ES Dimension

Automated versus human control: The knowledge dimension dominates other system components, determines appropriate inputs, performs analysis and produces recommendation reports. The system user functions only as an input agent in system operation.

Knowledge dimension coupling: As implied, the automated system results in tight dimension coupling. All of these factors suggest a strong ES approach to the problem.

Banking Case Synthesis

Several commonalities are evidenced in the banking case analysis, from a knowledge engineering perspective and also in the decision components embodied in the systems. These elements provide interesting insights into relevant information and techniques employed in the industry. See table 10 for a summary table of banking case dimensions ².

Knowledge dimension analysis reveals a concentration of component synthesis structured knowledge, segmenting the difficult loaning/credit decision problem into manageable components. The modularity inherent within this structure suggests the potential to apply object-oriented techniques to system design. The hierarchical nature inherent in several system designs (ie: MARBLE: Shaw & Gentry, 1988; PC Corporate Credit Management: Srinivasan & Kim, 1988) are candidates to benefit from an object-oriented system hierarchical structure. Networks can also be designed utilizing the object-oriented approach. The state of knowledge ranges between static and intermediate states; the overall structure remains constant, while the incorporation of company specific heuristics and levels is common. The use of inductive processing for knowledge refinement (ie: Credit Card Assessment: C.Carter et al, 1987; MARBLE: Shaw & Gentry, 1988) results in intermediate knowledge status.

Decision process components provide further commonalities among banking cases. Most of the cases examined utilized an analysis of historical decisions as a basis for verification or rule derivation for current cases; analysis was performed through inductive processing or database access. The derived criteria are then employed to generate acceptance/rejection decisions or probability weights associated with the credit decision. These commonalities fundamentally describe the emphasis of the banking industry on historical elements: past experience with similar credit cases is an essential guideline. The historical emphasis provides reasoning for the tendency

toward inductive and machine learning approaches. "Using machine learning can be quicker and cheaper than building an expert system by the conventional prolonged series of intense, systematic interviews, usually extending over a prolonged period of many months" (C. Carter et al, 1987). The scoring approach utilized in some cases (CAEL: P. Elmer et al, 1988; Credit Card Assessment; C. Carter et al, 1987) can be adapted for similar decisions; potential examples include poorly valued stocks, analysis used to target merger prospects, evaluation of commercial banks and other depository institutions; all provide warning signs of pending financial distress.

The knowledge intensive element of credit decisions results in a predominantly ES emphasis in five out of six cases examined. The explanation capability thus embodied, is essential for guiding inexperienced credit officers through the decision process, while providing an accurate record of process.

Some characteristic differences exist in the banking cases examined. Most are text based systems; however, graphical analysis is employed for trend evaluation in LASS (P. Duchessi, 1988). The degree of user influence varies from independent analysis capabilities embodied in LASS, analyst character evaluation in CLASS, to simply an input agent in MARBLE. Traditionally, knowledge refinement is an involved knowledge engineering task; in contrast inductive systems (ie: MARBLE) facilitate easier knowledge refinement.

B) Investments: A significant component of the financial industry concerns the analysis of appropriate investment vehicles and portfolios to ensure a reasonable rate of return and safety of principal. The complexity and volume of relevant considerations result in the applicability of computer-based DSS/ES technologies to aid in these important decisions. Several distinct elements comprise the investment decision area: financial planning, portfolio management/optimization, stock trading and option trading. Twelve cases (six cases from financial literature, and six cases from software packages) pertaining to these areas are reviewed in detail with respect to the financial dimensions described earlier for the purpose of deriving commonalities and differences in design.

Case 7**PlanPower A Comprehensive Financial Planner (J. Stansfield and Greenfield, 1987)**

Financial planners are advisers who study an individual's financial state and then guide that consumer toward the best long-term financial advantages. PlanPower, an ES designed to aid financial planners in the construction of comprehensive financial plans, provides guidance in many areas: cash management, tax planning, investments, estate planning, risk management, borrowing, retirement and special needs funding, all within the context of client specific information. Each area requires specialized expertise while maintaining an overall perspective.

The system contains knowledge regarding financial modelling techniques and basic first principles of financial planning. Operation of the system can proceed in automatic or interactive mode. *Automatic operation* facilitates a system guided consultation; in *interactive mode*, the user maintains control entering data in a 'forms' system, utilizing graphic capabilities and menu selections. Default calculations and error checking are provided to expedite the process. Individual cases can be incorporated into a knowledge base through a utility called Casemaker.

PlanPower proceeds in phases: problem description, three stages of analysis and finally, the plan document output. The knowledge incorporated in processing is represented in an integrated fashion; frames constitute structure within component domains, while rules direct the processing. Once again, object-oriented techniques are employed extensively in the implementation of frame (structure) hierarchies. Specialized features enable PlanPower to effectively aid in the financial planning process. A document construction language facilitates flexible report generation, customized explanation frames provide the necessary detailed explanations of system actions, and recommendation frames cover detailed action plans including exact timing and appropriate parameter values.

The extensive knowledge embodied in PlanPower could have been developed into several independent ES components (ie: a tax planner, cash management, retirement planning, etc.). An underlying difficulty was the interrelation between multiple domains to construct an effect financial plan. Due to this complexity, the system necessitated an evolutionary development approach; four prototypes were developed prior to field testing.

Dimensions for Case 7**PlanPower:****A Financial Planner**

Data Dimension

Source of data: By all indications, user input is the fundamental source of system information. External database access could be used for repeat customers.

Volume of data: A substantial quantity of data is required for detailed completion of financial plans. Customer specific information, combined with economic indicators, result in a mid-range to large data volume estimate.

Complexity of data: Financial plans incorporate accounting, monetary and qualitative considerations to recommend appropriate long-term courses of action. The multiplicity of considerations results in a very complex data set encompassing both numeric and textual responses.

Longevity: Point-of-use updating; data is entered and/or updated upon request of a financial plan by the customer. Consequently, the relevancy period of data is short and limited to the time period between successive plan preparation.

Knowledge Dimension

Knowledge state: Financial planning domain knowledge is static in nature; establishment of techniques and criteria in each area can be viewed as a single occurrence. An exception of necessity is the tax component, subject to change according to the tax law.

Knowledge structure: As discussed above, PlanPower follows a phased structure. Additionally, from within these phases, each component of the plan is given consideration resulting in a mixed sequential stage, component synthesis knowledge structure. The more expansive the knowledge, the greater the likelihood for the occurrence of mixed knowledge structure.

Evaluation/Analysis Dimension

In the sequential stage processing characterizing PlanPower, the potential exists for differing analysis characteristics corresponding to alternative stages. The system employs screening/pruning and drill-down analysis styles.

Output Dimension

PlanPower's operation results in a comprehensive financial plan, encompassing both text and graphics capabilities.

DSS/ES Dimension

Automated versus human control: This continuum characteristic varies according to system operation mode. Automatic mode results in a customary ES driven system; interactive mode facilitates greater user control, thus characterized in terms of DSS.

Knowledge dimension coupling: The extensive knowledge required to solve the complex financial planning problem pervades all other dimensions. The knowledge must control data and analysis processing despite the capability of the user to influence system recommendations. This application is fundamentally ES driven through necessity.

Case Eight**FSA****Financial Statement Analysis****(C. Mui and W. McCarthy, 1987)**

The Financial Statement Analyzer (FSA) is an AI-based system which attempts to standardize the extractive and interpretive processings necessary for the familiarization phase of financial deci-

sion making. A prime motivation for this development was a paradoxical problem: on one hand, individuals who act as proxies for other investors felt inundated with financial information of questionable value; on the other hand, present financial data sources were inadequate in many respects. To provide a uniform interpretation of complex information necessary for financial analysis, the system employs object-oriented techniques to represent accounting knowledge embodied in financial statements and textual footnotes which comprise an important supplementary source of information. FSA has two knowledge bases (KB): one KB incorporates financial accounting knowledge necessary to extract relevant numeric data for ratio analysis; the other KB analyses the textual footnotes.

Object-oriented hierarchies represented the natural approach to accounting knowledge; the structure of financial statement accounts can frequently be viewed in hierarchical terms. The developers of FSA stated: "We found that accounting problem solvers attempt to organize financial data into such hierarchies before reasoning with it." FSA is visualized as a preprocessor for advanced financial analysis systems which would incorporate more in depth reasoning, characteristic of investment analysis.

Dimensions for Case 8

FSA

Financial Statement Analysis

Data Dimension

Source of data: The implication is that system data would be accessed through databases and/or a scanning mechanism; the explicit source of data is unclear.

Volume of data: Corporate filings can be extensive resulting in a mid-range evaluation of volume.

Complexity of data: Very complex data: numeric financial data and free form footnotes. The structure and presentation of the financial data is by no means uniform; this requires interpretation of acceptable replacements or composite elements.

Longevity: Financial data is subject to static periodic updates, on either an annual or quarterly basis. As an independent unit, FSA processes financial statement data only once. As a preprocessor for a larger system, multiple processing as definitely feasible.

Knowledge Dimension

Knowledge state: The accounting knowledge is strictly regimented and widely accepted across practitioners: the state can be viewed as static.

Knowledge structure: The hierarchical representation of accounting knowledge, where higher levelled concepts constitute generalizations of the lower levels, result in a component synthesis approach.

Evaluation/Analysis Dimension

FSA essentially employs a drill-down analysis style, searching through the hierarchy to obtain the necessary detail for ratio analysis. The potential exist in an advanced system to utilize comparative, historic trend analysis.

Output Dimension

The system displays balance sheet and income statement ratio analysis, which could represent intermediate input in a larger system.

DSS/ES Dimension

Automated versus human control: The actor model inherent in object-oriented programming tends towards user control: both in the timing of processing and exact data to be employed in the processing. The selected data is then subject to knowledge-based analysis. This user triggering is characteristic of DSS technology style systems.

Knowledge dimension coupling: The knowledge incorporated in the system is a passive resource, only taking control upon user request; characteristic of DSS.

Case Nine**PFIDSS****Investment Portfolio System****(B. Shane et al, 1987)**

PFIDSS (Personal Finance Intelligent Decision Support System) simulates the activities of a professional investment adviser to the individual investor. It incorporates two knowledge bases and a consultation component.

The Economic Condition KB (EC_{kb}) contains knowledge pertaining to relevant economic factors and their effects on investment vehicles. The EC_{kb} modifies the second knowledge base: the Investment Suitability KB (IS_{kb}) which contains knowledge on investment instruments and adjusts suitability for individual investor attributes. The consultation portion relies on a database of past portfolio selections to filter acceptable portfolio mixes. Modification of the rules in the IS_{kb} , entails adjustment of investment vehicle certainty factors (cfs) in rules of the EC_{kb} .

System processing progresses as follows: a) input of economic conditions and personal information, b) modification of IS_{kb} rules to adjust for economic conditions and personal preference factors, c) generation of an array of portfolio mixes; calculation of risk return characteristics for each portfolio taking into account economic conditions and d) ranking of the suitability of these portfolios considering personal investor attributes and past portfolio experience. The portfolio selection filtering basis employs the following criteria: eliminate portfolios that 1) do not partially match past portfolio selection practices, 2) do not match investor's risk return characteristics, 3) show no congruence with investor's goals and 4) then rank the remaining portfolios in terms of

'best match' to personal goals. The risk return characteristics desired by the investor are judged through the results of a 'game' which derives the associated risk aversion curve. The system provides the capability for a guided session or an independent user-driven interaction.

Dimensions for Case 9

PFIDSS

Investment Portfolio System

Data Dimension

Source of data: The consultation require direct user input of relevant economic and personal information.

Volume of data: Prudent investment philosophies must incorporate economic conditions, financial instrument characteristics and individual investor profile; this necessitates the consideration of numeric financial information and qualitative textual responses (ie: as personal goals): a mid-range data volume estimate is reasonable.

Complexity of data: The data is very complex, due to the qualitative specification of goals and other text responses combined with conventional financial data.

Longevity: A consultation with the system requires updating of economic and personal information: characterized as point-of-use maintenance. Recommendations are made on the basis of one-time analysis of the economic and personal situations. Past portfolio suggestions are monitored in a database to become a component of the consultation system to aid in future recommendations. Multi-consultation users may incorporate some information reuse.

Knowledge Dimension

Knowledge state: The system knowledge could be varied by considered economic conditions and the IS_{kb} could be modified to reflect corporate heuristics and investment philosophies. Thus, an intermediate knowledge evaluation is most accurate.

Knowledge structure: A consultation proceeds through sequential phases to complete the overall investment advice; a structure best described as sequential stage analysis.

Evaluation/Analysis Dimension

To achieve plausible investment recommendations within the context of individual and economic conditions, the system must systematically employ a screening/pruning philosophy to reach its objective.

Output Dimension

An investment report represents system results: recommended investment portfolios and summary explanations. Graphical depiction of portfolio mixes is also available.

DSS/ES Dimension

Automated versus human control: The system has the capability to use knowledge in an active or passive manner. Inexperienced users employ the ES guided approach, while experienced analysts use the DSS independent functionality.

Knowledge dimension coupling: Knowledge determines the template for relevant data. Once data is entered, knowledge controls the analysis. The knowledge structuring of data and analysis characterizes ES functionality. The degree of independence permitted within the system indicates an influence apart from a solely ES paradigm; the emphasis still tends towards ES.

Case 10**PMIDSS****Investment Portfolio System****(J. Lee and E. Stohr, 1985)**

PMIDSS (Portfolio Management Intelligent Decision Support System) interactively supports the decision process of an investment adviser interviewing a perspective investor. The system will analyze stocks, bonds and cash equivalence; the current prototype involves only stock selection.

The investment decision process has two major components: analysis of investment timing and investment selection decision. These two components can be further decomposed. For example, the *analysis of investment timing* involves consideration of the following steps: determination of economic conditions, selection of economic scenarios fitting the economic conditions and determination of proportions to be invested in stocks, bonds, etc.; the *investment selection* component involves determination of the risk profile of the investor, selection of individual stocks, bonds, etc. and the amount to be invested in a particular asset. Each successive step involves individual considerations, necessitating a mixed knowledge representation scheme from question nets, frames to production rules. The stock selection stage also incorporates a management science optimization model to guide portfolio construction.

The general knowledge architecture is based on a layered format: from general economy and stock market analysis, to industries and finally to companies and selected stocks. This approach resembles the technique suggested for the Graham and Dodd's security analysis (Macklem, D., 1988).

Dimensions for Case 10**PMIDSS****Investment Portfolio System****Data Dimension**

Source of data: The consultation is designed to rely on user entry of appropriate personal information and economic conditions.

Volume of data: A mid-range volume estimate is derived from the combination of detailed personal information and significant economic indicators, the basis of system operation.

Complexity of data: High complexity is associated with system data; qualitative, textual responses (ie: personal goals and constraints) must be integrated with traditional financial figures for prudent analysis.

Longevity: A consultation with the system requires updating of economic and personal information: characterized as point-of-use maintenance. Recommendations are made on the basis of one-time analysis of the economic and personal situations. Multi-consultation interaction may lead to information reuse.

Knowledge Dimension

Knowledge state: Company specific heuristics may be incorporated to customize PMIDSS to a specific investment approach, resulting in an intermediate status evaluation.

Knowledge structure: The system follows a systematic set of stages to arrive at overall recommendations; sequential stage analysis best describes the underlying approach.

Evaluation/Analysis Dimension

The system must systematically employ a screening/pruning analysis philosophy to reach its objective of plausible investment recommendations, all within the context of individual and economic conditions.

Output Dimension

The recommended stock portfolios and the corresponding justifications are provided through a textual investment report.

DSS/ES Dimension

This dimension could not be judged on the basis of available information.

Case 11**CLP****Option Trading****(C. Lassez and K. McAloon, 1987)**

"A design of a framework for an expert option analysis system must provide rule-based programming that integrates numerical computation, problem description and facilities for symbolic analysis." Constraint Logic Programming (CLP) is described as a potential approach to rule-based systems for option trading. The algebraic nature of evaluation, combined with symbolic constraint capability makes CLP a suitable candidate.

The system has three parts: 1) a prolog-like *inference engine* can recognize constraints and solve simple constraints, 2) an *interface* between the inference engine and the constraint solver can solve complex arithmetical constraints and express these constraints in a canonical form, and 3) a *constraint solver* handles complex constraints not solvable by the other components.

Solution proceeds incrementally with constraints added until the system of constraints is solvable. Nonlinear constraints solvability is delayed until enough information is available to express these constraints in a linear format. The system incorporates rule-based programming with other AI concepts (ie: constraint systems) to arrive at a feasible and optimal solution.

Dimensions for Case 11**CLP****Option Trading**

Data Dimension

Source of data: Effective option trading systems rely on active line-feeds and data tickers to supply continuous, timely data.

Volume of data: The continuous supply of relevant data dictates a large data volume component for successful operation.

Complexity of data: Numeric financial data, including option characteristics and underlying stock values, classify the option trading system as involving medium data complexity.

Longevity: A real-time update cycle must be associated with option data to take advantage of brief market arbitrage opportunities. Hence, the associated relevancy period is extremely short; positive trading opportunities can dissipate within minutes.

Knowledge Dimension

Knowledge state: Option evaluation approaches are static and well accepted in the market; Black and Scholes option formula and the Binomial pricing strategy constitute prudent practice.

Knowledge structure: Many option portfolio strategies warrant evaluation in determination of the most advantageous position. Symmetric alternative solution processing characterizes the structure of the approach to the problem.

Evaluation/Analysis Dimension

A screening and pruning analysis style facilitates selection of appropriate securities under a variety of relevant constraints resulting in the 'best match' security combination.

Output Dimension

The positive option trading opportunities captured by the system are best employed as intermediate input to a larger system, allowing execution of observed arbitrage opportunities.

DSS/ES Dimension

Automated versus human control: Automated control must dominate the interaction to facilitate search for and execution of profitable trading positions. Upon knowledge establishment, analysts can only monitor system actions to hone performance by modification.

Knowledge dimension coupling: Option evaluation knowledge dictates the necessary data and the associated analysis procedures: an extremely tight coupling between dimensions. An option trading system cannot incorporate effective use of an explanation facility, due to time constraints. Despite tight coupling, these systems must be classed as an intelligent DSSs.

Case 12**Financial Knowledge-Based Systems Stock Trading****(D. Leinweber, 1988)**

'A real-time computer system can be taken to be one that can react to environmental change as fast as those changes occur.' Stock trading is an example application requiring real-time continuous data flow to successfully analyze complex financial market situations.

Demanding performance requirements necessitate the use of specialized tools and techniques. Expedient high volume transaction processing and continuous real-time complications are fundamental requirements that must be considered in the design of a trading system's architecture. In real-time operation, systems must recognize and act upon new facts asynchronously while disregarding or conditioning conclusions based on facts whose values change or become unknown. Efficiently implemented logical abilities provide the functionality to deal with dynamic environments and links to the external world facilitate access to diverse data resources.

Features embodied in effective stock trading system implementation include the following. a) *User-defined relations* allow flexible definition of relationships among variables to facilitate a logically correct view of the world. b) *Logical dependency mechanisms* permit flexible specification of fact truth relationships facilitating faster fact maintenance capabilities. These dependencies are particularly useful when combined with object-oriented triggering techniques to efficiently maintain an accurate fact database. c) Simultaneous consideration of multiple hypothesis can be provided through maximum salience rules. d) Adaptive alarms can indicate the occurrence of flag conditions. Rule-based technology can be employed to explain and investigate reasons for triggering of the alarm.

A basic overview of a generic stock trading system architecture will provide further insight into problem elements and system capabilities. (See figure 6). Multiple *data feeds* serve as the source of system operation. Rule-based approaches can be employed to facilitate proper integration. The traditional *computation, analytic and archiving* functionality remains present. Other distinguishing components include: a *grammar-driven rule editor* to facilitate user entry of proprietary closely held rules, and a *pattern recognition critic* which further serves to filter system recommendations. Conventional rule-based technology also functions as an *integrator and controller* of system component interaction.

Trader System Architecture

Figure 6

Dimensions for Case 12

Financial Knowledge-Based System

Stock Trading

Data Dimension

Source of data: A wide variety of data sources serve as operational bases for a stock trading system.

Volume of data: Effective monitoring and interaction within the stock market necessitates an extremely high volume of data for the consideration of alternative transactions.

Complexity of data: For fast-paced stock trading systems, the data analyzed is predominantly numeric, accounting financial data. Due to time requirements, few qualitative textual indicators enter the analysis.

Longevity: Stock market information enters the system on a continuous real-time basis; consequently, the relevancy cycle is extremely short.

Knowledge Dimension

Knowledge state: Stock market analysis incorporates static knowledge at a higher level; individual corporation and trader heuristics commonly influence system recommendations and analysis; an intermediate knowledge status is thus assigned.

Knowledge structure: The investment approach followed by the investment company/trader impacts the overall structure of problem solution. Feasible mixes can be envisioned between component synthesis and sequential stage analysis.

Evaluation/Analysis Dimension

Recommendations regarding appropriate stock investments require a screening/pruning analysis approach to arrive at a small, feasible number of appropriate transactions.

Output Dimension

The potentially profitable transactions isolated by the system, represent an intermediate input to a larger system, involving connection to execution and record keeping components.

DSS/ES Dimension

Automated versus human control: Automated control must dominate the interaction to facilitate search for and execution of profitable trading positions. Upon knowledge establishment, analysts can only monitor system actions to hone performance by modification.

Knowledge dimension coupling: Stock selection knowledge dictates the necessary data and the associated analysis procedures: an extremely tight coupling between dimensions.

Case Thirteen

The Economic Investor Stock Trading Software Package Econ Software Co. Ltd.

The Economic Investor embodies econometric analysis to predict and suggest stock selection transactions for an investor. The software is an arbitrage pricing model-based system incorporating seven economic variables to judge movements in the individual and/or groups of stocks. The factors chosen as a basis for the system include: inflation rate, housing starts, industrial production, price of crude oil, exchange value of the US dollar, risk premium associated with corporate bonds and the slope of the slope structure of interest rates.

Two alternative modes of analysis are available: macro-economic scenario mode and portfolio risk minimization mode. In the *macro-economic scenario mode*, data for the current and forecasted values of the seven economic variables represent the input. The Economic Investor then calculates the rate of return (ER) the investor can expect on a particular stock through a regression equation expressing ER in terms of the seven economic factors; a single equation of this form is available for each of the twelve hundred stocks monitored by the system. The resultant output is a ranking of perspective stock according to the level of ER. In the *portfolio risk minimization mode*, the composition of the investor's portfolio serves as input. The system suggests buy/sell transactions in order to minimize the overall portfolio risk, with respect to the seven economic factors.

Dimensions for Case Thirteen

Economic Investor

Stock Trading

Data Dimension

Source of data: System input is mode dependent. In economic scenario mode, the user keys in relevant data regarding forecasts of how some or all of the seven variables will change. For risk minimization, the portfolio composition to be analyzed represents the user-entered input.

Volume of data: The data set required for Economic Investor represents a small structured component.

Complexity of data: The numeric nature of the input results in a simplistic evaluation for data complexity.

Longevity: Data is subject to point-of-use updating resulting in a varied longevity evaluation dependent upon the frequency of system use.

Evaluation/Analysis Dimension

Economic Investor relies on mathematical regression equations to derive optimal results: mathematical computational models.

Output Dimension

The output provided is in the form of simplistic text and associated numerical calculations.

DSS/ES Dimension

Automated versus human control: Economic Investor employs the user solely as an input agent. The system proceeds sequentially through internal analysis to produce recommendations, completely under automated control; however, the absence of reasoning capabilities characterizes Economic Investor as a restricted form of DSS which is not subject to evolutionary refinement or adjustment. This fixed paradigm is best classified as a *closed* DSS.

Case Fourteen

Market Base

Stock Selection Software Package

MP Software Inc.

Market Base is an advanced fundamental stock analysis and database system. The flexibility incorporated in the package allows an investor to pursue a personal investment strategy; you can locate, analyze and compare financial results for companies traded on the New York Stock Exchange (NYSE), the American Stock Exchange (AMEX) and National Automated Systems Dealer Quotes (NASDAQ) national market systems, to isolate profitable investment opportunities.

Information is power, but only if you have good information and can control it. User definition of significant financial relationships and weighted ranking mechanisms, pioneered by Ben Graham, maintain investor control over the vast data resources provided by Market Base. In providing investor guidance, the software eliminates from consideration the stocks which fail to meet investor specified criteria; the remaining stocks can then be subjected to more in depth analysis to obtain a workable number of exceptional stocks for final investor consideration.

Dimensions for Case Fourteen

Market Base

Stock Selection

Data Dimension

Source of data: Access to the financial results of over 4700 companies stored on floppy diskettes is provided by MP Software Inc. Relevant information summarized includes: a five-year history of selected figures from income statements, balance sheets and statement of changes in financial position, latest weekly closing price, closely held insider stock positions, industry breakdowns, footnotes on significant company events, etc.

Volume of data: Potential analysis of the 4700 stocks requires a detailed, concise information set. The information accompanying Market Base can be considered an intermediate data volume status. The summarized nature of the data contributes to the compactness.

Complexity of data: The source data of Market Base is predominantly summary, numeric, accounting financial data; the associated complexity is low.

Longevity: The relevancy period and update cycle for Market Base are directly related. Weekly, monthly, quarterly or annual static periodic updates are available replacing past data for system analysis.

Evaluation/Analysis Dimension

Selection of appropriate stock investment opportunities with Market Base proceeds through a screening/pruning analysis style, accompanied by drill-down analysis for in depth investigation.

Output Dimension

This software incorporates a report generator with integrated numeric and text output to summarize the analysis preformed by the system.

DSS/ES Dimension

Automated versus human control: The versatility inherent in Market Base through user-defined selection criteria and financial relationships is characteristic of the flexibility incorporated in more traditional open DSS. The contrasting feature of the *open* DSS is the increased user capability to influence system analysis and procedures.

Case Fifteen

The Portfolio Evaluator

Portfolio Management

Precise Software Corp.

The Portfolio Evaluator encompasses comprehensive portfolio management capabilities. Tracking of portfolio performance, transaction record, on-line updating and customizable report generation are features which facilitate accurate, efficient monitoring capabilities. Portfolio information can be updated on a manual or on-line basis from either Dow Jones News/Retrieval or Warner Computer Systems to maintain current data maintenance.

Advanced flexibility features provide Portfolio Evaluator with significant advantages. a) The tracking of exiting portfolios both in composition and for tax purposes facilitate comprehensive monitoring capabilities. b) The creation and tracking of hypothetical portfolios permits the investigation of alternative investment strategies. c) The customizable report generator allows flexible, personalized information presentation in columnar format. The package is bundled with six standard report formats: quotes for a portfolio, unrealized gains and losses, tax income, year transaction to date and cross-reference. d) The incorporation of user defined buy/sell criteria signal portfolio adjustments. e) The ability to export Portfolio Evaluator information to other

applications, such as Lotus 1-2-3, permit more in depth analysis capabilities. f) Unattended automatic updating and batch report printing expand system flexibility.

A companion software component is available to enhance Portfolio Evaluator's capabilities. A stock charting and technical analysis module expands analysis by charting historic trends and indicators.

Dimensions for Case Fifteen	Portfolio Evaluator	Portfolio Management
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Data Dimension

Source of data: Portfolio Evaluator combines the dual capabilities of user entry and on-line database access to acquire relevant data.

Volume of data: The volume of data embodied in the system varies directly with respect to system usage. The average investor would have a mid-range data requirement.

Complexity of data: Low data complexity is incumbent in portfolio monitoring software; the predominant use of numeric, accounting, financial data characterizes this evaluation.

Longevity: The relevancy characteristics of portfolio data vary directly with the trader's trading activity and amount of system usage.

Evaluation/Analysis Dimension

The software facilitates both screening/pruning and historical trend analysis styles.

Output Dimension

Numeric, columnar, summary reports constitute the body of information produced as a result of interaction with Portfolio Evaluator.

DSS/ES Dimension

Automated versus human control: The system performs actions only in response to user commands. The ability to influence and change system analysis' procedures, characterizes the Portfolio Evaluator as an open DSS. The user-driven consultation is also an attribute of DSS software.

Case Sixteen

Profits! Technical Analysis Software Package Buttondown Software Inc.

Profits! represents a sophisticated technical analysis and charting package for the Apple Macintosh. The Macintosh environment lends ease-of-use and advanced graphic capabilities which provide Profits! with distinguishing features. The software is an integrated package combining database elements, a terminal emulation program and an advanced charting program to track price movement of stocks, commodities, indices, options and mutual funds. The software allows analysis of price trends and momentum through historic, comparative trend

analysis. Data can be entered by hand, down-loaded from CompuServe or Hale Systems Dial/Data or transferred from spreadsheet or database software.

The investor controls operation within the system. The menu-based paradigm allows setting of appropriate parameters for Profits! environments. Groupings of charts can be developed and activated simultaneously to facilitate consistent analysis. Delayed updating of database information and triggered chart printing on the basis of the resultant information, provide Profits! with some automated control capabilities.

An extensive library of charting alternatives are available for technical analysis within Profits! The variety of charts include views intended for commodities, stocks and option analysis.

Dimensions of Case Sixteen	Profits!	Technical Analysis
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Data Dimension

Source of data: Price data can be entered by the user or down-loaded from external database sources.

Volume of data: System usage is the fundamental determinant of data volume. Practical usage levels incorporate a medium data volume estimate.

Complexity of data: Low complexity characterizes the numeric nature of price trend analysis.

Longevity: The update cycle and consequent relevancy period of data are determined by the level of system usage. Maintenance of an extended period of past data is feasible for this technical analysis application, dependent upon the requirements set by the user.

Evaluation/Analysis Dimension

Trend analysis is the underlying mechanism of technical analysis. Future movements are predicted on the basis of historical patterns.

Output Dimension

Graphics and charts serve as the basis of technical analysis.

DSS/ES Dimension

Automated versus human control: The features and analysis capabilities embodied in Profits! are static. However, within these bounds, the menu-driven interface leads to user control. The software is best classed as a closed DSS.

Case Seventeen

Value/Screen II	Stock Selection/Portfolio Management	Value Line Inc.
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Value/Screen II is a stock selection and portfolio management package available for both the Macintosh and IBM computer hardware. This integrated system facilitates user stock selection,

stock reporting, portfolio management, report generation, statistical analysis and spreadsheet files. The *stock selection* capability allows the user to screen the entire Value Line database of 1600 stocks on the basis of predefined or user-defined criteria. Further analysis of the initially screen stocks is also available. *Stock reporting* gives information regarding individual or groups of stocks. *Portfolio management* facilitates user-entry of stock ownership information to create a hypothetical computer-driven portfolio; tracking of such hypothetical portfolios permits testing of stock screening criteria. Pre-formatted or customized reports are available from the *report generation* facility. In the Macintosh version, the menu-driven interface makes the software intuitive: actually enjoyable to use.

Dimensions for Case Seventeen	Value/Screen II	Stock Selection/Portfolio Management
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Data Dimension

Source of data: Value/Screen II relies on a database of corporate financial information as a basis for system analysis.

Volume of data: Mid-range volume of data: sixteen hundred stocks with relevant information are included in the fully operational system.

Complexity of data: The software predominantly utilizes numeric, financial, accounting data allowing the investor to investigate financial indicators and investment opportunities.

Longevity: The update cycle can be characterized by a static, periodic update; yearly, quarterly, monthly or weekly options are available.

Evaluation/Analysis Dimension

The functionally embodied in Value/Screen II can be described in terms of a screening/pruning analysis approach. Limited cross comparison capabilities are available.

Output Dimension

Text-based output is the communication media for this software. Fixed reports and analysis are available. Numeric output supports some analysis functions.

DSS/ES Dimension

Automated versus human control: This system is completely user-driven with an ability to influence algorithmic analysis; thus, is characterized as an open DSS.

Case Eighteen

Ultra II SCTA	Stock Charting and Technical Analysis	Wall Street Investor
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Ultra II SCTA is a stock charting and technical analysis software package run on IBM computer hardware which permits on-screen technical analysis through the use of user-defined criteria and/or twelve predefined indicators (ie: all moving averages, volume indicator, trend lines,

etc.); a technical analysis library-on-disk explains the use of the indicators for successful application. The system incorporates a communications module for data update, with linkage to Warner Computer Systems, Dow Jones/News Retrieval or CompuServe databases.

Dimensions for Case Eighteen

Ultra II SCTA

Stock Charting and Technical Analysis

Data Dimension

Source of data: Manual input, combined with the linkage to external databases provides the software with a degree of flexibility in obtaining appropriate input data.

Volume of data: System usage is the determining variable with respect to data volume: a direct relationship exists between usage and the data volume.

Complexity of data: Technical analysis relies fundamentally on numeric, accounting, financial data to produce indicators of future performance on the analysis of historical statistics.

Longevity: The update cycle and corresponding relevancy period of system data is also dependent upon the frequency of use. The package can be best classified as having point-of-use characteristics. Information replacement occurs on a FIFO basis after a user-determined time period.

Evaluation/Analysis Dimension

Technical analysis employs a screening/pruning style, on the basis of historical data, to identify attractive trading opportunities.

Output Dimension

The software utilizes graphical charts as an output media from which users can draw conclusions.

DSS/ES Dimension

Automated versus human control: SCTA Ultra II operates solely on a user-driven basis. The user dictates the charts to be drawn, supplies the input and activates the process; the software exhibits open DSS-style attributes.

Investment Case Synthesis

Despite the diversity of applications, various commonalities can be drawn across investment industry boundaries. The analysis approach, overall problem structure, data currentness and technological emphasis are some of the attributes which present interesting insight for design commonalities and differences. The contrasting features evident between the software cases and the cases drawn from the financial literature provide an additional source of comparison.

The DSS/ES cases examined within the investment sector suggest several *general commonalities* across application boundaries. See table 11 for positioning of investment cases along financial dimensions; these positionings are the basis for the discussion of generic and inter-application commonalities which follow.

The predominant presence of cases characterized by point-of-use or real-time data update indicates a reliance on *current data* in the decision making process. The vast size of the solution sets available for these applications result in the emphasis toward a *screening/pruning analysis* paradigm necessary to reduce plausible solutions to a workable number of alternatives (ie: areas of financial planning, investment selection and option trading). The structuring of investment decision knowledge is primarily *sequential stage analysis*, with some integration of component synthesis. Investment decisions require reporting mechanisms as an explanation, recommendation and justification for resource utilization and allocation; as a result, the cases indicate an emphasis toward *text-based report generation* to represent the conclusions reached through system operation. The integration of graphics and numerical elements with the text bases is common as an explanation facility.

Various *specific level inter-application similarities* can be derived from investment case analysis along the specified dimensions.

a) Case-oriented solution problems involving *financial planning and investment portfolio selection* (ie: PlanPower, PMIDSS and PFDSS) require a particular attribute set to facilitate appropriate customization due to the specialized requirements of these applications. Shared attributes include: user input, point-of-use updating, screening/pruning analysis and integration of text and numeric input responses, producing primarily text-based output.

b) Applications requiring *real-time* maintenance exhibit a concentration on large quantities of numeric data (CLP and Stock Trading). These systems lean towards DSS technology because the knowledge explanation facility provided through ES technology is of reduced utility due to processing time requirements. The explanation capability only serves as a monitoring mechanism in this environment, with the ability potentially to provide an audit trail. Real-time systems can also be connected as components of larger systems; for example, portfolio tracking and transaction execution systems complete the process of positive trading opportunities identified by the system.

c) Several investment fields can be characterized by static knowledge: financial planning (PlanPower), financial statements analysis (FSA) and option trading (CLP) are prominent applications examples.

d) Investment selection cases exemplify sequential stage knowledge structures; these stages consider individual company, industrial and broad economic factors, in combination with investor characteristics. The analysis can be viewed from broad to narrow, or general to specific information; thus, a hierarchical approach is feasible (Macklem, 1988).

e) The software cases analyzed present a unique set of interesting commonality insights. These packages embody analysis capabilities, such as filtering rules, graphic tool kits, ranking mechanisms and historic tracking. However, no inferential knowledge characteristic of ES is evident in any of these packages. As a result, these cases are best classed as DSS. Further analysis of these capabilities associated with the software lead to the proposal for two categories of DSS: 1) A *closed DSS* is characterized by a fixed set of capabilities and features, not adaptable to unique user requirements (ie: Economic Investor and the technical analysis area). These attributes are inherent in traditional data-processing software packages which are used to support decision making activities. 2) An *open DSS* facilitates user definition of system elements to expand and customize the analysis and recommendations (ie: Market Base). The underlying flexibility to customize analysis capabilities is a distinguishing feature embodied in most definitions of traditional DSSs.

Contrasting features drawn from the investment case analysis are not as evident as the similarities. However, the cases reviewed in the financial literature did involve more complexity than the software case analysis. The available software is strongly influenced by DSS technology, while the literature cases concentrate on ES technology applications; this could be an indication that ES technology to date, has been used only for large efforts and DSS have been accepted for a wide range of tasks. The sophistication of ES developmental methodologies result in low end-user development, a strong contributor to the DSS style software.

The investment selection area presents one contrasting example in applications. Fundamental investment analysis (ie: PFIDSS) relies heavily on text-based summary reports; technical analysis (ie: Profits!) employs graphical output as the important communication vehicle; real-time stock trading systems (Leinweber, 1988) produce input for larger systems.

C) Corporate Finance : This sector has received limited attention in DSS/ES development efforts, with capital budgeting and financial allocation/de-allocation decisions representing the only

application areas examined. Past scepticism of the business community regarding ES technology could be a major reason for the hesitancy of development efforts in corporate finance. Two cases will provide an understanding of design issues: one from the capital budgeting domain and the other concerns financial allocation decision making.

Table 12 presents a summary of corporate finance and accounting dimension results which serve to characterize domain problems.

Case Nineteen

ES for Capital Budgeting

Corporate Finance

(S. Myers, 1988)

"Many ESs serve to enhance the quality of the decision process by providing intelligent analytical and reasoning support to the decision maker or analyst, without necessarily automating the entire decision process" (V. Srinivasan et al, 1988). This statement adeptly describes this system designed as an ES to aid in capital budgeting decision making; due to proprietary considerations, the exact identity of the system is withheld. The system can be characterized as a consultant as opposed to a decision maker. It functions to advise as well as compute with no actual recommendation being rendered by the ES.

The architecture incorporates two components:

a) The *input block* provides problem description and background information through stored input or user entry. This component is very extensive, requesting differing levels of data dependent upon previous problem description: the more detail incorporated in the input block, the greater the analysis' capability of the system at a later stage of system consultation. Consistency checks and required data elements are enforced by the input block.

b) *Valuation and analysis* presents the results of the discounted cash flow (DCF) analysis from alternative perspectives: internal-rate-of-return (IRR) versus net present value (NPV) presents alternative measures of overall project value; margin of error involves conventional sensitivity analysis establishing critical values for key variables automatically; competitive analysis facilitates adjustments of cash flows in anticipation of competition.

Other salient features include the following elements. 1) A *tailoring block* facilitates the establishment of project parameter values and financial relationships for classes of projects within

different companies. 2) Contingent *inheritance hierarchies* permit sharing of project characteristics among similar projects. 3) An object-oriented, graphical user interface provides flexibility of interaction, permitting a user-driven, stepwise, system guided consultation. The navigation through proper screen sequencing from within operation is an interesting AI feature.

Dimensions for Case Nineteen

ES for Capital Budgeting

Corporate Finance

Data Dimension

Source of data: Data retrieved through database access and direct user entry provides problem description and structuring characteristics.

Volume of data: The amount of data employed in the capital budgeting system is case dependent. A first cut scenario might involve only a small structured information set; a detailed in depth decomposition could result in an intermediate volume assessment, as these projects would include cash flow projections, tax rates, capital cost allowances (CCA) and salvage values.

Complexity of data: The numeric financial accounting data characterizing system operation is not complex.

Longevity: The case-based guidance provided by the system necessitates point-of-use updating to incorporate specialized contours of the project under analysis. Following a single analysis, data is modified; hence, the relevancy period is short. Cases may be used as a basis for future scenarios; storage in a database is feasible.

Knowledge Dimension

Knowledge state: Discounted cash flow and project analysis techniques are both widely accepted knowledge components within the financial industry: a static knowledge evaluation.

Knowledge structure: Sequential stage analysis describes the problem solving approach in the capital budgeting domain. First, project data must be input, followed by an initial evaluation and then subjected to in depth analysis.

Evaluation/Analysis Dimension

A variety of parameters are available for the analysis process of a capital budgeting decision. Sensitivity analysis of project attractiveness to fundamental parameters is an essential component to reach a conclusion regarding acceptance/rejection of a project. Thus, parameter variation style analysis dominates capital budgeting operations.

Output Dimension

This corporate finance application possesses the ability to produce reports through a report-writer facility and exports graphic screens for inclusion in other reports.

DSS/ES Dimension

Automated versus human control: The 'button-oriented' interface implies the knowledge resource is passive in nature, activated only on user request. This consultation style characterizes user controlled DSS.

Knowledge dimension coupling: The flexibility incorporated in the input block guides the usage of passive knowledge. Static system analysis is performed on user request. This application is a prime example of an intelligent DSS.

Case Twenty**FAME****Corporate Finance****(E. Mays et al, 1987)**

FAME (financial marketing expertise) is an ES to aid in financial marketing decisions. Financial marketing denotes "the decision processes used in marketing products/services on such a scale as to significantly impact a company's financial status." A prime example is the acquisition/de-acquisition of computer equipment. In making large equipment proposals, financial considerations often become as important as the computing motivations. It is not sufficient to merely present a plan. FAME's ability to provide explanations persuades decision makers that proposals are reasonable.

Financial marketing domain knowledge is extensive and structured. FAME employs an object-oriented knowledge representation with knowledge segmented into twenty-three distinct knowledge bases including product information, financing alternative knowledge and tax considerations. The system automatically classifies new problem-specific concepts into the appropriate position of the inheritance hierarchy. Specialized rule structures control processing and modification to hierarchical problem structure. The resultant report summarizes the recommended action plan for acquisition/de-acquisition.

Dimensions for Case Twenty**FAME****Corporate Finance****Data Dimension**

Source of data: User entry of problem specific elements, combined with database access provides FAME with source input.

Volume of data: Variable data requirements are necessary for system operation; evaluation is case dependent.

Complexity of data: Predominantly, financial data is used during processing; the incorporation of few qualitative factors is feasible: medium data complexity.

Longevity: The system relies on point-of-use updating to incorporate case specific elements. The potential exists for influence on future cases.

Knowledge Dimension

Knowledge state: Financial marketing knowledge is mostly static in nature: accounting based analysis and financial theory.

Knowledge structure: FAME utilizes a mixed knowledge structure. Component synthesis characterizes elements of the financial marketing problem; sequential stage processing controls the creation and analysis of problem components.

Evaluation/Analysis Dimension

The system employs a screening/pruning analysis approach to derive the appropriate action plan.

Output Dimension

A written report summarizing the action plan and corresponding justifications is generated.

DSS/ES Dimension

Relevant information was not available.

D) Accounting: The rule-oriented structure and judgemental elements inherent in many accounting procedures naturally lend to DSS/ES approaches. Developmental efforts are predominantly in the prototype stage. Since 1983, private corporations have become involved and are actively engaged in accounting ES research (Silverman, 1987); consequently, real-world applications are being developed. TAXADVISOR is the chosen prime example of the application to accounting decision making.

Case Twenty-one

TAXADVISOR **Tax Planning** (R. Michaelsen and D. Michie)

TAXADVISOR is an ES designed to make estate-tax planning recommendations that will enhance the client's wealth: life insurance, investment planning, gifts, tax-shelters and retirement provisions are areas of consideration. The system interacts with the tax consultant and functions in a consultative paradigm. Querying is based on a hierarchical decomposition of relevant areas. Most questions request a positive or negative response. A list of recommendations are produced guiding the human consultant toward appropriate action.

Dimensions for Case Twenty-one	TAXADVISOR	Tax Planning
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Data Dimension

Source of data: The human tax adviser responds to the system inquiries to guide the overall path of the consultation.

Volume of data: A mid-range data requirement results from consideration of the various elements relevant to tax planning.

Complexity of data: Positive or negative response questions dominate system interaction: low data complexity.

Longevity: The required data must be entered on a case by case basis, dependent upon client specific attributes and frequency of use.

Knowledge Dimension

Knowledge state: TAXADVISOR's knowledge is a static resource. Changes in tax laws would require modification of heuristics and guidance rules. Tax knowledge is essentially intermediate state knowledge due to government influences.

Knowledge structure: The hierarchical structuring of accounting knowledge observed in TAXADVISOR is consistent with a component synthesis approach applied to achieve an overall set of recommendations.

Evaluation/Analysis Dimension

The system incorporates both a screening/pruning and drill-down analysis styles; the former approach isolates areas of interest, while the latter enables the detailed examination of these areas.

Output Dimension

Text recommendations, in the form of tax planning advice, constitute the completion of a system consultation.

DSS/ES Dimension

Automated versus human control and Knowledge Coupling: TAXADVISOR functions on the basis of automated control with the consultation under the direction of the embodied knowledge. As a result, knowledge dimension coupling is extremely tight.

E) Insurance: The insurance sector is another application area for DSS/ES technologies within the financial industry; underwriting and claims assessment are target decisions under study. The proprietary nature of these developments lead to difficulty in the acquisition of detailed design information. However, limited general design elements can be hypothesized.

An *underwriting assessment* contains many components similar to commercial loan and credit assessment areas. In particular, an architecture similar to LASS (loan analysis support system), coupled with drill-down analysis of observed weaknesses, is potentially applicable to the underwriting problem. Inductive processes employing historical case results could be appropriate for the *claims assessment* area. Again, drill-down analysis could be utilized to obtain more detail when abnormal circumstances are observed.

Table 13 provides a summary of overall case decomposition, combining banking, investments, corporate finance and accounting cases.

Further Extensions: Enhancements to the customary DSS/ES technologies approach the broader complexity of business-oriented problems. Hart et al (1987) propose the incorporation of causal modelling to improve the analysis involved in the corporate assessment problem. Work in qualitative physics establishes confluence relationships (ie: direct and indirect relationships between variables) represented as a network variation illustrating both positive and negative flows from a resource. The technique can be applied in a business context through a depiction of balance sheet and income statement accounts. The integration of symbolic and mathematical

modelling is examined by Dhar and Croker (1988) through a constraint system based approach. The representation of both qualitative and quantitative constraints connected in an network, permits maximum flexibility in analysis and computation. User influence is further expanded through 'choice-sets', which represent alternative values for relevant problem elements. Automated or user selection from these choice-sets propagate results through the system of qualitative and quantitative constraints.

Financial Industry Cross-Sector Analysis:

Observed Trends, Commonalties and Differences

With the completion of the case-based analysis and the derivation of intra-sector commonalties, the next step in the progressive analysis involves an examination of overall significant commonalties and differences among financial industry areas. Sector comparison will be accomplished through the positioning of case groupings along the financial system continua discussed previously ³. Table 15 provides a graphical representation. The positioning of financial application areas along these continua will serve as a basis for cross-sector analysis. Comparisons of the sectors will be generated first on a dimension basis (ie: data, knowledge, analysis/evaluation, output and DSS/ES), and then from a cross-dimensional perspective.

Data Dimension: The four data sub-dimensions present several overall trends and features of the financial problem areas studied.

The examination of *source of data* characteristics reveals an emphasis toward a synthesis of database and user input; banking, corporate finance and portfolio management software cases all utilize this approach. Database access reduces the necessity for tedious time-consuming, voluminous user input; the result being increased accuracy and speed of data access. The user input facilitates customization of system operation permitting the most current information and qualitative assessments to be incorporated. The portfolio management literature cases rely on user input due to the customization features inherent in problem solution. Conversely, the trading applications (ie: stock and option trading) depend upon expedient access to accurate data available through external database access.

The *volume dimension* is skewed to the right; very few small structured data sets are utilized for problem solving. As a discipline, finance can be viewed as data intensive. Stock and option trad-

ing applications are the most data demanding, while credit assessment and capital budgeting rest at the lower ebb of the intensity scale. It is observed that unless an application is heavily skewed toward one end of the volume continuum, the dimension has limited effects on design considerations.

A survey of *data complexity* reveals the focus of financial applications on numeric data. Most qualitative textual components remain the responsibility of the human analyst; any integration of qualitative estimates usually involves quantification (ie: management rating: 1 - excellent, 2 - good, 3 - fair, 4 - poor). Specific case-oriented problems may necessitate the combination of textual and numeric input for successful customization; financial planning and portfolio management literature cases are prime examples.

The examination of the *longevity* characteristics emphasizes the currentness of data requirement of financial domains. Point-of-use updating facilitates customization and the incorporation of qualitative factors. Real-time data access requirements of stock and option trading areas further stress the importance of timely data. Only software package cases and financial statement analysis employ static periodic updates as a sole data maintenance mechanism. A direct relationship potentially exists between data intensity and data replacement speed; the relationship definitely holds for real-time applications (ie: stock and option trading). Another maintenance characteristic is FIFO data cycling; limited storage media necessitates this approach. Constant addition is instituted for systems utilizing inductive learning approaches (primarily in the banking sector) or past-case comparison (ie: PFIDSS case in portfolio management).

Knowledge Dimension: Both state and structuring characteristics of the knowledge embodied in the reviewed financial systems provide a basis for divisions and commonalities.

The *knowledge state* continuum indicates a division of financial problems between static and intermediate positions. Corporate finance and option theory are well-accepted static areas of expertise; the inclusion of corporate guidelines, heuristics and thresholds shift the sectors of banking, stock trading and portfolio management to an intermediate status. Accounting decision making is basically static in nature with well-defined procedures and approaches; the changing tax regulations, subject to governmental forces, contribute toward an intermediate status. The absence of dynamic knowledge areas is primarily due to a technological constraint:

developmental tools and approaches have not been developed to facilitate the rapid knowledge maintenance necessary for successful operation in such domains.

The *knowledge structuring* dimension illustrates the tendency of financial problem solving toward decomposition and synthesis; this approach involves segmentation of problem elements into manageable components or phases. All financial areas, with the exception of option trading, rely heavily on problem decomposition. Object-oriented techniques embody the segmentation philosophy exhibited in financial decision making. "Structuring any problem hierarchically is an efficient and intuitive way of dealing with complexity and identifying the relevant components of the problem" (Srinivasan and Kim, 1988). In particular, component synthesis structured knowledge is a prime candidate to effectively utilize these techniques; banking, financial planning, financial statement analysis, accounting and investment selection areas exhibit elements of component synthesis.

"The business environment is complex and ill-defined. Broad areas of knowledge are necessary to solve problems, and each application may require a different knowledge representation scheme" (Lee and Stohr, 1985). The problem solving structure inherent in many financial areas is static (ie: banking and portfolio management), while the incorporation of corporate or individualistic heuristics provides differentiation. The synthesis of object-oriented techniques and production rule technology facilitates an effective integrative knowledge representation: generic networks or hierarchies (special cases of networks) provide a convenient mechanism to represent the static, structural elements; production rules can direct interaction between structural components providing a flexible dynamic capability.

Evaluation/Analysis Dimension: The evaluation and analysis approaches employed focus on two fundamental methodologies: *screening/pruning* and *historical cross-industry trend* analysis. The former approach is utilized to narrow the solution or acceptance set throughout portfolio management, financial planning and investment areas; the credit card application within the banking area exhibits similar characteristics. Production rule technology provides customization with flexibility in the development of screening mechanisms. The latter approach facilitates establishment of standards and permits estimation of relative strength positions considering a

temporal dimension. The banking industry emphasizes historical and relative evaluations in the decision making process.

The usage of drill-down analysis to augment the predominant styles allows in depth examination of critical elements. Causal reasoning applications require the drill-down approach to achieve justification and isolation; commercial loan analysis and financial planning are example disciplines.

Two approaches have limited application within the cases examined: parameter variation and mathematical computational models. The sole application of parameter variation is the corporate finance domain of capital budgeting; the analysis flexibility requirement of this application necessitates an approach appropriate for user-driven control and manipulation. The rigidity inherent in the mathematical computational analysis is not conducive to the complexity of financial decision making.

Output Dimension: An examination of financial system results portrayed by system output displays significant commonality across sector boundaries. *Text oriented output* is the dominate source providing a mechanism for greater detail regarding explanation of system operations. In addition, many application areas require the integration of multimedia results; the combination of text with graphics and/or numerics is often necessary to aid in the understanding of effective decision making. These elements indicate the need for powerful, flexible report generation facilities having the ability to incorporate other output media.

DSS/ES Dimension: The incorporation of a knowledge dimension in the design of a financial system indicates the tendency toward knowledge control of that system. The combination of *tight knowledge coupling with automated control* is evidenced in a significant portion of the examined cases; banking, security trading and accounting applications exhibit these characteristics.

The capital budgeting application area and a portfolio management system of PFIDSS are exceptions to the predominantly knowledge-driven systems; both allow user control of a consultation path with the knowledge serving as a passive resource. In the case of capital budgeting, the flexibility of parameter variation analysis necessitates a combination of user and automated control;

this is not a common design feature. In most systems, the design is oriented towards either human or automated control.

Cross-Dimensional Observations: Several cross-dimensional commonalities and differences can be drawn from the case-based synthesis of financial DSS/ES systems. This perspective suggests synergy in development efforts among financial domains. Significant comparative findings will be discussed below.

Accounting and commercial loan sectors are positioned similarly along several continua. Due to the vast amount of regulation from both government and corporate sources, automated control with tight knowledge coupling attempts to reduce the cognitive load of regulation consideration for the human analyst. "ES takes care of the things we understand, so that we can concentrate on things we do not understand," (Morton of MIT in J. Friedland, 1988). Other common attributes include: a concentration on historical, numeric, financial data; utilization of a combination of user and database input; characterization of knowledge structure as component synthesis; incorporation of drill-down analysis; static periodic updates and point-of-use maintenance.

Stock and option trading applications are characterized as real-time systems, employing large data sets with automated control. The latter attribute results directly from processing time constraints for effective decision making. Systems within the trading areas can be viewed as components of a larger overall system which executes, monitors, suggests and records trading transactions.

Several commonalities are evidenced in *case-oriented* decision making disciplines; individualistic characteristics of clients, projects and decision making environment are entered as a component of system operation. Data dimension attributes are common among banking, portfolio management software and corporate finance sectors. The output dimension illustrates a requirement for integration of text with some other media.

A fundamental difference in the application of ES technology presents a division in financial applications. *Explanation-based ESs* rely on the reasoning explanation capability of ES technology to interact with and then inform the user during system operation; banking and portfolio management ESs are prime examples. *Interface ESs* provide interaction through changes in the

direct user interface; examples are trading applications and capital budgeting. Interface ESs tend toward DSS-style systems; the knowledge explanation facility, a distinguishing characteristic of ES technology is not heavily utilized.

2.2.3 Design Limitation

The common dimensions developed may contain elements which pertain to a specific class of problems, and as such may not represent a completely generic appraisal. The case-based methodology employed in the research, together with the proprietary nature of many projects, may have resulted in a narrowed scope of projects surveyed.

Part 3 Money Market Preferred Shares

3.1 Background

Innovative financial instruments usually require specialized knowledge, techniques and heuristics in order to take full advantage of the characteristics inherent in the instrument. These characteristics lend themselves to DSS/ES methodologies, and the incorporation of the technologies within the specialized financial decision making process offers potential for enhanced use of capital market innovations.

Money Market Preferred Stock (MMPs) represent an innovation developed by capital markets to tailor a financial product to meet market demands and conditions. The first issue of MMP shares was issued in June, 1984 by American Express Co. The MMP is a variation of traditional preferred stock, with a primary differentiating feature being a flexible dividend rate which is set at definite time intervals by a Dutch-Auction process⁴. These equity instruments have enjoyed tremendous growth in popularity and as of May 1989, there were one hundred and ninety seven issues of MMPs outstanding with a total value of 25.1 billion dollars (Salomon Brothers, 1989). A full disclosure with respect to the characteristics, motivations and issues surrounding MMPs is given by Jog & Deshpande, 1987.

3.1.1 The MMP Dividend Rate: A Dutch- Auction Process

The prime differentiating feature of MMPs is the periodic resetting of the dividend rate of the stock by market forces through a Dutch-Auction process. This section examines in greater detail the auctioning characteristics of MMPs.

Upon initial issuance, the annualized dividend rate stipulated on the MMP by the issuer serves as the dividend rate for the first 49-day cycle. For all future cycles, the dividend rate is set through a Dutch-Auction process. An auction agent, usually a commercial bank, facilitates MMP buyer-seller interaction in an attempt to balance the supply and demand forces in the market.

Assume we are at the first MMP auction date following the initial 49-day cycle. Two market participants are involved in the auctioning process: 1) an *MMP-holder* who currently owns shares of the specific MMP issue being auctioned and 2) an *MMP-buyer/ bidder* who wishes to acquire

shares of this MMP issue. We will now examine the options available to these MMP market participants.

1) A current *MMP-holder* has three options: a) maintain his current holdings and receive the dividend rate set by today's auction for the next 49-day cycle, b) submit a dividend rate at which he would be willing to maintain his holdings, or c) to sell his position at par, subject to the availability of sufficient buy-orders. In the latter case, the MMP-holder becomes an MMP-seller; similarly, if the MMP-holder exercises the second option and the auction-set dividend rate is below the submitted rate, the holding is sold at par.

2) A potential *MMP buyer / bidder* can bid for the security by submitting the number of MMP shares he/she wishes to purchase, stating the minimum dividend rate at which he/she is willing to purchase these securities.

The auction agent matches the bids from potential bidders with the orders of existing holders. The dividend rate for the next 49-day cycle, called the win rate, is set at the lowest rate which clears the auction. Following a successful auction, this single win rate is applied to all MMPs, and all bids by existing holders and bidders with a rate above this auction rate are rejected. Appendix 3 provides an example of a successful MMP auction.

This thesis develops a prototype to support the MMP bidding process from the bidder's perspective. The bidder's task involves the generation of appropriate, minimum dividend rates (bid rates), with the goal of winning the auction. A variety of factors can influence the appropriate bid rate for a particular MMP auction: a) macroeconomic factors, such as interest rates, particularly the commercial paper rate, b) the dividend rates received on other MMP issues, c) issue specific factors and d) bidder specific factors, such as applied tax rates. The desire of the MMP bidder is to set his/her bid rate exactly equal to, or fractionally below the auction set win rate, thus ensuring acceptance of the purchase bid and maximizing return. The design of a computer-based DSS/ES prototype to support the MMP bidder's decision serves as the focal point for the second component of the research.

3.2 Conceptual Modelling of the MMP Bidding Decision

A conceptual modelling of the MMP bidding decision formed the foundation for an analysis of support requirements necessary for effective decision making; this analysis constituted the basis for DSS/ES design. Jog and Deshpande (1987) provided a foundation for an MMP bidding model; further components and capabilities were necessary additions to derive an effective decision making model.

Jog and Deshpande (1987) analyse various aspects of the MMP bidding decision; an integral part of their investigation concerned the identification of decision rules or bidding strategies to specify a bid rate which would maximize the probability of a successful bid. The following salient characteristics of the Jog and Deshpande study serve to identify key elements of an MMP model. a) The analysis was based solely on historical MMP auction data, thus emphasizing a significant element of the decision making process. b) An evaluation mechanism was established for strategies; a strategy which results in a bid rate equal to or marginally less than the corresponding auction win rate, was considered optimal. c) Three example classes of bidding strategies were proposed: naive, distribution-based and matching security strategies. These three classes of strategies will be discussed below and as will be seen later, these will form the basis for the strategy component in the support prototype.

The three classes of strategies hypothesized were:

1) *Naive strategies* forecast the win rate of the forthcoming auction based on the assumption that the win rate for a j th MMP is determined solely by the win rate of the same security at the previous auction. The win rate is expressed as a percentage of commercial paper rate (or prime rate). For example, if the win rate for a specific MMP on the last auction was 74.1% of the commercial paper rate, the forecasted win rate (bid rate) for the next auction would be 74.1% of the contemporaneous commercial paper rate. In order to pursue this strategy, the data required is the win rate of the previous MMP auction.

2) *Distribution-based bidding strategies* assume that the win rate of the j th MMP in the forthcoming auction is determined by averaging the changes in win rates of the most recent auctions of other MMPs, expressed as a percentage of the commercial paper rate. For example, if we assume that there have been 'n' auctions of other MMPs between the last auction of the j th MMP and the

forthcoming auction, then the forecasted win rate (bid rate) can be expressed in the following formula:

$$b_{oj} = \left[\frac{1}{n} \sum_{i=1}^n \frac{C_{oi}}{C_{-1i}} \right] \times C_{-1j} \times CP_0$$

where:

b_{oj} = the bid rate for security j on the forthcoming auction.

C_{oi} = the winning dividend rate for security i in an auction which takes place between the last auction for security j and the forthcoming auction, expressed as a percentage of the commercial paper.

C_{-1i} = the winning dividend rate for security i on the auction prior to where C_{oi} is measured, expressed as a percentage of commercial paper rate.

C_{-1j} = the winning rate for security j in the auction prior to the forthcoming auction, expressed as a percentage of the commercial paper rate.

CP_0 = the contemporaneous commercial paper rate.

Obviously, this distribution-based strategy proports that changes in win-rates of other MMPs influence the win rate for the jth security. Consequently, there is a demand for an expanded data set to include the win-rates of other MMPs of interest in the previous two auctions. Variations in this class of strategies are dependent upon the set of MMPs being employed for computation. Jog and Deshpande classify MMPs into four categories: industrial, financial, utility and thrift subsidiary; these categories form the basis for a variation of in the bid rate for this type of strategy.

3) The third class of bidding strategies is termed a *matching-security* strategy. This strategy entails the determination of a security i for which the changes in win-rates are closest to the changes in win-rates for the target MMP of security j in the two previous auctions. Mathematically, this relationship can be expressed as:

$$\text{Minimum } |\Delta_{-1j} - \Delta_{-1i}|$$

$$\text{where: } \Delta_{-1j} = C_{-1j} - C_{-2j} \text{ and}$$

$$\Delta_{-1i} = C_{-1i} - C_{-2i}$$

Following the determination of the matching security i , the bid rate for security j is determined as follows:

$$b_{0j} = (C_{1j} + \Delta_{0i}^*) \times CP_0$$

where Δ_{0i}^* is the change in win-rates for the matching security i^* .

The data set required for the implementation of the matching-security strategy contains the win-rates of other MMPs for the last two auctions. The increased size of this data bank would conceivably improve the choice of a matching security. Thus is similar to the second class of strategies.

The above outlined strategies account for issue-specific factors only in the industry or the MMP-classification level. Inclusion of alternative strategies based on other factors relying on non-historical data, must be supported in any prototype. The overall approach taken by Jog and Deshpande can be characterized as a closed DSS environment, which severely restricts user influence with respect to system operation and results. A typical MMP support system would not only embody the characteristics inherent in the Jog and Deshpande approach, but must also facilitate a great deal of user influence to reflect the expansion requirements and expertise associated with the MMP environment. These requirements are due to a wide variety of influential factors, the resultant variations of computational formulae and differing approaches to bidding strategy selection. A model which supports the necessary capabilities is outlined below.

The conceptual model for the MMP bidding problem was envisioned to have the following four components: 1) data input/modification, 2) strategy definition/modification, 3) strategy selection and 4) evaluation component. Elements involved in each of these components will be discussed below.

1. *Data Input/Modification*: Several different types of data serve as a basis for an MMP bidding decision. Provision for inclusion of each type forms an initial building block for system design. Three classes of data warrant consideration. First, *macro-economic, issue-specific and bidder-specific data* allows the customization and consideration of a wide variety of alternative factors in deriving and selecting the appropriate bid rate. For example: a specific bidder may consider the underlying company's stock price to be an important factor in the determination of an appropriate bid rate. The flexibility to define and modify the factors used by the system is essential. Secondly,

new issues of MMPs will appear over time. A mechanism to incorporate these new MMP issues and to allow the generation of bids for them permits the system to maintain currentness. Thirdly, *MMP auction data* must be maintained to ensure accurate computation and comparison of bid rates to actual results.

Under this scenario, the MMP bidding system should incorporate both historical data, in the form of auction statistics, and the various forms of current variables. Flexibility of change and addition through user interaction is a key consideration.

2. *Strategy Definition/Modification*: Alternative formulae for the computation of bid rates are feasible; these formulae can be based on historical auction data, on factor-values, or on a combination of the two. The ability to construct or modify the available computational formulae facilitates further bidder-specific customization of system operation.

3. *Strategy Selection*: The selection of an appropriate computational formula for the bid rate can take advantage of rule-based methodologies. Particular bidding strategies may be optimal under a specific set of conditions prevailing on the auction date. The construction of rule-based mechanisms to specify optimality conditions for alternative strategies offers potential to improve bidding strategy selection and hence, the auction bid rate. A support prototype should permit change of selection procedures, as well as provide a default selection mechanism.

4. *Evaluation component*: To determine the relative effectiveness of alternative bidding strategies, an evaluation facility must be provided. The evaluation of strategies is based on the ability of those strategies to closely estimate auction win-rates without exceeding the win rate. The strategy which generates a bid rate equal to or marginally less than the auction bid rate, is considered the superior strategy (Jog and Deshpande, 1987). For example: If there are three strategies of A, B and C and the auction win rate is 4.9%. Suppose strategy A generates 4.6% as the bid rate, while strategy B generates 4.7%, and strategy C generates 5.0%. Under this scheme, strategy B would be optimal because it most closely underestimates the auction win rate. Strategy A would be ranked second, while strategy C would be eliminated because the generated bid rate exceeds the win rate. A prototype should support the capability to modify and create additional evaluation mechanisms to facilitate further flexibility.

This component permits the bidder to gain perspective regarding the relative strength of various strategies for particular MMPs on the basis of historical performance, thereby potentially influencing selection heuristics.

As will be seen in the next section, three of the above components are supported through DSS technology: the data input/modification, strategy input/modification and evaluation component (#1, #2 and #4). The strategy selection component (#3) is supported through the capabilities of ES technology .

3.3 MMP Prototype Development Process

Salient problem characteristics impact all aspects of the prototype development process. Decisions regarding initial software and hardware selection through to the on-going prioritization of development tasks are fundamentally influenced by these characteristics.

Software/Hardware Selection: For any prototype development effort, the software/hardware selection is a crucial preliminary consideration which impacts the feasible, effective and successful completion of a project. The following pertinent features of the MMP problem necessitated specific capabilities which had to be embodied in the chosen development platform. First, the *dynamic system structure* required a mechanism which would permit the flexible incorporation of new components into the system. Secondly, the *volume of data* requirement combined with the *emphasis toward database access* for information retrieval, required the ability to access external databases for MMP auction and issue information. Thirdly, due to the *high degree of bidder interaction* the prototype had to embody the ability to manipulate additional data, strategies and selection heuristics upon bidder specification. The potential users of such a prototype do not want to become involved in complex, time-consuming computer-based interaction; thus, the appropriateness of a graphically-oriented user interface reduces the associated system learning time. Finally, the strategy selection component of the prototype utilizes the features of ES technology, necessitating the choice of an ES shell as a basis for a development platform; alternative development approaches were deemed time prohibitive. Due to extensive demands of the MMP problem, the ability to supplement the ES platform capabilities with the incorporation of external routines written in high-level languages was another important consideration.

To fulfil the set of requirements outlined above necessitated the integration of several hardware/software elements. To support the dynamic system structure, the concepts surrounding object-oriented systems including dynamic object creation/deletion, inheritance, class structures and instantiation are all ideally suited for such a flexible environment. The sole personal computer-based *ES shell* encompassing this fundamental object-oriented paradigm, combined with database access capabilities and external routine linkage was Nexpert Object ES shell from Neuron Data, California, USA. The chosen *hardware platform* was the Apple Macintosh because this environment inherently facilitates graphical user interface design; another influential factor was the availability of a mouse-based graphical interface builder for Nexpert Object (called AI Vision) only for the Macintosh.

Support System Specifications : The component-based conceptual model of the MMP bidding decision fundamentally impacted the development process of the resultant MMP bidding prototype. The prototype itself follows a component-based structure with a direct mapping between conceptual components and development components. Table 16 below illustrates the direct correlation between the prototype components and the conceptual model.

MMP Prototype Specifications

Table 16

Conceptual Model	Implementation Model
1. Data Input/Modification	1. Data Elements MMP Data
2. Strategy Input/Modification	2. Bidding Strategies
3. Strategy Selection	3. Strategy Selection
4. Evaluation Component	4. Strategy Evaluation Evaluation Query

Pertinent issues, functionality and features of the components of the MMP bidding prototype will be discussed below with a linkage to the conceptual model.

1 a. *Data Elements* : This component facilitates entry and modification of non-historical based variables: issue-specific, bidder-specific and macro-economic variables⁵. Two types of variables are incorporated. First, *global variables* represent factors for which there is a single value throughout the entire MMP bidding system. An example global variable could be the current

commercial paper rate. Secondly, *MMP variables* represent factors common to all MMP issues allowing the association of a variable with each MMP issue without time consuming repetitious data entry; these variables retain their own values for each MMP issue. For example: If stock price is an MMP variable, each MMP issue in the system would have a stock price variable associated with it, but each MMP issue could hold a different value for the actual stock price.

b. *MMP Data* : The incorporation of MMP issue specifications and the corresponding auction results represent a fundamental data component for any MMP bidding system. This component maintains historical auction data in correlation with MMP issue entry. MMP auction histories were obtained from Solomon Bros. Investment Corp., New York, USA. The form of the received data for each MMP issue was as follows: date of the auction, the auction win rate and the auction win rate as a percentage of the contemporaneous commercial paper rate.

Knowledge of MMP issues must be incorporated into the MMP bidder prototype to facilitate discriminating bids. Upon entry of each additional issue, the new issue must be given a identification name, along with the name of the issuing company, the MMP classification and a filename to serve as a source for auction data. The appropriate MMP classification is one of the following: industrial, financial, utility or thrift subsidiary. These classifications facilitate the definition of group or industry-based strategies such as the distribution-based form of Jog and Deshpande discussed previously.

The components of MMP Data and Data Elements combine to develop the data input/modification component of the conceptual model. The flexibility and high degree of user influence and interaction inherent in these components are characteristic of DSS methodologies.

2. *Bidding Strategies* : There is a direct correspondence between the bidding strategies component of the MMP prototype and the Strategy Input/Modification element of the conceptual model. This facility allows entry and modification of bidding strategy formulae comprised of previously defined data; this flexibility is characteristic of DSS technology. Four strategies, drawn from Jog and Deshpande (1987), form the basis for the current implementation of the prototype; these strategies include: one naive strategy, two distribution-based strategies and the matching security strategy. These strategies required the use of external routines written in the high level language C for successful implementation.

3. *Strategy Selection* : The selection of an appropriate bidding strategy to generate an auction bid rate has the potential to take advantage of the rule-based heuristic approach of ES technology; the inherent explanation capability is of great utility for training inexperienced bidders. This component permits the development and use of rule-based approaches for the strategy selection process.

The direct usage of the Nexpert Object environment allows the bidder to choose one of two options: execute a default strategy selection knowledge base or enter rules for the construction of their own knowledge base. The default knowledge base was developed in consultation with a money manager from the Ottawa area and through telephone conversations of Prof. Deshpande with four actual MMP market participants⁶. The exact composition of this default knowledge base will be discussed in detail in section 3.3.2.

4. *Strategy Evaluation and Evaluation Query* comprise the evaluation component of the conceptual model.

4a. *Strategy Evaluation* : This component of the prototype evaluates alternative bidding strategy performance for a particular MMP issue or MMP classification. A single evaluation mechanism is available in the current system which ranks alternative strategies on the basis of historical auction performance. A formatted report displays the results.

4b. *Evaluation Query* : This component can be used to augment or modify the evaluation mechanism. External routines are necessary for successful operation.

Another feature of the prototype development process warrants consideration. A sequential phased approach was required. It was necessary to develop the input/modification facilities prior to developing evaluation and selection facilities, as the data and strategies serve as a basis for the final two components. Similarly, the data input/modification facilities were developed prior to the corresponding strategy facility.

Appendix 2 provides a synopsis of further technical aspects of the development process. The MMP prototype knowledge base is available on request from the author. This development effort is a prototype intended to investigate the feasibility of integrating DSS/ES technologies to solve the

Overview of MMP Bidding Along DSS/ES Dimensions

Table 21

Dimensions	MMP Bidding Positioning
1. Data Dimension a) Source of Data b) Volume of Data c) Complexity of Data d) Longevity of Data	Database Access Large Numeric Periodic
2. Knowledge Dimension a) Knowledge State b) Knowledge Structure	Dynamic Component Synthesis and Sequential Stage
3. Evaluation/Analysis Dimension	Comparative/Trend Analysis, Screening/Pruning and Drill down
4. Output Dimension	Numeric
5. DSS/ES Dimension a) Automated vs Human Control b) Knowledge Dimension Coupling	Human Control Loose

Fundamental elements justifying the above assessments will now be discussed.

a) *Data Dimension*: The MMP problem utilizes a combination of database access and user input to serve as the *source* of data; the tendency towards database access is due to the volume of historical data. A substantial percentage of this data is auction data on which strategy analysis is based; thus, *volume* warrants a mid-range evaluation. The reliance on fundamental numeric data, integrated with potential qualitative assessments, characterize the MMP problem as low *data complexity*. The predominant *update cycle* utilized is static, periodic for auction data; occasional point-of-use inquiries are feasible. Continuous addition characterizes the *longevity* dimension as past auction results influence bidding alternatives. As a group, these characteristics exhibit similarities to the banking sector of the financial industry.

b) *Knowledge Dimension*: The knowledge *structure* incorporates elements of both sequential stage analysis and component synthesis. An effective MMP system can be decomposed into the four components discussed above. These components follow a logical, sequential ordering in the decision process; hence, sequential stage structure is also applicable. A distinguishing characteristic rests with the knowledge *state*: the incorporation of new data elements, bidding strategies and

test the system has a general knowledge of this material. The bidder interaction associated with either of these options will be presented in a simple example walkthrough.

a. Approach One

After initial system startup and choosing the strategy selection icon, the bidder chooses run from the active strategy selection screen. Following a brief pause, the default strategy selection knowledge base will be activated, requesting relevant information from the user in order to generate an appropriate bid rate. Table 17 below outlines the system inquiries, suitable responses and justification for inquiry inclusion.

Default Selection Knowledge Base Overview

Table 17

Inquiry	Suitable Responses	Justification
1. For which MMP do you wish to bid?	Any valid MMP name.	Isolates the appropriate MMP.
2. What is the trend in overall bid rates?	+ increasing - decreasing = no trend	Trends in overall and sector bid rates are the factors determining the appropriate base strategy.
3. What is the trend in sector bid rates?		
4. What is the current commercial paper rate?	Positive floating point number.	Necessary to computation base strategy rate.
5. What is the current trend in the money supply?	+ increasing - decreasing = no trend	Inverse relationship between level of money supply and the expected bid rates.
6. What is the trend in the difference between the commercial paper rate and the LIBOR rate?	+ widening - narrowing = no change	The difference between the commercial paper rate and these two rates of return indicate a necessary adjustment - an inverse relationship.
7. What is the trend in the difference between the commercial paper rate and the rate on tax free municipal bonds?		
8. What have been the sector events recently?	+ positive - negative = none	Events within a sector have a direct relationship with the appropriate bid rate.
9. What have been the company specific events recently?	+ positive - negative = none	Company specific events have a direct relationship with the appropriate bid rate.
10. What is the relative size of the MMP issue?	Large Small Unsure	The win rates on small issues are potentially influenced by large bidders.
10a. Is the bidder potentially influential on the resulting win rate?	True False	(Asked only if Small is chosen in question 10.) The bidder <u>could</u> influence the win rate.
11. What is the bidder's current position in this MMP security?	Existing holder New bidder	A new bidder bids aggressively. Adjust the bid rate.
11a. Which factor is most important to you as an existing holder?	Rate of return Maintain holding Undecided	(Asked only if an existing holder is chosen in question 11.) If you choose Rate of return, adjust upward. If you choose Maintain holding, adjust downward.

Questions one through nine are asked in sequential order due to the nature of this sample knowledge base. The potential branching mechanisms are illustrated in inquiries 10 and 11.

The following represents a brief discussion of the overall structure of the strategy selection knowledge base incorporated in the MMP bidder.

Base Strategy Selection Criteria

Table 18

		Overall		
		+	=	-
Sector	+	Distribution 2	Distribution 1	Best
	=	Distribution 1	Naive	Distribution 1
	-	Best	Distribution 1	Distribution 2

There are two fundamental components. The first component determines the appropriate base strategy. Trends in the overall and sector win rates guide this selection. Table 18 provides the base strategy selection criteria for the default knowledge base. The second component analyses appropriate adjustments to the base strategy bid rate on the basis of selected macroeconomic, issue specific, and bidder specific factors. Table 19 illustrates the underlying relationship between relevant variables and bid rate adjustments embodied in the current implementation.

Bid Rate Adjustment Relationships**Table 19**

Adjustment Factor	Appropriate Adjustment	Relation-ship
Money supply increases	Decrease bid rate	Inverse
Commercial paper rate minus LIBOR increases and Commercial paper rate minus tax free muni. bonds increases	Decrease bid rate	Inverse
Sector events positive	Increase bid rate	Direct
Company events positive	Increase bid rate	Direct
Issue is small and potential for bidder influence exists	Decrease bid rate	-
Bidder is existing holder and rate of return is more important than maintaining holding	Increase bid rate	-
Bidder is existing holder and maintaining holding is more important than rate of return	Decrease bid rate	-
New bidder bids aggressively to gain shares	Decrease bid rate	-

A concrete example will clarify the approach taken in the selection knowledge base. Appendix 6 outlines the rule-based structure of this knowledge base along with the output generated by a consultation embodying the responses of table 20 below.

characteristics of DSS technology. Strategy selection possesses the ability to take advantage of the reasoning and explanation facilities inherent in ES technology.

Several barriers to the effective technological integration surfaced with the progression of the development process. Using an ES shell as the development platform, the number of rules was directly proportional to the number of available actions. This interconnection increased the complexity and associated development time. The computational nature of financial problems required the use of external high-level language routines for efficient interaction. The interface to this external environment was a complex programming intensive task. In the author's view, the combination of computational restrictions and complex external environment interfaces will restrict, in the short run, the usage of personal computer ES shells as a development platform for financial problems. External environment interface design for ES technology is a direction for future research. At present, the addition of ES functionality to programming environments represents an approach which addresses these weaknesses.

b. Approach Two

To design his /her own MMP bidding system, a bidder proceeds through the following steps:

1. Decide on the appropriate variables to be used in strategy and heuristic definition.
2. Define any additional MMP issues.
3. Define any additional strategies.
4. Evaluate the performance of his /her strategies.
5. Develop strategy selection heuristics.

Elements involved in each of these steps will be discussed briefly below:

- Step 1: Global variable definition: Enter the name, type and one of prompt or expression fields to facilitate specification of a value for the variable. MMP variable definition: specify the name and type of the variable. The value is specified in the file associated with the MMP issue.
- Step 2: Specify a name, MMP classification (financial, industrial, utility or thrift subsidiary), and the filename containing the associated data and values for MMP variables.
- Step 3: Specify a name, one of formula or execute to compute the value for the strategy. The formula field allows entry of simplistic mathematical formula (ie: $a + b$), while execute represents a filename of a high level routine to be executed allowing complexity.
- Step 4: Select a particular MMP issue or MMP class as the scope of evaluation. Enter the evaluation query to be applied. In the current system, only the 'best' query exists. Choose the report button to generate a text-based evaluation report, called 'MMP. Best'. New queries can be added to the system by specifying a name and a filename for the external routine which performs the evaluation.
- Step 5: Developing strategy selection heuristics implies direct entry into the Nexpert Object knowledge construction environment. Heuristic networks can be developed employing data, strategies and evaluation criteria defined above. This development necessitated knowledge of Nexpert Object's development environment.

Part 4 DSS/ES Technologies and MMP Bidding: Significance and Implications

Upon the completion of the prototype development effort, we can now gain a final perspective of the significance and associated implications provided by the detailed examination of the MMP bidding problem. The significance is drawn from technological integration and the employment the MMP problem as a verification case for the DSS/ES design dimensions developed in the first component of the thesis. Difficulties encountered during the development process provide implications for future integration efforts.

The examination of technological integration was a prime motivating factor in the choice of the MMP bidding decision. Three components of the MMP bidding conceptual model utilize the capabilities of DSS technology while the fourth element incorporates ES technology. The MMP bidding decision is a real-world problem that can be addressed by a DSS/ES system, as an effective design would be of great utility to MMP bidders in the course of making their decisions. The main goal of this prototype was the examination of the integration of DSS/ES technologies within the context of financial decision making.

4.1 Positioning the MMP Problem Along Financial Dimensions

The characterization of the MMP bidding problem in terms of the financial dimensions outline in the first component of the research provides a verification mechanism for these dimensions. Table 21 below presents an overview of the positionings.

Overview of MMP Bidding Along DSS/ES Dimensions

Table 21

Dimensions	MMP Bidding Positioning
1. Data Dimension a) Source of Data b) Volume of Data c) Complexity of Data d) Longevity of Data	Database Access Large Numeric Periodic
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4. Output Dimension	Numeric
5. DSS/ES Dimension a) Automated vs Human Control b) Knowledge Dimension Coupling	Human Control Loose

Fundamental elements justifying the above assessments will now be discussed.

a) *Data Dimension*: The MMP problem utilizes a combination of database access and user input to serve as the *source* of data; the tendency towards database access is due to the volume of historical data. A substantial percentage of this data is auction data on which strategy analysis is based; thus, *volume* warrants a mid-range evaluation. The reliance on fundamental numeric data, integrated with potential qualitative assessments, characterize the MMP problem as low *data complexity*. The predominant *update cycle* utilized is static, periodic for auction data; occasional point-of-use inquiries are feasible. Continuous addition characterizes the *longevity* dimension as past auction results influence bidding alternatives. As a group, these characteristics exhibit similarities to the banking sector of the financial industry.

b) *Knowledge Dimension*: The knowledge *structure* incorporates elements of both sequential stage analysis and component synthesis. An effective MMP system can be decomposed into the four components discussed above. These components follow a logical, sequential ordering in the decision process; hence, sequential stage structure is also applicable. A distinguishing characteristic rests with the knowledge *state*: the incorporation of new data elements, bidding strategies and

bidding strategy selection heuristics are fundamental to successful decisions in this domain; as a result, the application is best portrayed toward the dynamic end of the knowledge state continuum. For the systems reviewed, the MMP problem requires the most dynamic knowledge state. The ability to analyze past auction history through an inductive process is also applicable.

c) *Evaluation/Analysis Dimension*: The analysis style incorporates components of comparative/historical, screening/pruning and the drill-down analysis. The historical analysis is preformed on the basis of past auction performance of alternative bidding strategies; screening/pruning elements enter in the selection of the 'best' strategy; drill-down analysis could improve strategy selection through the explanation facility.

d) *Output Dimension*: The necessary output for successful MMP decisions is numeric in nature. In most cases, the output would be represented by a percentage of the commercial paper rate and/or a ranking of alternative strategies.

e) *DSS/ES Dimension*: The dynamic nature of the MMP bidding problem necessitates human control and modification of system building blocks. The ability to modify data strategies and selection heuristics implies a flexibility requirement which is not incorporated in many financial decision making systems. The strategy selection does contain some elements of automated control, primarily due to the construction of an ES on the basis of user-defined data, strategies and selection heuristics. Knowledge coupling tends toward the loose end of the continuum; the defined data and strategies influence the selection heuristics employed in the knowledge component.

4.2 Developmental Difficulties

Several factors contributed to the time consuming nature of the prototype development effort. Restrictions and difficulties occurred during development within the Nexpert Object ES environment while attempting to accommodate the flexibility inherent in the MMP problem. Two areas of fundamental difficulties are outlined below.

1) The flexible user-driven interface requirement of the MMP problem uncovered a direct relationship between the number of rules required and the number of actions available to the user at any point in time. Due to this strong interconnection, any changes in the user interface necessitated corresponding changes in the ES rules. Figure 7 illustrates this concept. The first compo-

ment of the right hand side actions creates a global data definition object while the remaining elements specify the user interface considerations (ie. establishing appropriate system conditions to allow the appearance of the appropriate system component). In the author's opinion, there should be some allowance for separation between user interface considerations and ES rules. The Hypercard bridge is expected to provide this functionality.

Figure 7**Example User Interface Difficulties**

```
(@RULE= GlobalDefinitionAccept
  (@LHS=
    (Yes (GlobalVariableDefinitionOptionSelected))
    (Is (GlobalVariableDefinitionOption) ("Accept"))
    (Execute ("NotObjectExists"))
    (@ATOMID=GlobalVariableTemplate.name;))
    (Yes (GlobalVariableDefinitionAcceptOk))
  )
  (@HYPO= GlobalVariableDefinitionAccept)
  (@RHS=
    (Execute ("BuildGlobalVariable"))
    (@ATOMID=GlobalVariableTemplate.comment,\
GlobalVariableTemplate.expression,GlobalVariableTemplate.name,\
GlobalVariableTemplate.prompt,GlobalVariableTemplate.type;\
  ))
    (Execute ("CreatePossibleGlobalVariableNamesRule"))
    (Reset (GlobalVariableDefinitionAccept))
    (Reset (GlobalVariableTemplateTypeOk))
    (Reset (GlobalVariableDefinitionAcceptOk))
    (Reset (GlobalVariableDefinitionAcceptNotOk))
    (Do ("Clear") (GlobalVariableDefinitionOption))
    (Do (TRUE) (SystemChanged))
    (Do (GlobalVariableDefinitionOption)
      (GlobalVariableDefinitionOption))
  )
)
```

2) The complexity associated with the implementation of external routines presented continuing challenges. Nextpert Object has a complex library of callable routines which can be used in the construction of external routines, but to incorporate their functionality required C expertise and continual manual reference. For example: The mathematical limitations necessitated the development of routines to support complex strategy formulae and evaluation computations. Overall, 35 external routines were needed to implement various aspects.

The dynamic nature of this MMP bidding problem has extensively tested Nexpert Object's capabilities. In the author's opinion, several aspects of the system had not been fully tested. Technical assistance from Neuron Data's knowledge engineers was available through a computerized bulletin board; a total of 32 query messages were necessary in the problem solving process. Due to problem reports, new versions of both the Nexpert Object Shell and the AI Vision Interface Builder replaced the original versions. The fact remains that without the flexible characteristics of Nexpert Object provided through the object-oriented techniques and the provision for the integration of external elements, an ES shell could not have been used as a development platform.

4.3 Implications of MMP Development for Technology Integration

The MMP prototype development process has interesting implications for other projects attempting to integrate technologies. With integrating technologies, strengths of both must be derived from their synthesis. The independent power of each technology is irrelevant if an effective communication bridge is not established. More emphasis must be placed on the design of interfaces as an essential component of system design and development. From a personal perspective, the design of object-oriented data type interfaces embodying the principal of information hiding reduces user concern for implementation detail.

The MMP bidding prototype may have been more efficiently implemented in an object-oriented programming environment, with the reasoning and inferencing capabilities of ES technology being added through interfacing and/or unification. This approach would allow the flexibility to define or change problem structure, while still facilitating inferencing on the basis of this structure. A separation between problem structure (for example: objects) and the resulting inferencing would dramatically reduce development time.

Part 5 Research Summary

This final section of the thesis provides direct linkage between the motivating research questions and the results derived from the study. This synopsis is decomposed in a manner parallel to the dual component structure of the thesis.

The first component of the research was the examination of commonality in DSS/ES system design for financial decision making, addressing the existence of common dimensions which form a framework for DSS/ES system design. The examination of characteristics which can be viewed along continua to facilitate maximum flexibility, suggests that a commonality framework is feasible. These key variables were grouped into five dimensions: data, knowledge, evaluation/analysis, output and DSS/ES. Several of these dimensions are further decomposed to provide more in depth analysis. a) The data dimension encompasses the source, volume, complexity and longevity of data. b) The knowledge dimension entails both the state and structure of the associated problem solving knowledge. c) The DSS/ES dimension is decomposed into human versus machine control of the decision making process, and knowledge coupling which governs the degree to which the associated knowledge dictates system behaviour. Various financial DSS/ES systems have been analyzed and positioned relative to these dimensions.

The second component of the research proposed a detailed examination of a particular financial decision making problem, namely MMP bidding. The characteristics associated with MMP bidding facilitated an in depth examination of issues involved in the integration of DSS/ES technologies for an effective solution. The development of a DSS/ES prototype to support this MMP bidding decision was the focal point. This focused perspective also provided a simple verification check for the dimensions developed in the first component.

The purpose of the prototype was to examine the feasibility of integrating DSS/ES technologies in providing a solution to a real world financial problem. Necessary features and implementation barriers were of prime interest. Pertinent problem characteristics facilitated the software selection and task prioritization processes. The prototype design and development identified essential features to be embodied in an effective DSS/ES system for MMP bidding. Flexible data and strategy definition facilities combined with expandable evaluation capabilities, all tend toward the

characteristics of DSS technology. Strategy selection possesses the ability to take advantage of the reasoning and explanation facilities inherent in ES technology.

Several barriers to the effective technological integration surfaced with the progression of the development process. Using an ES shell as the development platform, the number of rules was directly proportional to the number of available actions. This interconnection increased the complexity and associated development time. The computational nature of financial problems required the use of external high-level language routines for efficient interaction. The interface to this external environment was a complex programming intensive task. In the author's view, the combination of computational restrictions and complex external environment interfaces will restrict, in the short run, the usage of personal computer ES shells as a development platform for financial problems. External environment interface design for ES technology is a direction for future research. At present, the addition of ES functionality to programming environments represents an approach which addresses these weaknesses.

2 OF/DE 2

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

Part 6 End Notes, Appendices and Tables**End Notes**

1. 'Money Market Preferred' stocks (MMPs) are equity for which the dividend rate paid for shares is set periodically by Dutch-auction process (the standard for USA being every 49 days). The rate received for these shares is the lowest dividend rate which clears the 'supply & demand' forces in the MMP market. It can be shown that incentives exist for both purchaser and sellers of MMPs to make the "bid rate" reasonable to ensure clearance of the market.
2. Table 9 gives a legend of cases/software summaries to be used in the derivation of tables 10, 11, 12 and 13.
3. Table 14 provides a legend for case decomposition by financial area. This legend will be used in table 15.
4. The time period between actions is every 49 days for U.S.A. issues and every 33 days for Canadian issues. Both time periods were chosen to ensure that auctions would fall on a week day, and also allow security holders the minimum holding period to utilize the tax-exempt provision for dividends.
5. The type of data element must be compatible with Nexpert Object variable types.
6. The ideal approach to building the prototype would be to incorporate expertise from at least five experts in the MMP bidding field. However, the dispersed geographic location of these experts throughout the U.S.A. would necessitate extensive travel; too expensive in both terms of time and money.

Appendix 1

Letter to Software Vendors

Doug Macklem
Box #556
Carleton University Residence
1233 Colonel By Drive
Ottawa, Ontario
K1S 5B7 CANADA

Meca Ventures Inc.
355 Riverside Ave.
Westport, Connecticut
06848 U.S.A.

Managing Your Own Money

Dear Sir

Presently, I am a graduate student at Carleton University. As an integral part of my program, I am working on my master's thesis. My thesis topic is to investigate the existing models for decision support and expert system technology in financial applications. I plan to design a framework for decision support and expert systems for use in this area.

I am currently in the process of evaluating the design structures of commercially available software packages in financial decision making. I am told that your product "Managing Your Money" is a very popular and well designed product that I must include in my assessment. I would be grateful if you can provide me with any information regarding the structure of your application. In particular, I am interested in receiving any documentation, magazine reviews, and demonstration materials, including software for Macintosh or IBM platforms. This material will be used to compare and evaluate your system with other available systems.

I thank you in advance for any material that you may provide to me, and for the time taken to forward it. If you have any questions, please do not hesitate to call me at (613)739-3898 or (613)623-2569 or contact my thesis supervisor, Prof. Vijay Jog at (613)564-7410.

Sincerely, _____

Doug Macklem

Software Vendors and Addresses

1. **Product: Managing Your Own Money** Tel. # 1-203-222-9087
Meca Ventures Inc.,
355 Riverside Ave., Westport,
Connecticut, USA, 06848
2. **Product: Portfolio Evaluator** Tel. # 1-713-467-1601
Premise Software Corp.,
1000 Campbell Rd., Suite 208-128,
Houston, Texas, USA., 77055
3. **Product: Economic Investor** Tel:# 1-800-628-2828
Econ Investment Software, ext. 799
1 World Trade Centre,
7967 New York City,
New York, USA., 10048
4. **Product: Stock Charting & Technical Analysis** Tel. # 1-212-884-5408
Wall Street Micro Investor,
P.O. Box # 6, Riverdale,
New York, USA., 10471
5. **Product: Profits** Tel. # 1-805-499-9380
Button-down Software,
172 Donegal Ave., Newbury Park,
California,USA., 91320
6. **Product: Market Base** Tel. # 1-617-449-8460
MP Software Inc.,
P.O. Box 37, Needham Hts.,
MA , U.S.A., 02194
7. **Product: Value/Screen II** Tel. # 1-212-687-3964
Value Line, Inc.,
711 Third Ave.,
New York, N.Y. 10017

Appendix 3**MMP Dutch-Auction Example**

The Dutch-Auction process employed to determine the dividend rate for MMPs is illustrated below. This example was taken from a prospectus of a "Texas Instruments Inc." issue of MMPs dated Feb. 27, 1986. The auction-set dividend rate is the rate applicable for the next cycle (typically, 49 days). The example assumes that the contemporaneous commercial paper rate is 10.000%, with the pre-specified maximum rate at 110.000% of the commercial paper rate (11.000%), and also that 100 MMPs are outstanding on the date of the auction.

The auction proceeds as follows:

A. Orders by Existing Holders and Potential Holders:**Submission of Orders by Broker-Dealers to the Auction Agent.**

Broker-Dealers obtain the following BIDS and SELL ORDERS from EXISTING HOLDERS.

BIDDER**ORDER**

- # 1 Continue to hold 10 shares if the new rate is at least 7.000%.
- # 2 Sell 20 shares.
- # 3 Continue to hold 30 shares if the new rate is at least 7.250%.
- # 4 Continue to hold 30 shares if the new rate is at least 7.250%.
- # 5 Continue to hold 10 shares if the new rate is at least 7.250%.

Broker-Dealers obtain the following BIDS from POTENTIAL HOLDERS.

BIDDER**ORDER**

- # 1 Buy an additional 20 shares if the new rate is at least 7.000%.
- # 6 Buy 20 shares if the new rate is at least 7.125%.
- # 7 Buy 15 shares if the new rate is at least 7.100%.
- # 8 Buy 50 shares if the new rate is at least 7.350%.
- # 9 Buy 60 shares if the new rate is at least 7.400%.
- # 10 Buy 40 shares if the new rate is at least 7.275%.

By 12:30 P.M. (New York City time) the Broker-Dealers have submitted the above ORDERS to the Auction Agent. Such ORDERS are SUBMITTED ORDERS.

B. Determination of Sufficient Clearing Bids, Winning Bid Rate and Applicable Rate

The Auction Agent determines:

(1) the available MMPs , which is the total number of MMPs outstanding , minus the number of MMPs, subject to HOLD ORDERS:

$$100 - 0 = 100 \text{ shares of available MMPs}$$

and

(2) whether the number of shares bid by POTENTIAL HOLDERS specifying rates equal to or lower than the pre-specified maximum rate, is equal to or exceeds the sum of the number of shares subject to sell orders and the shares bid by EXISTING HOLDERS, at rates higher than the pre-specified maximum.

- (a) 20 shares bid for by BIDDER #1 plus
- 20 shares bid for by BIDDER #6 plus
- 15 shares bid for by BIDDER #7 plus
- 50 shares bid for by BIDDER #8 plus
- 60 shares bid for by BIDDER #9 plus
- 40 shares bid for by BIDDER #10.

Total of: **205 shares** bid for
exceeds

- (b) 20 shares offered to be sold by BIDDER #2.

Therefore, sufficient CLEARING BIDS exist.

The win rate is the lowest rate specified in the SUBMITTED BIDS which would result in EXISTING HOLDERS and POTENTIAL HOLDERS owning all available MMPs.

BIDDER	SHARES	ORDER
# 1	10	Continue to hold if the new rate is at least 7.000%.
# 1	20	Buy if the new rate is at least 7.000%.
# 7	15	Buy if the new rate is at least 7.100%
# 6	20	Buy if the new rate is at least 7.125%.
# 3	30	Continue to hold if the new rate is at least 7.250%.
# 5	<u>10</u>	Continue to hold if the new rate is at least 7.250%.
Total:	105 shares	

The winning bid rate is 7.250%. At the next lowest rate of 7.125%, only 65 shares would continue to be held or purchased; this would be less than the 100 available MMPs.

C. Acceptance and Rejection of Submitted Bids, Submitted Sell Orders and the Allocation of Shares

SUBMITTED BIDS and SUBMITTED SELL ORDERS are accepted and rejected according to priorities set forth in the auction procedures, to insure that existing holders and potential holders of MMPs hold and/or purchase, all available MMPs. The stipulation of priorities proceeds in the following fashion:

(1) Each existing holder with a submitted order specifying any rate higher than the winning-bid rate, shall sell the MMPs subject to the corresponding order.

Therefore, BIDDER #2 would sell 20 shares. (Bidder #2 is a seller at any rate)

BIDDER #4 sells 30 shares. (Bidder #4 had bid 7.300%)

(2) Each existing holder with a submitted bid specifying a rate that is lower than the winning bid rate, shall continue to hold the MMPs, subject to that submitted bid.

Therefore, BIDDER #1 would continue to hold 10 shares.

(3) Each potential holder with a submitted bid specifying a rate that is lower than the winning bid rate, shall purchase the MMPs, subject to that submitted bid.

Therefore, BIDDER #1 purchases an additional 20 shares.

BIDDER # 6 purchases 20 shares.

BIDDER # 7 purchases 15 shares.

(4) Each existing holder with a submitted bid specifying a rate equal to the winning bid rate, shall continue to hold the MMPs subject to that bid, unless the number of shares specified by such orders exceeds the number of remaining MMPs available after execution of the previous procedures. In such a case, each bidder involved in the tie, must sell a number of shares determined on a pro rata basis according to the submitted bids.

(a) 40 shares bid for at the win rate (30 by bidder #3 and 10 by bidder #5) exceeds

(b) 35, the number of remaining available shares ($100 - 65 = 35$).

The two bidders involved in the tie collectively own 40 shares; they must sell a total of 5 of these shares to balance the market; the distribution of sale is conducted through the application of the following formula:

Number of shares sold = bidder's shares involved in the tie - (remaining available shares
X the bidder's proportion of all shares involved in the tie).

The results of the tie breaking procedure for the illustration would be as follows:

For BIDDER #3: $30 - (35 * 30/40) = 3.75$

Therefore, BIDDER #3 would sell 4 shares of the 30 bid shares.

For BIDDER #5: $10 - (35 * 10/40) = 1.25$

therefore, BIDDER #5 would sell 1 share of the 10 bid shares.

D. Settlement

The transfer of MMPs is as follows:

Bidder #4 sells	30 shares
Bidder #2 sells	20 shares
Bidder #3 sells	4 shares
Bidder #5 sells	<u>1 share</u>
	55 shares sold
 Bidder #1 buys	20 shares
Bidder #6 buys	20 shares
Bidder #7 buys	<u>15 shares</u>
	55 shares bought

After settlement, the distribution of MMPs is as follows:

Bidder #1 holds	30 shares
Bidder #2 holds	0 shares
Bidder #3 holds	26 shares
Bidder #4 holds	0 shares
Bidder #5 holds	9 shares
Bidder #6 holds	20 shares
Bidder #7 holds	<u>15 shares</u>
	100 shares

Appendix 4**The MMP Prototype Technical Synopsis**

A variety of technical aspects form the foundation for a successful implementation of the MMP bidding system. These include the implementation of the flexible user interface and features embodied in each of the five system components. A summary of these issues will be presented briefly below.

User Interface Construction: The MMP bidder interface was built with AI Vision, a mouse-based graphical interface builder for Nexpert Object on the Mac. The interface extensively employs a feature of this package called 'question forms' for which a value of a variable is returned from the region in which the user clicks the mouse button. Nonmonotonic reasoning capabilities, in combination with the ability to direct evaluation of variables, enabled the appropriate user interface and system functionality.

Data Definition: To facilitate flexible data definition required consideration of two fundamental types of data: global data, for which one copy suffices for the entire system, and local MMP variables, where values of these variables change with each specific MMP issue. Different technical considerations were relevant to these two data types.

The concept of global data was implemented through the creation of permanent objects with a call to the Nexpert Object Library of NXP_Compile. This external routine takes a text description of the global data objects with its characteristics, and compiles the object into the MMP bidder knowledge base. The choice of the more complex permanent object creation, in lieu of the easier dynamic object creation, was dictated by two factors: a) It was impossible to merge dynamic objects into another knowledge base under program control, implying that newly created data elements for each session would have to be saved in a separate knowledge base. b) Dynamic objects would not have provided the necessary semantic meaning to the objects. Two classes were created to structure global data creation: the class 'SystemGlobalVariable' contains system data elements, while user defined elements are instances of the class 'UserGlobalVariable'. The latter class is a subclass of the former which takes advantage of the object-oriented feature of inheritance. This structure also permits error detection for name duplication.

The MMP local variables necessitated an examination of the structure of MMP security information within the system; each MMP issue had to maintain its own copy of these local variables.

Inheritance was the essential mechanism to implement this concept. A six class structure facilitated the appropriate conceptualization of the MMP issues. The figure below demonstrates the class structure.

Figure A1 **MMP Class Structure**

The addition/removal of MMP variables requires the redefinition of the properties associated with the most general class, and changes are inherited down the hierarchy. The implementation procedure involves the deletion and recompilation of the MMP class. In addition, there is a parallel two class structure for MMP variables: `SystemMMPVariable` and `UserMMPVariable`; these classes implement the identical functionality for MMP variables as the corresponding global variable classes.

NOTE: The four classes at the lower end of the hierarchy represent the alternative classifications of MMPs.

Strategy Definition: The implementation approach employed in strategy definition is identical to that of global data definition; the associated class names have been appropriately modified to 'SystemStrategyDefinition' and 'UserStrategyDefinition'.

MMP Issue Data: This component required the consideration of relevant characteristics of the MMP issues and an appropriate mechanism for accessing MMP auction data. Prototype design incorporates the MMP specific auction data and variables through direct file access. This file-name is specified explicitly as a field in the MMP data screen; the correct format for such a file is as follows:

```
MMPVariableName [tab] value { variable name [tab] variable value}
- - { MMP variable and auction data separator}
YYDDMM dddddd dddd {date of auction, auction win rate, auction win rate as a
percentage of commercial paper rate}
- - { file termination}
```

New variables and auction data can be added to facilitate system update while maintaining conformity with this format.

The storage of auction data follows an object-oriented class structure with each auction being an instance of two classes: *MMPAuction* and its appropriate classification. This structure parallels MMP securities and eases the implementation of grouping strategies such as the distribution strategies.

Strategy Evaluation: This component necessitated a phased approach to facilitate the computation, communication and output of strategy performance over various MMPs and associated auctions. Three phases embody the example implementation: *StrategyEvaluationReport*, *StrategyEvaluationLoop* and *StrategyEvaluationTerminate*. Each of these phases require a production rule and external routine for successful operation.

StrategyEvaluationReport executes an external routine with a parameter value of 1, loading in the data, and finally directing the process to perform the next phase by 'suggesting' the appropriate hypothesis.

StrategyEvaluationLoop executes an external routine with a parameter value of 2 to set up the appropriate data for strategy evaluation and also to perform the actual evaluation. Upon completion of the evaluation of the strategy, the same execute routine is invoked with a parameter value equal to 3. This execution collects the result of strategy evaluation and produces the

appropriate output to a file. If looping is completed, *StrategyEvaluationTerminate* is suggested. If looping must continue, *StrategyEvaluationLoop* is reset and the second phase of the process is repeated. *StrategyEvaluationTerminate* closes the output file and suggests the appropriate hypothesis to continue flexible DSS user driven interaction. This complex three-phased structure illustrates the difficulty of mathematical manipulation, transfer of information and output of relevant results which greatly hindered the development of evaluation examples.

Strategy Selection: This component allows user entry of heuristic rules in choosing a base strategy and suggesting any appropriate adjustments. In the accomplishment of this task, the initial rules embodied in the MMP bidder must be removed from working memory, while allowing any objects (data elements, strategy definitions, MMP issue information) to remain as a source for rule construction. This functionality is implemented through an external routine which removes all the rules from working memory, while leaving objects undisturbed. This component facilitates the direct activation of default selection heuristics through complex knowledge base manipulation. The ability to restart a consultation with the bidder following a selection consultation provides a closed loop system. Auction data can also be incorporated through the same strategy selection template knowledge base.

The provision for a rule editing environment was a key issue. To build this functionality with AI Vision on top of Nexpert Object would have been extremely time consuming and programming intensive. The conscious decision was made to allow direct user entry into the Nexpert Object environment where advanced rule editing capabilities already exist.

Additional Functionality: The additional functionality of loading, saving, and clearing the MMP bidder system required the use of complex external routines. The ability to load a new MMP system involved the manipulation of multiple knowledge bases.

Appendix 5**User Guide for MMP Bidder Version 1.01b1****1. INTRODUCTION****1.1 Overview**

The Money Market Preferred (MMP) Bidder Version 1.01b1 represents an initial prototype intended to investigate the support requirements of the Money Market Preferred Share bidding process. This guide will provide an overview of both prototype usage and the sequential phase structure of the MMP bidding problem.

1.2 General User Interface Techniques

To avoid repetition, an overview of general user interface techniques employed in the MMP bidder prototype will be provided in the following section. All components of the MMP bidder display two common icons.

Figure A1 Home and Help Icons

The Home icon returns the user to the initial MMP bidder screen. The Help icon provides a context-sensitive text-based help facility.

Data entry fields outlined as shown in Figure A2 require the entry of data from the keyboard or a choice from the menu provided. In the former case, the entry must be terminated by hitting either the Enter or Tab keys. Until one of these keys is pressed, data within these fields is not recognized.

Figure A2 Data Entry Field

Clicking on buttons similar to the one illustrated in Figure A3 below serve to activate system functionality.

Several of the text entry fields incorporate menu driven entry as an alternative to direct keyboard input. These menus are activated by clicking near the left edge of the text entry field. To indicate that the menu will pop up, the cursor changes from an I-beam to a miniature menu icon. This

allows those who prefer to use the mouse to do so, while retaining the keyboard as the primary input mechanism.

Figure A3 Example Button

Accept

Five buttons provide common functionality between four MMP bidder system components: *Accept*, *Find*, *Remove*, *Clear* and *Cancel*. *Accept* creates a new object of a particular type possessing the characteristics specified in the text entry fields. If an object already exists with that name, the user is asked whether he/she wishes to modify the existing object. If the response is affirmative, the changed definition is accepted and the user is returned to a new blank entry screen. If *Cancel* is chosen, the user is returned to the modified entry screen for further alterations. The *Find* button retrieves the information corresponding to the object specified by the entry in the Name text entry field. If no object exists under that name, an appropriate alert message will be displayed. *Remove* simply removes the object corresponding to the element specified by the Name text entry field. Once again, an appropriate alert message is generated if no such object exists. *Clear* erases the content of the text fields and returns the user to the appropriate definition screen. *Cancel* restores the contents of the entry fields to their previous values. This functionality allows the undoing of inadvertent changes to existing objects.

1.3 System Startup

MMP Bidder startup is straight-forward. Simply double click the Nexpert Object Icon shown below in Figure A4.

Figure A4 : Nexpert Object Icon

NEXPERT OBJECT 1.1.1

As a result of this action, the base MMP bidder system will be loaded and the system entry screen shown in Figure A5 below will appear. Be patient: the elapsed time for system start-up is in the range of three to five minutes.

2.0 MMP BIDDER CONSULTATION

A typical consultation within the MMP bidder follows a sequential approach. The prototype is comprised of the following five components:

- 1) data definition,
- 2) strategy definition,
- 3) MMP issue definition,
- 4) strategy evaluation and
- 5) strategy selection.

These components will be discussed in an order which follows the path of a typical consultation.

All components are accessed via the System Entry Screen shown in figure A5 below. Additional functionality including saving, exiting and clearing MMP system contents is also provided at this level. Under normal operation, the appearance of the screen shown in figure A5 indicates the readiness of the MMP bidder for user interaction. The actions which result from clicking on each of the icons in figure A5 will be discussed briefly below.

Figure A5 System Entry Screen

1) Data Definition:

- After clicking on the above icon, the screen shown in figure A6 below will appear.

Figure A6 Variable Definition Type Selection

What type of variable do you wish to define ?

The functionality of the MMP bidder allows the definition of two types of variables: global and MMP. Global variables are variables for which a single copy is maintained throughout the entire system. MMP variables, in contrast, have distinct values for each MMP issue present in the system. Clicking on either the a) global buttons or b) the MMP button on the screen will proceed to the appropriate definition module.

a) Global Variable Definition: The global button will result in the appearance of the screen illustrated in figure A7. This screen facilitates entry/editing of global data elements.

Figure A7 Global Variable Definition Screen

The screenshot shows a window titled "Global Variable Definition". In the top right corner, there is a question mark icon with the word "Help" below it, and a house icon below that. On the left side, there are two buttons: "Find" and "Remove". The main area contains five text input fields, each preceded by a label: "Name:", "Type:", "Prompt:", "Expression:", and "Comment:". At the bottom of the window, there are three buttons: "Clear", "Accept", and "Cancel".

As illustrated in the above screen, global variable definition involves five text entry fields: *Name*, *Type*, *Prompt*, *Expression* and *Comment*. *Name* is a unique identifier for a global data element within the system. The name can be entered manually or an alternative can be chosen from the available menu. *Type* represents a Nexpert Object compatible data type. Five options are available from the associated menu: String, Float, Integer, Date and Boolean. Data for each of these two fields must be entered in order for the data elements to be considered valid. *Prompt* provides the relevant question posed to the user upon request of a value for the associated global variable. *Expression* allows the entry of a constant or expression to compute the global variable value. *Comment* provides a description mechanism for user-defined global variables. This field only serves for documentation purposes. If neither of prompt or expression is entered by the user, Nexpert Object will generate a default question to be poised during variable inquisition.

b) MMP Variable Definition: The functionality and interaction with the MMP variable definition screen is identical to that of global variable definition component, with one major exception: MMP variable values are retrieved from a file specified in the MMP data definition screen. Thus the Prompt and Expression fields present in the case of global variable definitions have been eliminated. Figure A8 illustrates the MMP variable definition screen which appears upon clicking the MMP button in figure A6.

Figure A8 MMP Variable Definition

MMP Variable Definition

Help

Find

Remove

Name:

Type:

Comment:

Clear

Accept

Cancel

2) Bidding Strategy Definition

Upon completion of the definition of global and MMP variables, clicking on the bidding strategy icon shown below, facilitates the combination of variables into mathematical computations for win rate values.

$$A=B*C$$

Bidding Strategies

The relevant strategy definition screen is illustrated in figure A9 below.

Figure A9 Bidding Strategy Definition Screen

Bidding Strategy Definition ?

Help

Find

Remove

Name:

Execute:

Formula:

Comment:

Clear

Accept

Cancel

The concept of bidding strategies within the MMP bidder is characterized in terms of four text entry fields: *Name*, *Execute*, *Formula* and *Comment*. *Name* uniquely identifies a strategy within the MMP bidder. *Execute* specifies the name of an external routine to be executed in the computation of a value corresponding to a strategy; this attribute was necessitated due to the mathematical limitations of Nexpert. Please see Nexpert Object manual, volume 2, for the structure and appropriate features of *executes*. *Formula* facilitates direct entry of simplistic mathematical formula to be used in the derivation of a result for the strategy. This field is not error checked; as a result, simple expressions are highly recommended. *Comment* provides the usual documentation facility.

Note the similarity in button interface incorporated in both data and strategy definition. The functionality is identical between the two components, thus reducing overall learning time.

3) MMP Issue Data

Data elements and bidding strategies are the building blocks for the MMP bidding process. However, these concepts are only relevant within the context of MMP security issues. Clicking on the icon shown below allows entry/edit of MMP issue data to provide a contextual background for data and strategy definition.

Figure A10 below illustrates the MMP data definition component. Within the MMP bidder, MMP security issues are characterized in terms of four text entry fields. *Name* uniquely identifies the MMP issue. *Classification* permits grouping of several MMPs based on fundamental industry characteristics. Four classifications are available from the corresponding menu: *Industrial*, *Financial*, *Utility* and *Thrift Subsidiary*. *Filename* specifies the disk file to be accessed for the corresponding MMP variable and auction data. The appropriate format for an MMP file is as follows:

```
--
<MMP Variable Name><Tab><MMP Value>
--
<Auction Data =
    Date, Win Rate, Win Rate as a percentage of the Commercial Paper Rate>
--
```

Figure A10 MMP Data Definition Screen

MMP Data Definition

 Help

Find

Remove

Name:

Classification:

Filename:

Comment:

Clear

Accept

Cancel

Comment facilitates description of the MMP issues entered into the system. The button interface again parallels the previous two components with identical functionality.

4) Strategy Evaluation

Following the specification of appropriate bidding strategy computations, an evaluation facility is necessary to provide an overview of the effectiveness of alternative bidding strategies. Two components facilitate this functionality: *evaluation* and *evaluation query*. The former allows the direct execution of relevant evaluation routines with appropriate parameters; the latter permits the modification of evaluation capabilities embodied in the MMP bidder. Access to these components are provided by clicking on the icons below.

$A=B \cdot C \ \$$ $A=B+Z \ \$$ $A=X+Y \ \$$ Evaluation	$A=B \cdot C \ \$$ $A=B+Z \ \$$ $A=X+Y \ \$$ Evaluation Query
--	--

Clicking on the evaluation icon results the appearance of the evaluation screen shown in figure A11 below. This screen permits the specification and execution of evaluation queries present in the system. The features embodied in this component will be discussed briefly below.

Figure A11 Strategy Evaluation Screen

Help

Strategy Evaluation

Report

Query:

MMP name:

other MMP:

MMP class:

Strategy name:

other Strategy:

auction:

for last:

Clear

Eight fields permit parameterization of query facilities. The query field dictates the evaluation routine to be executed. Two MMP names can be specified in the next two fields permitting direct comparison in strategy performance between two specific MMPs. The specification of an MMP class allows strategy evaluation to be executed within the context of a group of MMPs. The previous four classifications of MMPs are available. The two fields which follow focus the evaluation on specific strategies. Overall, these first six fields possess menu choice attributes. The auction field dictates a particular starting auction index for evaluation purposes. '0' indicates the most recent auction and '-1' indicates the current action. The 'for last' field provides an evaluation range from the auction index backward in time; for example: 6 indicates that 6 auctions should be considered in the evaluation.

The report button activates query execution with the parameters specified in the fields of the evaluation screen.

The current version of the prototype supports only one query, due to the complexity of developing appropriate external routines. The query coined 'best' provides an evaluation of the most accurate

bidding strategy for a particular MMP or MMP class. The query ranks strategies on an auction basis, sending the results to a file. Low scores are given to closely approximating strategies, while undesirable strategies receive a higher overall score. These scores are then summed over the range of auction specified and the sequential ordering from lowest to highest score provides the mechanism to compare the performance of alternative strategies.

The second aspect of strategy evaluation encompasses the ability to change the evaluation capabilities of the MMP bidder. Figure A12 illustrates the evaluation query screen which implements this feature; salient elements comprising this screen will be discussed.

Figure A12 Evaluation Query Screen

Evaluation Query Definition ?
Help

Find **Remove**

Name:

Execute:

Comment:

Clear **Accept** **Cancel**

Three fields characterize this modification component: *Name*, *Execute* and *Comment*. *Name* serves to uniquely identify a query within the system. *Execute* dictates the external routine to be performed on the request of this query. *Comment* permits documentation. The name field incorporates menu-driven selection.

5) Strategy Selection

The culminating aspect of the MMP bidder is a facility permitting the specification of strategy selection heuristics which lead to an appropriate bid rate on the basis of previously defined data elements, strategies and auctions. The rule-based formalisms embodied in Nexpert Object, in combination with object creation capabilities, provide an ideal environment for rule specification. All of the variables, strategies and MMP securities previously defined can be components of these

heuristic bid rate selection rules; these building blocks are represented through the object or structure dimension of Nexpert Object.

Clicking on the selection icon shown below will result in the activation of the screen of Figure A13.

Figure A13

Strategy Selection Screen

Strategy Selection

Help

KB Name

Run

New

Cancel

Load

This screen facilitates the execution, design and editing of strategy selection knowledge bases through the customary text entry field and button interface. In addition to the standard Home and Help buttons, four additional buttons encompass the functionality of the strategy selection component.

1. The *run* button executes the knowledge base named in the text entry field. If no such knowledge base exists, an error dialogue is displayed and the strategy selection screen reappears for the entry for of a valid selection knowledge base name. To utilize the current implementation of the run button, any selection knowledge base must be activated through isolation of a single hypothesis in the Nexpert Object's suggest list. See Nexpert Object documentation, Vol.1, for details and explanation.

2. The *new* button permits the design of new strategy selection knowledge bases employing the existing data elements, bidding strategies and MMP issues. This operation cautions the user

that knowledge of Nexpert Object's environment is necessary for successful completion, and the user must confirm that he/she wishes to proceed. Following the confirmation, direct entry into the Nexpert Object development environment is completed. To separate new rules into a distinct knowledge base, choose the Set Knowledge Base command from the expert menu. Click 'new' in the resultant dialogue and then enter the knowledge base name. This separation allows clear distinction between the objects outlined in the MMP bidder system and strategy selection rules which operated on these objects.

3. The *cancel* button clears the contents of the knowledge base name field and returns the user to the same screen.

4. The *load* button permits editing of existing strategy selection knowledge bases. The behaviour of this operation is identical to 'run' discussed previously, with one key exception. The valid selection knowledge base is loaded into Nexpert Object's environment but is not executed; the system relies upon user interaction for editing or activation.

Following the design of the 'selection' knowledge base, the rules embodied must be saved by choosing 'Save Knowledge Base' from Nexpert Object's Expert Menu. See Nexpert Object, Volume 1, for documentation of the appropriate saving procedure.

The capability exists from within the strategy selection environment to restart a consultation with the MMP bidder. This functionality is provided by setting the variable 'GoBackToBidderDesired' to true. This can be accomplished through a rule in a selection knowledge base or set directly by an experienced Nexpert Object user. Setting this variable to true when the inference engine is running will result in the return to the most recently activated MMP bidder system.

6) Additional Functionality

The system entry screen of figure A5 provides three additional capabilities in the operation of the MMP bidder. Clicking on the *Clear* icon will remove all user objects from the MMP bidder and leave only the navigational and system components.

Clear

By its nature, this is a destructive operation and should only be used to create a clean version of the MMP bidder. To avoid a destructive removal of all objects, an alert confirmation is provided to

verify that the command is to be executed.

Clicking on the *quit* icon terminates the MMP bidder consultation and returns the user to the Nexpert Object environment.

To completely exit the system, it is also necessary to quit the Nexpert Object application. This is accomplished through choosing the Quit Nexpert option from the file menu.

Clicking on the *load* icon below permits the activation of alternative MMP bidder systems with differing data elements, bidding strategies and MMP issues. Figure A14 corresponds to the load system screen.

Figure A14

Load System Screen

Load System

?
Help

🏠

Name:

Cancel

Load

Two distinct buttons implement the load system functionality. The *load* button loads and activates the MMP bidder system named in the text entry field. If no such system exists, an error dialogue is displayed and the previous MMP bidder system is reactivated. The *cancel* button clears the contents of the text entry field and returns the user to the same screen.

The current implementation of load system allows complete interaction with an alternative or newly loaded system. However, upon choosing quit from the main option screen of this system, the user is immediately exited from the Nexpert Object application by a software crash.

A final feature is the ability to save a modified version of the MMP bidder as a starting point for a later session. Clicking on the *save* icon below results in the save system screen illustrated in figure A15.

The desired filename is entered in the text field and the save button is clicked on to execute the save operation. The corresponding knowledge base is written to disk in the Nexpert Object folder. Clicking on the cancel button erases the filename previously entered and returns to a blank save system screen.

Figure A15

Save System Screen

Save System

Name:

Cancel

Save

3.0 Desirable Extensions

Several supplementary features could be envisioned to enhance the MMP bidder prototype toward a production system. The ability to load other MMP bidder knowledge bases is an important missing element in the current prototype. The inability to parameterize the filename to be loaded results in this limitation. With the relaxation of time constraints, this ability is implementable. Additionally, a facility to specify an alternative evaluation mechanism would provide greater power and flexibility encompassed in the evaluation components. Currently, the context sensitive help systems are stubbed out to be replaced by appropriate text files as time would permit. These features together with a substantial increase in speed would improve the prototype status significantly.

Appendix 6**Overall Structure of Default Strategy Selection Knowledge Base****Top Level Rule:**

- a) If CurrentMMPName is known and
 - b) ChooseBaseStrategy is known and
 - c) BaseStrategy is known and
 - d) CurrentPaperRate is known and
 - e) AdjustBids is known and
 - f) MoneySupplyAdjust is known and
 - g) LIBORandMuniAdjust is known and
 - h) SectorAdjust is known and
 - i) CompanyAdjust is known and
 - j) InfluentialAdjust is known and
 - k) HolderAdjust is known,
- then the Result bid rate is known.

Second Level Rules:

- a) CurrentMMPName is an object for which the value is prompted directly.
- b) ChooseBaseStrategy has one rule.

If an ALERT of : 'The first stage determines the appropriate base strategy on the basis of trends in overall and sector win rates' is displayed,
then ChooseBaseStrategy is TRUE.
- c) BaseStrategy has nine rules.
 1. If OverallBidRateTrend is "+" and SectorBidRateTrend is "+"
then BaseStrategy is assigned TRUE and Result = Distribution2.
 2. If OverallBidRateTrend is "+" and SectorBidRateTrend is "="
then BaseStrategy is assigned TRUE and Result = Distribution1.
 3. If OverallBidRateTrend is "+" and SectorBidRateTrend is "-"
then BaseStrategy is assigned TRUE and Result = Best.
 4. If OverallBidRateTrend is "=" and SectorBidRateTrend is "+"
then BaseStrategy is assigned TRUE and Result = Distribution1.

5. If OverallBidRateTrend is "=" and SectorBidRateTrend is "="
then BaseStrategy is assigned TRUE and Result = Naive.
 6. If OverallBidRateTrend is "=" and SectorBidRateTrend is "-"
then BaseStrategy is assigned TRUE and Result = Distribution1.
 7. If OverallBidRateTrend is "- " and SectorBidRateTrend is "+"
then BaseStrategy is assigned TRUE and Result = Best.
 8. If OverallBidRateTrend is "- " and SectorBidRateTrend is "="
then BaseStrategy is assigned TRUE and Result = Distribution1.
 9. If OverallBidRateTrend is "-" and SectorBidRateTrend is "-"
then BaseStrategy is assigned TRUE and Result = Distribution2.
- d) CurrentPaperRate is an object for which the value is prompted directly.
- e) AdjustingBids has one rule.
- If an ALERT of "The final stage determines the appropriate bid rate adjustments from macroeconomic effects to bidder specific factors" is displayed,
- then AdjustingBids is assigned TRUE.
- f) MoneySupplyAdjust has three rules.
1. If MacroMoneySupplyTrend is "+",
then MoneySupplyAdjust is TRUE and
Result = Result - MacroMoneySupplyAdjust.
 2. If MacroMoneySupplyTrend is "-",
then MoneySupplyAdjust is TRUE and
Result = Result + MacroMoneySupplyAdjust.
 3. If MacroMoneySupplyTrend is "=",
then MoneySupplyAdjust is TRUE and
no adjustment to Result is necessary.
- g) LIBORandMuniAdjust has four rules.
1. If DifCPandLIBOR is "+" and DifCPandTaxFreeMunicipal is "+",
then LIBORandMuniAdjust is TRUE and Result = Result - CPandLIBOR
adjust.

2. If DifCPandLIBOR is “-” and DifCPAndTaxFreeMunicipal is“-”,
then LIBORandMuniAdjust is TRUE and $\text{Result} = \text{Result} + \text{CPandLIBOR adjust}$.
 3. If DifCPandLIBOR is “=”,
then LIBORandMuniAdjust is TRUE and no adjustment to Result is necessary.
 4. If DifCPandTaxFreeMunicipal is “=”,
then LIBORandMuniAdjust is TRUE and no adjustment to Result is necessary.
- h) SectorAdjust has three rules.
1. If SectorEvents is “+”,
then SectorAdjust is TRUE and $\text{Result} = \text{Result} + \text{SectorEventsAdj}$.
 2. If SectorEvents is “-”,
then SectorAdjust is TRUE and $\text{Result} = \text{Result} - \text{SectorEventsAdj}$.
 3. If SectorEvents is “=”,
then SectorAdjust is TRUE and no adjustment to Result is necessary.
- i) CompanyAdjust has three rules.
1. If CompanyEvents is “+”,
then CompanyAdjust is TRUE and $\text{Result} = \text{Result} + \text{CompanyEventsAdj}$.
 2. If CompanyEvents is “-”,
then CompanyAdjust is TRUE and $\text{Result} = \text{Result} - \text{CompanyEventsAdj}$.
 3. If CompanyEvents is “=”,
then CompanyAdjust is TRUE and no adjustment to Result is necessary.
- j) InfluentialAdjust has two rules.
1. If IssueSize is “large” or “unsure”,
then InfluentialAdjust is TRUE and no adjustment to Result is necessary.
 2. If IssueSize is “small” and InfluentialBidder is TRUE
then InfluentialAdjust is TRUE and $\text{Result} = \text{Result} - \text{InfluentialAdjust}$.

k) **HolderAdjust** has four rules.

1. If **BidderPosition** is "New bidder",
then **HolderAdjust** is TRUE and $\text{Result} = \text{Result} - \text{NewBidderAdj.}$
2. If **BidderPosition** is "Existing Holder" and **AdjCriteria** is "Rate of Return", then **HolderAdjust** is TRUE and $\text{Result} = \text{Result} + \text{RateofReturnAdj.}$
3. If **BidderPosition** is "Existing Holder" and **AdjCriteria** is "Maintain Holding", then **HolderAdjust** is TRUE and $\text{Result} = \text{Result} - \text{RateofReturnAdj.}$
4. If **BidderPosition** is "Existing Holder" and **AdjCriteria** is "Undecided", then **HolderAdjust** is TRUE and no adjustment to **Result** is necessary.

* All adjustments to the bid rate are in terms of basis points.

The output below provides an example of consultation results corresponding to table 20 responses.

Example Strategy Selection Knowledge Base Output

\Expression\="distribution2-SectorEventsAdjustment-
MacroMoneySupplyAdjustment-CPAndLIBORAdjustment"

\Result\="4.92"

Appendix 7**Example Strategy Evaluation Reports****A Single MMP**

Results of the 'Best' query on the last 5 auctions (starting from auction 0) of AXP_PRA.

Auction 0: 4.19

Strategy: Distribution1	result: 4.6 (96.88% of actual)
Strategy: Distribution2	result: 3.99 (95.2% of actual)
Strategy: Matching	result: 4.21 (0.30% over actual)
Strategy: Naive	result: 4.37 (4.27% over actual)

Auction 1: 4.59

Strategy: Distribution2	result: 4.32 (93.95% of actual)
Strategy: Naive	result: 4.30 (93.55% of actual)
Strategy: Distribution1	result: 4.26 (92.80% of actual)
Strategy: Matching	result: 4.64 (1.2% over actual)

Auction 2: 4.50

Strategy: Distribution1	result: 4.4 (89.92% of actual)
Strategy: Distribution2	result: 4.3 (89.67% of actual)
Strategy: Matching	result: 4.50 (0.15% over actual)
Strategy: Naive	result: 4.73 (5.16% over actual)

Auction 3: 5.19

Strategy: Matching	result: 5.24 (0.89% over actual)
Strategy: Distribution2	result: 5.38 (3.52% over actual)
Strategy: Distribution1	result: 5.39 (3.84% over actual)
Strategy: Naive	result: 5.87 (12.94% over actual)

Auction 4: 6.0

Strategy: Distribution1	result: 5.36 (89.42% of actual)
Strategy: Distribution2	result: 5.36 (89.42% of actual)
Strategy: Naive	result: 5.34 (89.6% of actual)
Strategy: Matching	result: 6.3 (0.52% over actual)

Here is the ordering from the best strategy to the worst for AXP_PRA:

- Distribution1 (3)
- Distribution2 (5)
- Naive (7)
- Matching (15)

A Class of MMPs

Results of the 'Best' query on the last 5 auctions (starting from auction 0) of class Utility.

MMP CSGA_PR_B:

Auction 0: 4.30

Strategy: Distribution1	result: 4.20 (97.69% of actual)
Strategy: Distribution2	result: 2.86 (66.55% of actual)
Strategy: Matching	result: 4.45 (3.67% over actual)
Strategy: Naive	result: 4.52 (5.29% over actual)

Auction 1: 4.80

Strategy: Naive	result: 4.33 (90.36% of actual)
Strategy: Distribution1	result: 4.31 (89.79% of actual)
Strategy: Distribution2	result: 2.40 (50.1% of actual)
Strategy: Matching	result: 5.15 (7.40% over actual)

Auction 2: 4.40

Strategy: Distribution1	result: 4.16 (94.77% of actual)
Strategy: Distribution2	result: 2.21 (50.26% of actual)
Strategy: Naive	result: 4.86 (10.66% over actual)
Strategy: Matching	## No result due to some error (so ranked as last).

Auction 3: 5.59

Strategy: Distribution1	## No result due to some error (so ranked as last).
Strategy: Distribution2	## No result due to some error (so ranked as last).
Strategy: Matching	## No result due to some error (so ranked as last).
Strategy: Naive	## No result due to some error (so ranked as last).

Auction 4: No Data.

Here is the ordering from the best strategy to the worst for CSGA_PR_B:

Distribution1 (5)
 Distribution2 (8)
 Naive (9)
 Matching (14)

MMP CSGA_PR_A:**Auction 0: 4.0**

Strategy: Matching	result: 4.0 (100.0% of actual)
Strategy: Distribution1	result: 3.93 (98.38% of actual)
Strategy: Distribution2	result: 2.89 (72.45% of actual)
Strategy: Naive	result: 4.21 (5.40% over actual)

Auction 1: 4.59

Strategy: Distribution2	result: 2.20 (48.3% of actual)
Strategy: Matching	result: 4.62 (0.43% over actual)
Strategy: Distribution1	result: 4.82 (4.83% over actual)
Strategy: Naive	result: 4.89 (6.30% over actual)

Auction 2: 4.80

Strategy: Naive	result: 4.33 (90.34% of actual)
Strategy: Distribution1	result: 3.70 (77.1% of actual)
Strategy: Matching	result: 4.81 (0.41% over actual)
Strategy: Distribution2	## No result due to some error (so ranked as last).

Auction 3: 4.69

Strategy: Distribution1	result: 4.79 (2.9% over actual)
Strategy: Matching	result: 4.86 (3.51% over actual)
Strategy: Naive	result: 5.17 (10.7% over actual)
Strategy: Distribution2	## No result due to some error (so ranked as last).

Auction 4: 5.59

Strategy: Naive	result: 5.77 (3.19% over actual)
Strategy: Distribution1	result: 5.79 (3.48% over actual)
Strategy: Distribution2	## No result due to some error (so ranked as last).
Strategy: Matching	## No result due to some error (so ranked as last).

Here is the ordering from the best strategy to the worst for CSGA_PR_A:

Naive (8)
 Distribution1 (9)
 Matching (12)
 Distribution2 (14)

MMP CEW_PR:

Auction 0: 4.50

Strategy: Matching	result: 4.50 (100.0% of actual)
Strategy: Distribution1	result: 4.22 (93.80% of actual)
Strategy: Distribution2	result: 3.8 (68.62% of actual)
Strategy: Naive	result: 4.52 (0.55% over actual)

Auction 1: 4.90

Strategy: Distribution2	result: 3.43 (70.14% of actual)
Strategy: Distribution1	result: 5.7 (3.67% over actual)
Strategy: Naive	result: 5.12 (4.66% over actual)
Strategy: Matching	## No result due to some error (so ranked as last).

Auction 2: 4.90

Strategy: Distribution1	## No result due to some error (so ranked as last).
Strategy: Distribution2	## No result due to some error (so ranked as last).
Strategy: Matching	## No result due to some error (so ranked as last).
Strategy: Naive	## No result due to some error (so ranked as last).

Auction 3: No Data.

Here is the ordering from the best strategy to the worst for CEW_PR:

Distribution2 (6)
 Distribution1 (8)
 Matching (8)
 Naive (9)

Here is the ordering from the best strategy to the worst for class Utility:

Distribution1 (2)
 Distribution2 (4)
 Naive (5)
 Matching (7)

DSS Component Overview**Table 1**

A DSS has 3 major components.

Component Name	Functionality & Purpose
Database Management Subsystem	- to organize data and allow flexible access for multiple applications.
a) DSS Database	- stores and organizes related data for DSS access
b) Database Mgt. System (DBMS)	- organizes and facilitates flexible data access across applications
c) Query Facility	- allows user-friendly interaction with the outside world - flexible questions asked of data
d) Data Directory	- maintains definitions and security for all data in the system
Model Management Subsystem	- organizes and controls access to models and procedures employed in system processing.
a) Model Base	- storage facility for system models and procedures.
b) Model Base Mgt. System (MBMS)	- organizes and controls access to, and coordination between system models.
c) Model Directory	- contains definitions and security for system models.
Dialog Subsystem	- handles system interaction with the user
a) Input Language Processor	- takes and interprets user input for the system
b) Output Language Processor	- provides appropriate responses to the user ie: graphics, text or sound.

References: Turban 1988.

Influential Factors of DSS Development Methodologies**Table 2**

The influences on the choice of development methodologies can be characterised in 4 broad categories of factors.

Type of Factor	Tendency Towards SDLC	Tendency Towards Iterative	Key Factors
Organizational	broad org. scope of project large effect and cost for company	restricted dept. scope flexible change of versions lower cost	organizational scope overall effect on organization associated cost
Environmental	structured, repetitive routines	dynamic changing info requirements flexibility a necessity	information set requirements task characteristics
Technical	availability of low level tools with an necessity for technical personnel involvement	availability of DSS/ES high-level tools facilitating more end-user involvement	availability of differing levels of DSS/ES technologies within the organization
Additional Key Factors	low end-user involvement few decision styles	high end-user involvement multiplicity of decision styles multi-level managerial support	end-user involvement multi-user capability multi-level influences

References: Alavi & Napier 1984, Alter 1980, Hogue & Watson 1984, Hogue & Watson 1983, Turbin 1988.

Issues Involved in Inference Engine Design

Table 3

Key Issues	General Description
Reasoning Under Uncertainty	This capability is provided through the use of certainty factors: a decimal between zero and one. These are associated with facts and rules in determining the degree of truth: zero indicating definite falsehood, and one indicating certain truth.
Control Strategies	Two basic alternatives exist: forward-chaining and backward-chaining. Forward-chaining is a mechanism whereby the inference engine "works from known facts to new deduced facts" (Winston, 1984). The premises of facts are examined for truth, new resultant facts are added to working memory, more premises are tested and fired, continuing until a final goal is reached (Harmon and King, 1985). Backward-chaining is the other alternative control mechanism where "the system can hypothesize a conclusion, ... and work backward toward the hypothesis-supporting facts" (Winston, 1984). The inference engine starts with the goal/hypothesis and works "backward" through the subgoals/subhypothesis to choose an answer. Forward-chaining provides answers for "Why did you show...? questions" by moving one step forward; backward-chaining provides answers for "How did you show...? questions" by moving one step backward.
Search Strategies	Two fundamental search strategies are employed for traversing the knowledge base: Depth-first search has a theme of "detail first" in traversing a knowledge base. This technique investigates one particular path before altering its line of reasoning. This tends to formulate a consultation with the user in a meaningful way as all questions in a related area are posed in sequence. Breadth-first search employs a parallel search mechanism: all premises of a particular rule are investigated before more detail is required in a particular area.
Reasoning Capability	Monotonic versus Nonmonotonic Reasoning: In the monotonic system, conclusions for attribute values remain true for the entire consultation. Facts which are asserted remain so throughout, as the amount of truth-knowledge grows steadily or monotonically. Conversely, in a nonmonotonic system, the truth of facts can be retracted as circumstances and information dictate. This poses the difficulty of tracing all effects of retracted truth throughout the system; a difficult conceptual and expensive process.

References: Harmon and King 1985.

Small System Building Tools

Table 4

Name of Tool/ Environment	Developer	Consultation Paradigm	Knowledge- Representation	Reasoning	Hardware Compatibility	Particular Comments
ES/P ADVISOR	Expert Systems Inter- national (England)	Diagnosis/ pescription	AV Pairs and Production Rules	Backward Chaining	IBM PC PC DOS 2.0 128K	- facilitates "text animation". - uses text to generate rules and advice.
EXPERT- EASE	Expert Software Inter- national	Diagnosis/ pescription	Rules based on examples and attribute values	Decision- tree Algorithm	IBM PC Dec Rainbow Victor 9000 128K	- easy to use and understand. - good for the inexperienced. - inflexible type of knowledge.
INSIGHT KNOWLEDGE SYSTEM	Level 5 Research	Diagnosis/ pescription	OAV triplets and production rules	Forward Chaining, Breadth- first then Backward Chaining	IBM PC Dec Rainbow Victor 9000 128K	- titles of rules for tracing capabilities. - comment capability. - rules/user response.
M 1	Teknow- ledge Inc.	Diagnosis/ pescription	OAV triplets and production rules	Backward Chaining, Depth-First Limited Forward Chaining	IBM PC & XT	- for prototyping small systems. - user by experienced programmer. - trace screens. - c.f.
PERSONAL CONSULTANT	Texas Instru- ments	Diagnosis/ pescription	OAV triplets and production rules	Backward Chaining	Texas Instr. 10 Meg hard disk	- comes with training course. - possibility of using EMYCIN applications.
GURU	MDBS Inc.	Diagnosis/ pescription	OAV triplets and production rules	Backword and forward chaining	IBM PC	- integrated business package. - graphics, rule sets, spreadsheets. - familiarization of business profession.
NEXPERT OBJECT	Neuron Data	Diagnosis/ pescription	Rules and frames	Backword, forward, and mixed chaining	IBM PC Macintosh VAX SUN Appollo HP	- object oriented paradigm. - integrate with code. - graphics interface.

References: Harmon and King 1985, Peter Smith 1987.

Large Narrow System Building Tools

Table 5

Name of Tool/ Environment	Developer	Consultation Paradigm	Knowledge- Representation	Reasoning	Hardware Compatibility	Particular Comments
Expert	Rutgers University (NY State)	Diagnosis/ pescription	OAV Triplets and Production Rules	Determined by order and category of rules	written in FORTRAN wide variety of hardware	- Facts are: finding (f) & hypothesis (h). - H & F rule categories are developed.
KES	Software Archit- ecture & Engineer- ing (Virginia)	Diagnosis/ pescription	OAV Triplets and Production Rules	Backward Chaining	written in LISP any LISP machine	- Statements of action. - User entered command statements to be executed during consultation.
OPS 5	Carnegie- Mellon University	Planning	OAV triplets and production rules	Forward Chaining	written in LISP any LISP machine	- Line oriented: - No graphics package. - Original version needs an experienced programmer.
S 1	Teknow- ledge Inc.	Diagnosis/ pescription	OAV triplets and production rules	Backward Chaining, Depth-First Procedural Control	written in LISP any LISP machine	- Graphics display. - Phone in user consultation.
TIMM	General Research Corp.	Example Driven	Examples	Decision tree algorithms & examples	written in FORTRAN IBM PC	- Line oriented. - Certainty factors.
KC (knowledge Engineering System)	Carnegie Group Inc.	*	Frames	Non- monotonic	written in LISP wide variety	- Interactive search. - Graphical interface. - Object oriented programming.
DUCK	*	Planning and/or Diagnosis/ pescription	Rule based	Non- monotonic forward and backward chaining	*	- Programmer can direct search.

* means not available

References: Harmon and King 1985, Peter Smith 1987.

Large Hybrid System Building Tools

Table 6

Name of Tool/ Environment	Developer	Consultation Paradigm	Knowledge- Representation	Reasoning	Hardware Compatibility	Particular Comments
ART	Interface Corp.	Paradigm of Choice	A variety of packages can be purchased separately,		DEC VAX LISP Machines	- Powerful graphical interface.
KEE	IntelliCorp	Paradigm of Choice	Frames with slot, rules, and inheritance	User defined	LISP Machines including Symbolics 3600's	- Graphical display. - Gauge and active values for monitoring system.
LOOPS	Xerox	Paradigm of Choice	Frames with slots. Rule sets stored in slots of frames. Lattices of objects.	User defined	Xerox 1100's.	- Graphics supported in browsing in knowledge base.

References: Harmon and King 1985, Peter Smith 1987.

A Rule-based Representation for Expert System Applicability**Table 7**

Goal: Determine if ES approach is *appropriate*.

Top-Level Rule:

- If:** the ES approach is
1. relevant and
 2. feasible and
 3. optimal and
 4. success-oriented,
- Then:** an ES approach is appropriate.

Second-Level Rules

Relevancy Rule

- If:**
1. There is a shortage of skilled employees, or
 2. job performance requires extensive amount of human training, or
 3. no single individual can hold all necessary knowledge, or
 4. difficulties in applying existing knowledge lead to working around problems or
 5. large numbers of solutions need to be considered in routine problem-solving,
- Then:** the ES approach is relevant.

Feasibility Rule

- If:**
1. A problem takes a few minutes to a few hours to solve, and
 2. generally accepted domain rules exist, and
 3. experts exist in the field, and
 4. knowledge can be represented using existing techniques,
- Then:** the ES approach is feasible.

Optimality Rule

- If:**
1. Reasoning is necessary with imperfect data and makes hundreds or thousands of judgements, and
 2. inference engine approaches to problem-solving lend themselves to the problem more than conventional techniques, and
 3. extensive interaction required with humans via natural language processing and
 4. the explanation capability is required, and
 5. justification of presented conclusions,
- Then:** the ES approach is optimal.

Success-oriented Rule

- If:**
1. Solutions in the domain are of high value, and
 2. top management supports ES approach, and
 3. an existing ES tool can be used for the core of the application, and
 4. the prototyping process can be employed with problem being tested on a subset of expert knowledge, and
 5. test cases are available for incremental development of the ES, and
 6. all system results can be inspected and critiqued by experts, at each incremental stage, and
 7. a knowledge engineering team is available with a successful track record,
- Then:** the ES approach is success-oriented.

Financial Expert Systems

Table 8(a)

SYSTEM NAME	DEVELOPER	FUNCTION	SUBJECT	LANGUAGE/SHELL
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ACCOUNTING (AUDITING)

Tax Advisor		Tax Planning	Planning.	EMYCIN
Auditor		Audit	Auditing allowance for bad debt	AL/X
Aggregate		Accounting information systems	System design of aggregate financial statements	Prolog
Ice		Audit	Auditing planning process	Interlisp
Ticom		Audit	Internal control evaluation	Pascal
Taxman		Tax Planning	Tax consequences: corporate reorganizations	MicroPLANNER Lisp
EDP Auditor		EDP Audit	Auditing advanced EDP systems	AL/X

BANKING

LASS	New York State University (prototype)	Credit Analysis	Analyse commercial loan applications	OPS5+ and other high level languages
A.A. (Authorization Assistance) AMEX	Inference	Credit Analysis	Help authorizer filter through credit data. Makes credit approval recommendation. Explains reasoning.	Written in ART.
CLASS	N.Y.U. at Alban	Credit Analysis	Commercial Loan Analysis	Gen-X Shell
CAEL	Fannie Mae & Freddie Mac	Credit Assessment	S&L Assessment	.
MARBLE	University of Illinois	Credit Assessment	Determines Creditworthiness	Common Lisp

Financial Expert Systems

Table 8(b)

SYSTEM NAME	DEVELOPER	FUNCTION	SUBJECT	LANGUAGE/SHELL
-------------	-----------	----------	---------	----------------

INVESTMENTS

Folio	Stanford University	Portfolio Management	Investment portfolio advice	MRS
Personal Financial Decision Support System (PFDSS)	Oregon State University	Investment decisions	Personal investment advice	Prolog
PlanPower	Applied Expert Systems	Financial planning	Produces comprehensive financial plans for clients	EMYCIN, then Loops, as base only
PMIDSS	Lee & Stohr	Portfolio Management	Portfolio management advice	Prolog
Le Courtier	Cognitive Systems	Investments	Interactive investment advice	*
ACCI	Roycroft & Loucopoulus	Taxation	Apportionment of close companies income	Advisor
FSA	Aurthur Anderson Co.	Investment Analysis	Financial Statement Extraction and Ratio Analysis	KEE on Lisp Machine

CORPORATE FINANCE

DECMARK	Bohanek, Bratko & Rajkovic	Corporate finance	Capital budgeting decisions	*
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INSURANCE

EQUITABLE CO. UNDER-WRITING	Equitable Company & Arthur D. Little	Insurance policy decisions	Determines credit risk for insurance policy	*
EQUITABLE CO. EXTERNAL AUDIT		Internal audit	Monitors accounts receivable & other financial data	*

References: Silverman 1987

Legend for Summaries of Cases/Software Dimensions**Table 9**

1.	CAEL	Credit/Bankruptcy Analysis
2.	MARBLE	Credit Assessment/Loan Evaluation
3.	LASS Loan Assessment	Credit/Loan Analysis
4.	CLASS	Credit/Loan Analysis
5.	PC Corporate Credit Analysis	Credit Analysis
6.	Credit Card Assessment	Credit Analysis
7.	PlanPower	Financial Planning
8.	FSA	Financial Statement Analysis
9.	PFIDSS	Investment Portfolio Selection
10.	PMIDSS	Investment Portfolio Selection
11.	CLP	Option Trading
12.	Trading Systems	Stock Trading
13.	Economic Investor	Stock Trading
14.	Market Base	Stock Selection
15.	Portfolio Evaluator	Portfolio Management
16.	Profits!	Technical Analysis
17.	Value/Screen II	Stock Selection/Portfolio Management
18.	Ultra SCTA II	Stock Charting and Technical Analysis
19.	ES for Capital Budgeting	Corporate Finance
20.	FAME	Corporate Finance
21.	TAXADVISOR	Accounting / Tax Planning

+ (following a number) means that the corresponding case has elements of more than one characteristic.

NOTE: Omissions of a case number in some categories indicate unavailability of data.

Dimensions Summary for Banking Cases

Table 10

=====				
Data Dimension				
=====				
Source of data:	User input 4	External database access 1	Combination of both: 2, 3, 5, 6	

Volume of data:	Small Structured 1, 6	Mid-range 2, 3, 4, 5	Large	

Complexity of data:	Numeric accounting financial data 1, 4, 5, 6	Qualitative textual/ numeric scales 2+3+	Integration of text/ numeric data responses	

Longevity:	Update cycle		Relevancy period	
	1)Real-time	2)Static periodic updates	3) Point of use	1)Constant 2) Info addition replacement
		1, 2+, 3+, 4, 5+	2+, 3+, 5+, 6	6 1 2, 3, 4, 5
=====				
Knowledge Dimension				
=====				
Knowledge state:	Static 3, 4, 5	Intermediate state 1, 2	Dynamic	

Knowledge structure:	Component Synthesis 1, 2, 3+, 4+, 5, 6	Sequential stage analysis 3+, 4+	Symmetric alternative solution processing	
=====				
Evaluation/Analysis Dimension				
=====				
Math. computational	Comparative /cross industry/historic trend analysis 1, 2, 3+, 4+, 5	Screening/ pruning 6	Parameter variation	Drill-down 3+, 4+
=====				
Output Dimension				
=====				
Text 2+, 3+, 4+, 5, 6	Numeric 1, 2+	Graphics 3+, 4+	Input to larger system	
=====				
DSS/ES Dimension				
=====				
Automated versus human control:	Automated 1, 2, 3+, 4, 5, 6		Human control 3+	

Knowledge dimension coupling:	Loose	Flexible 3	Tight 1, 2, 4, 5, 6	
=====				

* See Table 9 for the case number description.

Dimensions Summary for Investment Cases

Table 11

=====				
Data Dimension				
<i>Source of data:</i>	User input 7,9,10,13		External database access 8, 11, 12, 14, 17	Combination of both 15, 16, 18

<i>Volume of data:</i>	Small Structured 13		Mid-range 18 8,9,10,14,15,16,17	Large 7 11,12

<i>Complexity of data:</i>	Numeric accounting financial data 8+, 11, 12, 13, 14, 15, 16, 18		Qualitative textual/ numeric scales	Integration of text/ numeric data responses 8+, 7, 9, 10

<i>Longevity:</i>	Update cycle			Relevancy period
	1)Real-time	2)Static periodic updates	3) Point of use	1)Constant 2) Info addition replacement
	11,12	8,14	7,9,10,13 15,16,17,18	9,15+,16 7,8,10,11 12,13,14 15+,17,18
=====				
Knowledge Dimension *				
<i>Knowledge state:</i>	Static 7, 8, 11		Intermediate state 9, 10, 12	Dynamic

<i>Knowledge structure: analysis</i>	Component Synthesis 7+, 8	Sequential stage 7+, 9, 10, 12	Symmetric alternative solution processing 11	
=====				
Evaluation/Analysis Dimension				
Math computational models	Comparative /cross industry/historic trend analysis	Screening/ pruning	Parameter variation	Drill-down
13	15+, 16,17+,18+	7+, 9, 10, 11,12 14+, 15+,17+,18+		7+, 8, 14+
=====				
Output Dimension				
Text system	Numeric 7+, 9+, 10, 13+, 14+,17+	Graphics 8, 13+, 14+, 15 17+	Input to larger 7+, 9+, 16 11, 12	
=====				
DSS/ES Dimension				
<i>Automated versus human control:</i>	Automated 11, 12, 13		Human control 7, 9	8, 14, 15, 16,17,18

<i>* Knowledge dimension coupling:</i>	Loose	Flexible 8	Tight 7, 9,11,12	

* means not applicable to software packages.

See table 9 for the case number description.

Case Dimensions Summary for Corporate Finance and Accounting

Table 12

Data Dimension					
Source of data:	User input 21		External database access 21		Combination of both 19, 20
Volume of data:	Small Structured 19		Mid-range 21	Large 20	
Complexity of data:	Numeric accounting financial data 19, 20, 21		Qualitative textual/ numeric scales		Integration of text/ numeric data responses
Longevity:	Update cycle 1)Real-time 2)Static periodic updates		3) Point of use 19, 20, 21		Relevancy period 1)Constant addition 19 2) Info replacement 20, 21
Knowledge Dimension					
Knowledge state:	Static 19,20,21		Intermediate state		Dynamic
Knowledge structure: analysis	Component Synthesis 20+, 21		Sequential stage 19, 20+		Symmetric alternative solution processing
Evaluation/Analysis Dimension					
Math computational models	Comparative /cross industry/historic trend analysis		Screening/ pruning 20	Parameter variation 19	Drill-down 21
Output Dimension					
Text 20,21	Numeric 19+		Graphics 19+		Input to larger system
DSS/ES Dimension					
Automated versus human control:	Automated 21		Human control 19		
* Knowledge dimension coupling:	Loose		Flexible 19		Tight 21

* means not applicable to software packages.

See table 9 for the case number description.

Overall Case Decomposition for Financial Dimensions**Table 13**

=====				
Data Dimension				
<i>Source of data:</i>	User input 4,7,9,10,13, 21		External database access 1,8,11,12,14,17	Combination of both 2,3,5,6,15,16,18,19,20

<i>Volume of data:</i>	Small Structured 1, 6,13		Mid-range 19 2,3,4,5, 8,9,10, 14,15,16,17,21	Large 7,17 11,12

<i>Complexity of data:</i>	Numeric accounting financial data 1,4,5,6,8+,11,12,13,14, 15,16,17,18,19, 20,21		Qualitative textual/ numeric scales 2, 3	Integration of text/ numeric data responses 8+,7,9,10

<i>Longevity:</i>	Update cycle			Relevancy period
	1)Real-time	2)Static periodic updates	3) Point of use	1) Constant 2) Info addition replacement
	11,12	1,2+,3+,4, 5+,8, 14, 17	2+,3+,5+, 6,7 9,10,13,15,16 17,18,19,20, 21.	6,9, 2,3,4,5,7,8,10, 15+,16 11,12,13,14, 19. 15+,17,18,20,21
=====				
Knowledge Dimension				
<i>Knowledge state:</i>	Static 3,4,5,7,8,11,16,19, 20,21		Intermediate state 1,2,9,10,12	Dynamic

<i>Knowledge structure:</i>	Component Synthesis		Sequential stage Analysis	Symmetric Alter. Soln. Processing
	1,2,3+,4+,5, 6,7+, 8. 20+,21		3+, 4+,7+,9, 10,12,,20+	11
=====				
Evaluation/Analysis Dimension				
Math computational models	Comparative /cross industry historic trend analysis 1,2,3+,4+,5 15+,16,17+,18+		Screening/ pruning 6,7+,9,10,11, 12,14+ 15+,17+,18+, 20	Parameter variation 19 3+,4+,7+,8, 14+, 21
13				
=====				
Output Dimension				
Text 2+,3+,4+,5,6, 7+, 9+,10,13+, 14+,17+, 20, 21	Numeric 1,2+, 8, 13+, 14+, 15 16+,17+,19+		Graphics 3+, 4+,7+,9+, 16+,18,19+	Input to larger system 11,12
=====				
DSS/ES Dimension				
<i>Automated versus human control:</i>	Automated 1,2,3+,4,5,6,11,12,13,21		7,9,19	Human control 3+,8,14,15,16,17,18

<i>Knowledge dimension coupling:</i>	Loose		Flexible 3, 8,19	Tight 1,2,4,5,6,7,9,11,12,21

* See table 9 for the case number description.

Case Decomposition by Financial Areas**Table 14****Banking:*****a) Credit Analysis***

CAEL (1)
 PC Corporate Credit Analysis (5)
 Credit Card Assessment (6)

Credit/Bankruptcy Analysis
 Credit Analysis
 Credit Analysis

b) Commercial Loan Assessment

MARBLE (2)
 LASS (3)
 CLASS (4)

Credit Assessment/Loan Evaluation
 Loan Assessment
 Credit/Loan Analysis

Investments***a) Financial P'anning***

PlanPower (7)

Financial Planning

b) Portfolio Management/Optimization

PFIDSS (9)
 PMIDSS (10)
 Portfolio Evaluator (15)
 Profits! (16)

Investment Portfolio Selection
 Investment Portfolio Selection
 Portfolio Management
 Technical Analysis

c) Stock Trading

FSA (8)
 Trading Systems (12)
 Economic Investor (13)
 Market Base (14)
 Value/Screen II (17)
 Ultra SCTA II (18)

Financial Statement Analysis
 Stock Trading
 Stock Trading
 Stock Selection
 Stock Selection/Portfolio Management
 Stock Charting and Technical Analysis

d) Option Trading

CLP (11)

Option Trading

Corporate Finance***a) Capital Budgeting***

ES for Capital Budgeting (19)

Corporate Finance

b) Financial Marketing

FAME (20)

Corporate Finance

Accounting***a) Tax Planning***

TAXADVISOR (21)

Accounting / Tax Planning

General Case Groupings Along Financial Dimension Continua

Table 15 (a)

a Cross-Sector Analysis

Data Dimension

Source of data

Volume of data

Complexity of data

Longevity of data (update cycle)

←→ Continuum line

* Accounting is positionned according to the expected domain position.

Table 15 (b)

Knowledge Dimension				
Knowledge state				
Static		Intermediate		Dynamic
Financial planning Option trading Capital budgeting Financial marketing Accounting		Credit assessment Commercial loan assessment Portfolio management Stock trading		
Knowledge structure				
Component Synthesis		Sequential Stage		Symmetric Alternative Processing
Credit assessment Commercial loan assessment Accounting Financial planning Stock trading Financial marketing		Portfolio management Capital budgeting		Option trading
Evaluation/Analysis Dimension				
Math Model	Comparative/ Trend Analysis	Screening/ Pruning	Parameter Variation	Drill down
	Portfolio mgt. software Credit assessment Commercial loan+ Accounting+	Credit card assessment Portfolio mgt. cases Financial planning+ Stock trading+ Option trading Financial marketing	Capital budgeting.	Stock trading+ Commercial loan+ Financial planning+ Accounting+
Output Dimension				
Text	Numeric	Graphic	Larger System Input	
Financial marketing Commercial loan+ Credit assessment+ Portfolio mgt.+ Financial planning + Accounting+	Commercial loan+ Credit assessment+ Capital budgeting+ Accounting+	Capital budgeting+ Portfolio mgt. + Financial planning+	Stock trading Option trading	

Table 15 (c)

Automated versus human control

Loose ← **Flexible** → **Tight**

Capital Budgeting

Credit assessment
Commercial loan assessment
Accounting
Stock trading
Option trading
Portfolio management
Financial planning

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