A DISTRIBUTED KNOWLEDGE-BASED SUPPORT SYSTEM FOR STRATEGIC MANAGEMENT

by

Vevekanand Ram

Submitted in partial fulfilment of the
requirements for the degree of
Doctor of Philosophy,
in the
Department of Business Administration,
University of Natal
Pietermaritzburg, 1990

Abstract

Strategic management is both a complex and an important management function in any organization. It is complex because of the multiplicity and uncertainty of its inputs. It is important because it provides a basic understanding of how the organization will compete in its environment and because there is strong empirical evidence to suggest that the practice of strategic management can improve the long-term performance of an organization. The effectiveness of strategic management has however been severely criticised in recent years because of difficulties experienced in its practice. These difficulties arise out of the overwhelming number of options and variables that must be considered and they become more acute as environments grow more turbulent.

Managers have turned to computer-based systems for support and although a considerable amount of research has been pursued, the systems arising out of this activity has been confined to a limited area of the problem. A system to support the total strategic management process has not yet been developed mainly due to the size and complexity of the application area. The research presented in this thesis is an attempt to provide such support through the use of a distributed knowledge-based system. The distributed approach allows the problem area to be compartmentalized into natural partitions and thus reduces the problem of size. The nature of knowledge-based systems, especially the use of heuristic methods and symbolic reasoning, enables it to be applied more effectively to the complexity than conventional procedural systems. The distributed approach also allows access to powerful methods such as the blackboard control system and the centralized multi-agent system which were both developed for use in the area of distributed artificial intelligence.

The prototype distributed support system described in the thesis consists of a Control Module which also acts as a strategy formulation expert and individual modules for each of the functional areas of Marketing, Finance, Production and Organization. The control module uses a set of organizational and environmental factors to generate a strategic option which is translated into functional action plans by the individual modules. The thesis is essentially organized in two parts. The first part of the thesis is devoted to a detailed examination of the application area, its problems and the status of current research. The remainder of the thesis concerns the design, development and evaluation of the prototype system.

Preface

The research work described in this thesis was carried out in the Department of Computer Science, University of Natal, Pietermaritzburg, under the supervision of Professor Gavin R Finnie.

This research represents original work by the author and has not been submitted in any form to another university. Where use was made of the work of others, it has been duly acknowledged in the text.

Acknowledgements

I would like to thank the many people without whom I would never have completed the thesis. Professor Gavin Finnie, my supervisor, who provided the expert guidance both in the research and its presentation. Professor Nick Phillips for his advice and constant encouragement and Professor Mathew Lynas for his valuable input. The staff of the Computer Science Department: Stef, Rob, Chris, Arleen, Bobby, Simon, Egmont, Mike and Barbara who shared my marking burden during the compilation.

I would like to thank my wife Indranie and our children Kadambari, Yashoda, Vibhav and Siddhartha for their constant support and tolerance.

I would also like to express my sincere gratitude to my parents for their support and encouragement and for the wonderful values that they have instilled in me. My debt to them is immeasurable. I would also like to thank Radha, a special person who is no longer with us and from whom I have learnt so much.

Finally, I would like to thank the committee of the University of Natal Research Fund for their assistance in the purchase of software and supplies and also in enabling me to attend conferences.

List of Contents

List of Illustrations

CHAPTER 1

Introduction

The research presented in this thesis is an exploration of the use of Knowledge-based systems to support the special kind of decision making and control activity known as Strategic management.

Knowledge-based systems, together with robotics, perception systems, natural language systems, theorem proving and game playing systems, form part of the general field of artificial intelligence. Knowledge-based systems are computer programs that use symbolic and heuristic reasoning processes rather than the more conventional computational techniques in order to solve problems in specific decision making domains. Distributed knowledge-based systems are systems in which a set of discrete individual knowledge-bases interact and cooperate in order to solve a problem in a specific decision making domain. This thesis describes the design and construction of an experimental prototype using a network of distributed knowledge bases that interact and cooperate in order to assess an organizations strategic posture, generate strategic alternatives, assist in the choice of an optimal strategy and monitor and control the implementation of the functional plans that are derived from the chosen strategy. The network consists of a control module that acts as a strategy formulation expert, and separate modules for each of the functional areas of Marketing, Production, Finance and Personnel. The control module controls the coordination of the network and as the formulation expert, makes use of a powerful heuristic to generate generic strategic options which are translated into functional plans by the individual modules. The area of strategic management is used as the specific domain area of application for two important reasons. Firstly, strategic management is probably the most complex decision making and control activity due to its unstructured nature and the multiplicity and uncertainty of its inputs. It is also the most crucial decision making and control activity in any organization since the impact of the decisions made in this context can have profound effects on the organization and even on the industry within which it operates. Secondly, the practice of strategic management has been severely criticised recently for not being as effective as it could be because of the manner in which strategic principles are applied. The knowledge-based system described in this thesis is capable of providing the support necessary for improving the quality of strategic decision making and can also ensure that strategic principles are applied in the proper context.

The term expert system is often used synonymously with knowledge-based system even though many knowledge-based systems do not contain sufficient expertise to be classified as such. The term knowledge-based system is preferred and will be used throughout the thesis.

The use of knowledge-based systems in business marks the latest phase in the accelerated shift in emphasis from the traditional electronic data processing systems and management information systems to decision support systems and management support systems. This transition reflects a fundamental and powerful shift in human-technological concerns from data and information to knowledge and wisdom and brings with it a profound reorientation in management, decision making and organization of work (Zeleny 1987). This shift represents a change in the importance of computing in business from pure computation to complex decision making support and the preservation of expertise.

1.1 Research objectives

As the nature of the research is exploratory, it is more appropriate to phrase a fundamental research question or objective rather than to formulate a hypothesis. The purpose of the research is to investigate the appropriateness of the application of a distributed knowledge-based system to support the strategic management process. The explicit relationship between the use of such a support system and the improvement in strategic performance can only be tested as a hypothesis when the prototype constructed in this research is extended to a full system. With this in mind, the following research objectives can be formulated:

> **The major research objective of this thesis is to show that a distributed knowledge-based system has the potential to support the strategic management process in its entirety and this potential can be demonstrated through a prototype**

> **A minor objective in support of the first is to examine the available literature to show that the problems currently experienced in the practice**

of strategic management emphasise the need for support and that available support methods do not address the complete spectrum of activities in the strategic management process.

1.2 Overview of thesis

This thesis describes the development and implementation of a distributed knowledge-based support system for strategic management. Although knowledge-based systems development is a relatively recent discipline, several frameworks have been suggested to assist in the development process (Waterman(1986), Hayes-Roth et al (1983), Goul (1987), Boehm (1988), Weitzel and Kerschberg (1989), Harmon and King (1985)). These frameworks all share the same view that knowledge-based system development is made up of five interdependent and overlapping phases: Identification, Conceptualization, Formalization, Implementation and Testing. These phases form an extremely convenient and logical structure and will be used to organize the presentation of the research in this thesis.

Chapters 2 and 3 cover the **Identification** phase which concerns the identification of the application area, a definition of its scope and an examination of the objectives of the system to be developed.

Chapter 4 covers the **Conceptualization** which refers to the process of combining theoretical concepts from the application area into a problem solving framework within which the system may be constructed.

Chapters 5, 6, 7 and 8 cover the **Formalization** phase which involves expressing the concepts and problem solving relationships in a formal way. The basic architecture for the system is developed at this stage.

Chapters 9 and 10 present the **Implementation** which refers to the transformation of the formalized knowledge into a working computer system. In this stage, domain knowledge from the application area, that is the data structures and inference rules made explicit in the formalization, is given form through an implementation language.

Chapter 11 covers the **Testing** phase which involves the evaluation of the performance and the utility of the prototype system.

1.3 Detailed readers guide

Chapter 2 presents an extensive examination of the area of strategic management by considering various views and establishing a unified framework within which the system is developed.

Chapter 3 examines the practice of strategic management in order to identify the problems currently being experienced in the area. The resolution of these problems forms part of the goal of building the system.

Chapter 4 examines current approaches to strategic management support in an attempt to establish an integrated framework. A rationale for a distributed framework as a solution is presented.

Chapter 5 examines the field of Distributed Artificial Intelligence in order to identify the formal techniques currently being used in distributed networks, in order to assess their suitability for inclusion into the system design.

Chapter 6 presents a discussion of the basic Artificial intelligence concepts used in the development of the support system and also presents the framework for the heuristic strategy generating mechanism used by the control module to optimize network activity.

Chapter 7 presents the distributed architecture and describes its components. An overview of the intended operation of the system is also presented in this chapter.

Chapter 8 describes the formal requirements of the Blackboard architecture and the network control and scheduling mechanisms used in the system.

Chapter 9 presents the Prolog implementation of the control module and the blackboard structure. The implementation of the heuristic strategy generating mechanism is also described.

Chapter 10 presents the Prolog implementation of the individual knowledge modules.

Chapter 11 is devoted to the evaluation of the system in terms of its general objectives. The effectiveness of the knowledge representation schemes, the control mechanisms and the network efficiency is examined. The major limitations and the required extensions to the prototype system is also discussed.

Chapter 12 concludes the thesis by summarizing the results obtained from the prototype system and presenting the major contributions of the research. Areas for further research and related work is also presented.

CHAPTER 2

Strategic management - An overview

There is at present a web of semantic confusion entangling the concept of strategic management. Both researchers and practitioners in the field are divided on the definition of strategic management. Terms such as Policy, Corporate Planning, Strategy and Strategic Planning have all been used to describe the special kind of problem solving and control activity that an organization engages in, in order to achieve a dynamic match between its internal functioning and its external environment. Since this problem solving and control activity forms the major focus of this thesis, this chapter begins by examining a range of views of the concept of strategic management in order to extract a unified view that can be used in the remainder of the research.

2.1 The nature of strategic management

2.1.1 An examination of different views

The first formal definition of the concept can be attributed to Henry Fayol, who in 1949 described it as "assessing the future and making provision for it". Since Fayol's time however, the perception of the strategic problem has been undergoing rapid and drastic change. According to Igor Ansoff (1976), this is due to an improved understanding of the real nature of the mismatch with the environment and of the processes involved in redressing it. In the early part of this century, the scope and content of the operations of most organizations were limited. Environmental forces were relatively weak and forecasting could be accomplished with much confidence. As a result, many organizations enjoyed almost total control over their operating environments. Efficiency and productivity were measures of success and the strategic problem consisted of finding the most technically efficient course of action and optimizing the means of its implementation. In more recent times, management emphasis has been forced to shift from a focus on efficiency to a focus on effectiveness and the strategic problem now consists of a focus on the "choice of future directions after a consideration of the internal and external environments" (Radford 1980). This shift is very aptly captured in a statement by Drucker that "it is more important to do the right things than to do things right" (Drucker 1954). He went further to say that an organization doing the right thing wrong is better off in the long term than an organization doing the wrong thing right. Put another way, if a choice has to be made between effectiveness and efficiency, effectiveness should receive priority.

Chandler (1962) defined organizational strategy as " the determination of the basic long term goals and objectives of an organization and the adoption of courses of action and the allocation of resources necessary for carrying out these goals" (Chandler 1962). Andrews defined organizational strategy as " the pattern of decisions in an organization that determines and reveals its objectives, purposes or goals, produces the principal policies and plans for achieving those goals, and defines the range of business the organization is to pursue, the kind of economic and non-economic contribution it intends to make to its shareholders, employees, customers and communities" (Andrews 1980). Both Chandler and Andrews include in their view, the formulation of objectives as well as the means for achieving those objectives. Hofer and Schendel (1978) call this the broad concept of strategy in contrast to the narrow concept of strategy which does not include the formulation of objectives. Another broad view of the concept is that held by Steiner and Miner who describe it as a process that involves a surveillance of the internal and the external environment, the identification in that environment of opportunities to exploit and dangers to avoid, an evaluation of relevant company strengths and weaknesses, the formulation of missions and objectives, the identification of strategies to achieve company aims, the evaluation of the strategies and a choice of those that will be implemented and finally, establishing a monitoring process to make sure that strategies are properly implemented (Steiner and Miner 1982). A further broad view is that of Gilmore and Brandenburg who suggested a comprehensive framework in 1962 which is expressed in terms of a master plan which includes the formulation of the economic mission, the determination of the competitive strategy, the specification of a program of action and a reappraisal of activities and results (Gilmore and Brandenburg 1962).

Proponents of the narrow view of the concept of Strategy do not include the formulation of missions or objectives in their frameworks. Hofer and Schendel (1978) view strategy as the fundamental pattern of present and planned resource deployments and environmental interactions that indicates how the organization will achieve its objectives. Day (1984) describes the concept by identifying four distinguishing features; an external orientation, a process for formulating strategies, methods for the analysis of strategic situations and alternatives and a commitment to action. Ackoff (1970) views the strategic problem as the simultaneous consideration of the set of interdependent decisions facing an organization for the purpose of extracting a satisficing solution which allows the organization to do well enough but not as well as is possible. Ansoff also subscribes to the narrow view of the concept but he adds the additional sub-problems of implementation and control which according to him distinguishes strategic management from strategic planning. To make this distinction more explicit, he lists the following differences between strategic management and strategic planning. Strategic planning is concerned with the external linkages of the firm while strategic management is concerned with both the external and the internal linkages. Strategic planning focuses primarily on the formulation of strategy as a problem-solving process while strategic management also includes the problems of implementation and control (Ansoff 1976).

It is possible to extricate from the views presented a single unifying thread that ties together the terms Strategic Management, Strategic Planning and Strategy. Strategy refers to the formulation of basic organizational objectives, the formulation of tasks to achieve the objectives and the formulation of methods to implement the tasks. Strategic Planning is the process of devising Strategy. Strategic Management is the management of the strategy and thus includes the monitoring and control of the implemented strategy.

Policies can be regarded as guides for carrying out an action. A business policy can be defined as management's expressed or implied intent to govern action in the achievement of an organization's aims (Steiner and Miner 1982). An organization can have defined policies at every level of management. There can be literally hundreds of operational policies at the low level and only a few broad policies at the very top. At this level policies and strategies become indistinguishable.

Since many organizations have a very wide scope of operations in sometimes very diverse areas, it is important to be able to apply a given view of strategic management in a hierarchical framework. Hofer and Schendel (1978) differentiate between corporate strategy, business strategy and functional strategy. Andrews (1980) refers to corporate strategy and business strategy. Corporate strategy concerns itself with the determination of the set of businesses in which an organization will compete and the allocation of its resources among the selected businesses. Business strategy is the determination of how a given business will compete and position itself among its competitors. Functional strategy focuses on the maximization of resource productivity and the development of distinct competencies. Hamermesh (1986) refers to another level which he calls institutional strategy which determines the basic character and vision of the organization. Andrews (1980) refers to this as "..the kind of economic and human organization it is or intends to be".

The examination of the range of views of the concept of strategic management, is reminiscent of the old parable of the four blind men and the elephant. Each feels a different part of the elephant's body and believes it to be the total being. The man feeling the tail believes the elephant to be a rope, another believes the trunk to be a snake, the third believes the side to be a wall and the last man believes a leg to be a tree trunk. At least three parts of the strategic management elephant have been identified in this examination and although this provides convincing evidence of its nature, there are other considerations. Taylor (1982), for example, believes that strategic planning can be viewed as a political and social learning process. Cyert and March (1963) view the concept as strategic adjustment through organizational adaptive learning. The importance of these more philosophical and socio-psychological considerations is acknowledged but as they are not sufficiently related to the purpose of the research in this thesis, they will not be examined further. Another consideration, that of strategic behaviour or patterns of strategic activity, will be examined later in this chapter.

2.1.2 A unified definition of strategic management

The examination of the range of views of strategic management has emphasized the distinction between broad and narrow strategies, the different levels at which strategic management is exercised and the relationship between Policy, Strategy, Strategic Planning and Strategic Management. A view can now be defined that encompasses all the aspects of the concept of strategic management that are relevant to the establishment of a framework within which the support system can be constructed. The definition chosen is narrow since the area of interest is in the support of the management of strategy, a process to which many analytical and heuristic methods may be applied. The setting of goals requires the simultaneous consideration of theoretical, economic, social, aesthetic, political and religious factors and is best done in the subjective manner to which owners and shareholders have become accustomed. Guth and Taguiri (1965) have shown that these value factors influence the choice of strategic goals and objectives and while values can not be classified as good or bad, the success of the organization depends on the appropriateness of the values to the situation in which they are employed.

It is assumed then, for the purpose of this thesis, that the broad organizational goals have been defined and the focus will be concentrated on the support of the processes of strategy formulation, implementation and control. With this in mind, the following definition of strategic management is proposed.

Strategic management is the **process** through which strategies that achieve the goals of an organization are formulated, implemented and controlled and takes into consideration the following

- The scope of an organization's activities
- The equilibrium between an organization's activities and its environment
- The equilibrium between an organization's activities and its resources
- The allocation of resources within the organization

2.2 The process of strategic management

The word process in the preceding definition is emphasized since it is believed, in much the same way as Gilmore and Brandenburg (1962) believed, that in order to develop a more systematic approach to strategic management, a logical scheme which enables a clearer understanding of the major characteristics of strategic management must be constructed. The process of strategic management as described above comprises the three subprocesses of strategy formulation, strategy implementation and strategic control. Strategy formulation in turn consists of strategic analysis and strategic choice. Figure 2.1 displays the logical scheme of the process of strategic management. The relationships and the ordering between subprocesses are clearly visible.

It is stressed that while the diagram shows all the important aspects of strategic management, it may give the false impression that the process consists of a series of predictable steps. This is not the case in reality where many of the relationships between the processes can become convoluted. The subprocesses strategic analysis, strategic choice, strategic implementation and strategic control will now be examined in detail.

2.2.1 Strategic analysis

Strategic analysis is concerned with the identification of factors that define the relationship between an organization and its environment. Ansoff (1976) calls this relationship the organization's strategic posture. He combines the factors that influence the strategic posture into the following three areas; the changing environment, the linkages between the organization and its environment, and the internal configuration of the organization's resources. Steiner and Miner (1982) call their analysis subprocess, the situation audit, the purpose of which is " to identify and analyse the key trends, forces and phenomena that may have a potential impact of importance on the formulation of strategy". The scope of the activities within strategic analysis is clearly shown in figure 2.2. Three main

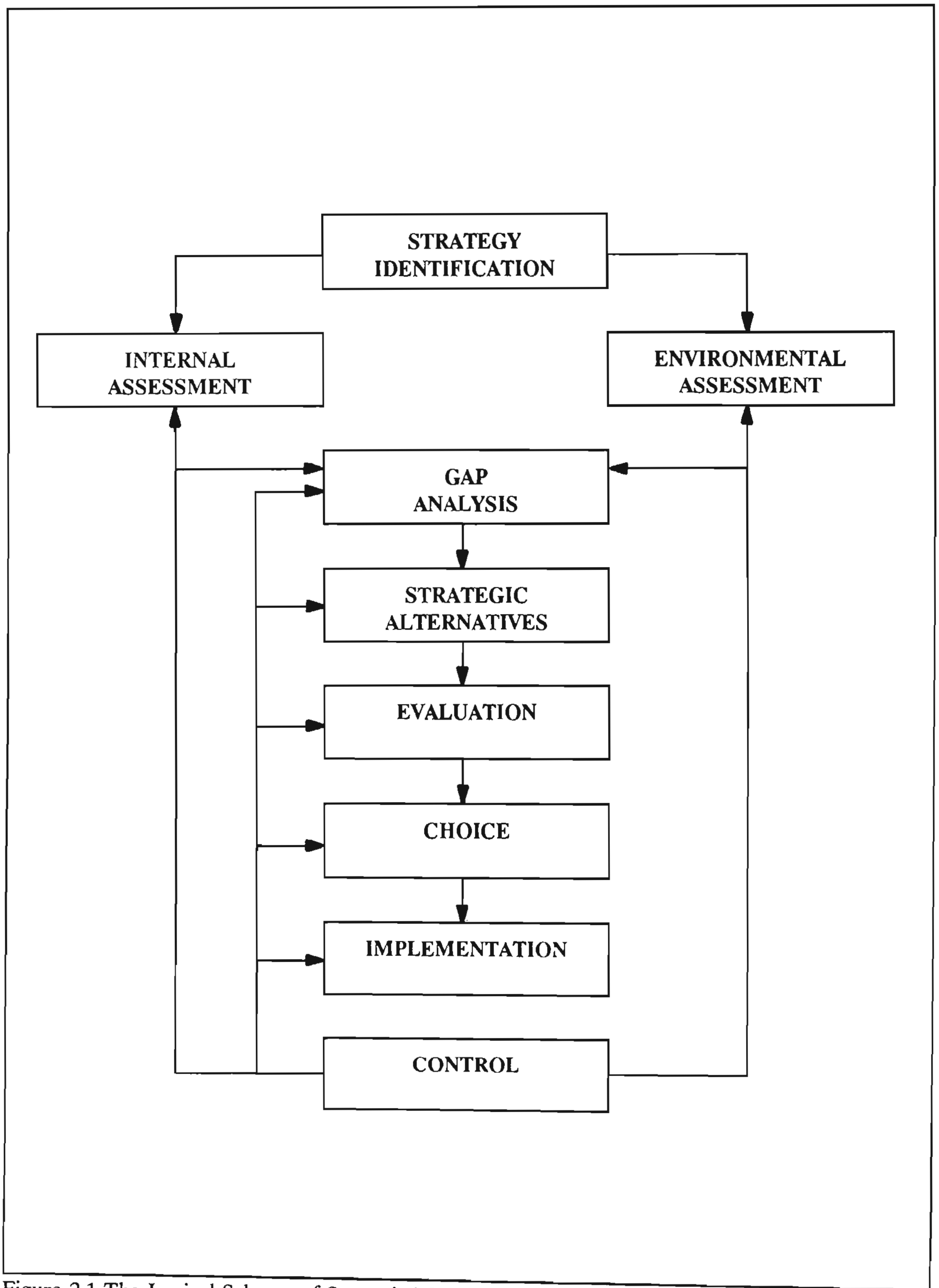


Figure 2.1 The Logical Scheme of Strategic Management

categories of analysis can be identified. These are environmental analysis, competitor analysis, and resource and competence analysis.

ENVIRONMENTAL ANALYSIS

Political
Economic
Technological
Societal
Market Size & Potential
Customer Trends
Segmentation
Suppliers
Distributors
Pricing Trends
Demand Sensitivity

COMPETITOR ANALYSIS

Direct Competition
Potential Competition
Substitute Products
Forward Integration by Suppliers
Backward Integration by Customers

RESOURCES AND COMPETENCIES

Ability to Conceive and Design
Ability to Produce
Ability to Market
Ability to Finance
Ability to Manage

Figure 2.2 The scope of Strategic Analysis (adapted from Day(1984))

Environmental analysis is concerned with the nature of the economic, political, technological, ethical and social world within which an organization operates. This environment is changing constantly and it is to the advantage of the organization to identify changes before they occur rather than after they occur. The search for and the evaluation of environmental forces should be systematic because the range of environmental variables can become overwhelming. The work of Narchal et al (1987) and Fahey et al (1981) is particularly useful in this regard and will be referred to in the construction of the support system. Many variables in the environment give rise to opportunities which the organization can take advantage of and many variables will exert pressure or threaten the well-being of the organization. The main objective in the environmental analysis is to extract from the complexity of variables an analytically based view of the most important environmental impacts for the purpose of strategy generation and choice. A useful visual representation of the complexity of the environment is shown in figure 2.3 as the environmental wheel which is constantly rolling in response to the occurring changes.

Competitor analysis concerns the identification and evaluation of the most important competitive forces that exist in the industry within which an organization operates. The work of Porter (1980) provides a useful guide in this area. His framework is called structural analysis and identifies the following five major competitive forces

- The threat of new entrants
- The threat of substitute products
- The bargaining power of suppliers
- The bargaining power of customers
- The intensity of rivalry among existing competitors

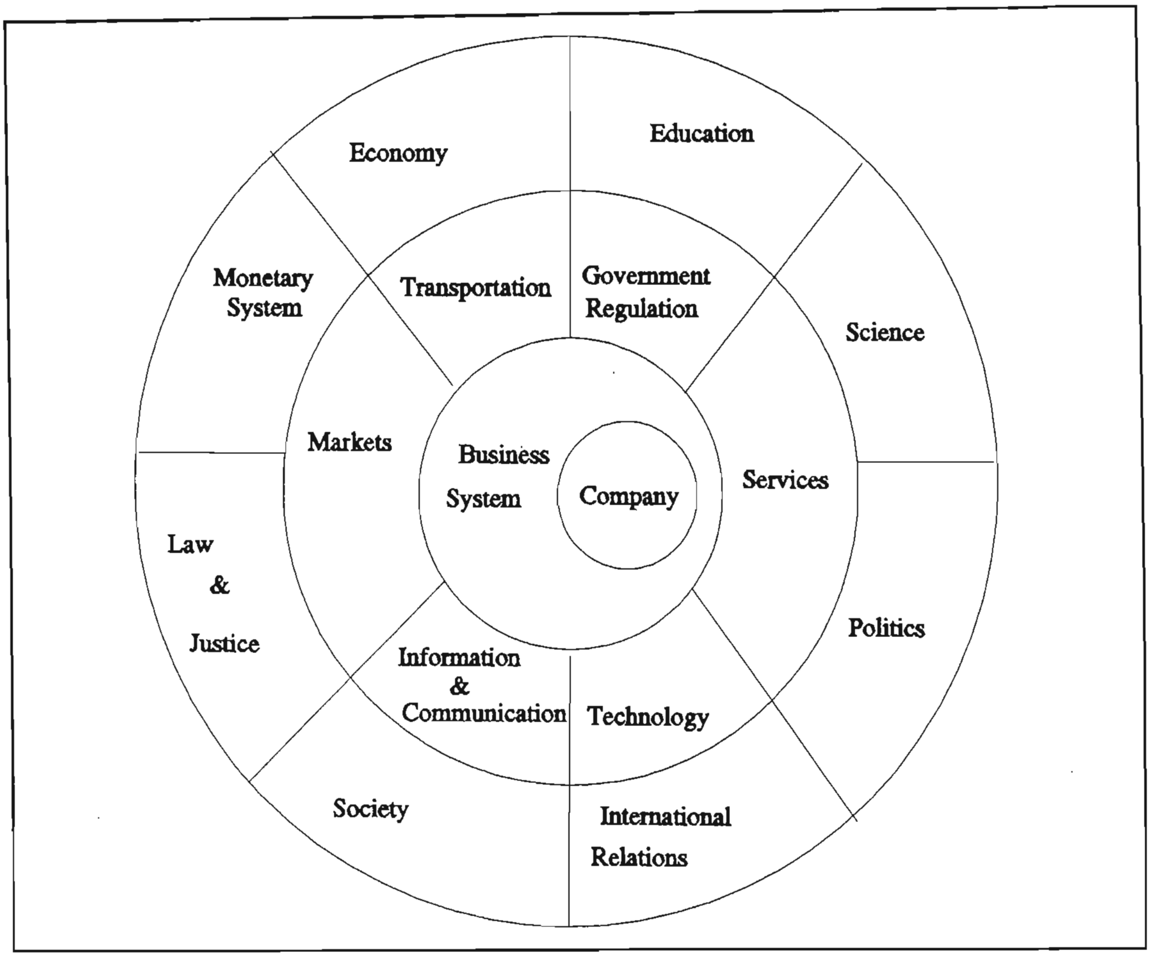


Figure 2.3 The Environmental Wheel (adapted from Narchal et al (1987))

The threat of entry concerns the conditions under which a new competitor will enter the industry. In general, a new competitor will only enter an industry if the barriers to entry are low and the reaction from existing competitors is expected to be low also. Initial capital requirements form the major barrier to entry for a new competitor. The economies of scale and experience curve benefits enjoyed by the existing competitors can also be a barrier. Product differentiation in the form of a strong brand image, restricted access to distribution channels and legislative protection are also strong barriers to entry. The strength of the competitive position of an existing competitor is directly related to the extent of the barriers to entry in a given industry.

The threat of substitute products concern the probability that a substitute product may encroach upon an organization's activities and the action that can be taken to minimize this probability. The substitution may be a new product serving the same function or the substitution may be even more complicated, for example, an activity or a new way of thinking that is substituted for a physical product. The higher the pressure exerted from substitute products, the less attractive the industry.

The bargaining power of suppliers concerns the conditions of supply in the organization's resource markets of labour, raw material and facilities. Sources of supply influence costs and can be an important factor if there are only a few sources of supply, the switching costs from one source to another is high, there is a possibility of a supplier integrating forward or the customer from the suppliers point of view is not important. In general, an increase in supplier power tends to reduce an organization's competitive position.

The bargaining power of customers concerns the conditions under which an organization sells its products and can be an important factor if there is a concentration of buyers with a high purchase volume, there are alternative sources of supply as in the case of an undifferentiated product or there is a threat of backward integration by the customers.

In both the cases of the bargaining power of suppliers and buyers, the concept of value added is extremely important. Value added refers to the relative proportion of value added to a product at different stages of production. In industries with low value added, the effects of bargaining power in adjacent stages are magnified since inputs form the major portion of total cost on the one end and there is very little opportunity to cut costs or to absorb the effects of price changes on the other.

The intensity of competitive rivalry concerns the actual competitiveness of the competitors in an industry. The more intense this rivalry is, the more difficult it becomes for the existing organizations to compete or even survive. The number of competitors and their relative shares of the market plays an important role. A few large competitors with equivalent shares can lead to a quest for domination. Most stable markets have at least one dominant competitor. The rate of growth of the market, the level of fixed costs and the degree of product differentiation all influence the intensity of rivalry.

Figure 2.4 shows the relationships between the five competitive forces discussed above.

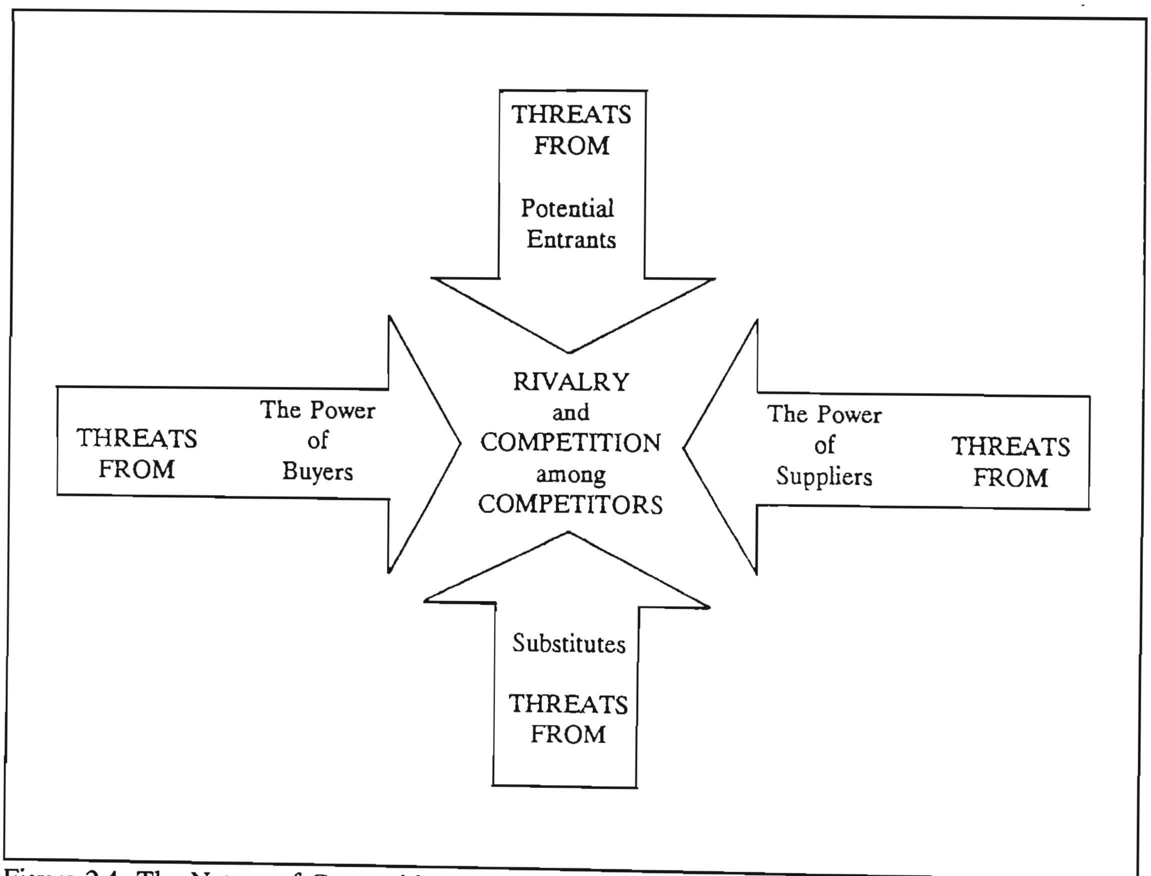


Figure 2.4 The Nature of Competitive Forces (adapted from Porter (1980)

Resource and competence analysis is concerned with the factors that influence the organization internally. These factors can arise out of one of four areas inside the organization.

- Managerial
- Marketing
- Financial
- Technical

Managerial factors concern the ability of the organization to manage. It includes leadership and planning capabilities, depth of experience and effectiveness of controls. Marketing factors concern the ability of the organization to market. It includes coverage of the served market, knowledge of the served market and the level of response to customer needs. Financial factors concern the ability of the organization to generate income and maintain profitability. Technical factors concern the ability of the organization to design and produce a marketable product. It includes product costs, productivity, flexibility of manufacturing processes and technological research. The above is by no means an exhaustive list of the factors influencing the internal configuration of the organization. It is merely a summary of the kinds of factors that are involved in each area. In considering these factors, it is possible to establish the organizational strengths that can be used to achieve its objectives. It is also possible to identify any possible weaknesses or limitations in the organization that will impede the attainment of its objectives. The strengths and weaknesses of the organization thus identified must be related to the results of the environmental analysis in order that the organization's strengths can be used to take maximum advantage of any opportunities existing in the environment and that the organization's weaknesses do not fall prey to threats from the environment.

2.2.2 Strategic choice

The process of strategic choice encompasses three stages. These are

- The generation of strategic options
- The evaluation of strategic options
- The selection of strategy

The generation of strategic options forms the linkage between the predominantly cognitive and reflective strategic analysis phase and the more action-oriented implementation phase. It is important that a broad array of strategic options are generated. This helps to overcome the narrowing of strategic vision, or "tunnel vision" as Ohmae (1982) describes it, and prevents the premature closing on one option. There are two ways in which strategic options can be generated. The first is to consider generic options, a portfolio of options that prescribe the actions that are to be taken in order to achieve or prevent a certain strategic posture. The other way is to use strategic thinking in order to generate innovative and unusual strategies.

Generic strategic options can be generated by considering prescriptive options put forward by various proponents such as Porter (1980) and Ohmae(1983), or derived from analytical methodologies such as the experience curve, the product life cycle theory, the growth matrix, the portfolio matrix or the GE business screen. These methodologies accept as input certain organizational and environmental factors and use these factors to map the relationship between them onto a grid. Specified areas in the grid contain prescriptive strategies.

Strategic options can also be generated by encouraging strategic thinking about changes in the determinants of competitive success and how these changes can be exploited or deliberately shaped in order to achieve an enhanced competitive position. Day (1984) lists a variety of "thought triggers" that encourages strategic thinking. These are: challenge the present strategy, look for strategic windows, play on competitors' vulnerabilities, change the rules of the game and finally, enhance customer value. Ohmae (1982) for example, recommends the following triggers. Challenge the strategic assumptions, exploit the degrees of freedom and change the battleground.

Evaluating strategy is a lengthy and circuitous process. Some strategies can be rejected early, new options are formed by combining the best features of others, and details and refinements are added continually. Day (1984) compares the evaluation of strategy to the testing of a scientific theory. While a theory can never be proven to be absolutely true, it can be declared to be absolutely false if it fails to stand up to testing. Similarly, it is impossible to prove that a strategy is optimal or to even guarantee that it will work. A set of evaluation criteria is needed to isolate those strategies that have critical flaws and to increase the probability that the best option will be chosen. The set of criteria most widely used by writers on strategy is that proposed by Seymour Tilles in 1963. In terms of these criteria, a strategy must satisfy the following six requirements

- Internal consistency

- Consistency with the environment
- Appropriate in the light of available resources
- Satisfactory degree of risk
- Appropriate time horizon
- Workability

According to Tilles, if all of these criteria are met, " you have a strategy that is right for you. This is as much as can be asked ". Each of these criteria will be discussed briefly.

Internal consistency refers to the cumulative impact of individual strategies on organizational goals. Each strategy should not be judged on its own but also in terms of how it relates to the other strategies and the goals of the organization. An inconsistent strategy can lead to the organization having to make a strategic choice without enough time to search for or to prepare more attractive alternatives.

Environmental consistency concerns the way that a particular strategy will influence the relationship between an organization and its environment. Consistency with the environment has both a static and a dynamic aspect. In a static sense, it implies having to evaluate a strategy as it relates the organization to its environment now and in a dynamic sense, it implies having to evaluate a strategy as it relates the organization to its environment as the environment changes. Tilles remarks that establishing a strategy is like " aiming at a moving target: you have to be concerned not only with its present position but also the speed and direction of its movement".

The appropriateness of a strategy in terms of available resources relates to the capacity of an organization to respond to threats and opportunities in the environment within a chosen strategy. The capacity or the major resources available to an organization consists of money, competence or expertise and physical facilities. Money is regarded to be the most flexible resource as it provides the freedom to choose from among the widest range of alternatives and so reduces an organization's short-term risk. Expertise is the resource which allows an organization to do well in its chosen business activity. In determining a strategy, an organization must carefully appraise its own skills and adopt the strategy to make the greatest use of its strengths. Physical facilities have no intrinsic strategic value on their own. Their strategic value arises out of their location relative to markets, sources of labour and raw material and because of this, the acquisition or disposing of physical facilities should only be considered in relation to other aspects of the overall organizational strategy.

The degree of risk involved is determined by the combination of a strategy and the resources which it demands. There are many quantitative techniques for assessing probabilities and payoffs but an examination of the following values can give a rough estimate of risk. The amount of resources whose continued existence is not assured, the length of time for which resources are committed and the proportion of total resources committed to a single venture. The higher the values, the higher the degree of risk.

Setting appropriate time horizons for accomplishing strategies are just as important as formulating the strategies themselves. Many reward systems in organizations encourage short-term views and this must be prevented. Also, organizations need time to adjust to new configurations and this must be allowed for. There is considerable advantage to be gained from a single consistent strategy over a long period.

A workable strategy is one that not only satisfies quantitative criteria but also generates a degree of consensus among the organization's executives concerning the chosen strategy. This is an important point that is often overlooked and results in executives not supporting the implementation of the strategy.

It must be remembered that while the criteria discussed above are used primarily for the evaluation of strategic options, they are equally appropriate for assessing the adequacy of an organization's current strategy.

Few decisions have as significant an impact on an organization as the selection of an overall strategy and this selection is rarely based on the evaluation criteria alone. It involves political and behavioural considerations as well as the attitudes toward risk and uncertainty that prevail in an organization. It is strongly influenced by the values of the managers and other groups with interest in the organization and in the end the choice may reflect the power structure in the organization. The decision making style of the managers whose responsibility it is to select the overall final strategy also plays a major role in the way that the strategy is selected. Various techniques such as multiattribute decision making, scenario analysis and cost benefit analysis can be used to assist in the choice.

2.2.3 Strategic implementation

Strategic implementation is concerned with the translation of general strategies into action plans. It is an important component of strategic management for without implementation, nothing happens. Implementation involves two main considerations. These are the planning of resources and the required change in organizational structure.

Resource implications of a strategy are not always considered as a whole and often one set of resources is given consideration while others are neglected. Johnson and Scholes (1984) put forward the following set of questions that help to avoid this imbalance.

- Exactly what resources will a strategy require for its implementation ?
- To what extent are these required resources different from the existing ?
- Can the resources be integrated with each other ?
- What are the priorities ?
- What should be the plan of action ?
- What are the key assumptions on which this plan is based ?

Organizational structure is the other important consideration in strategy implementation. The people inside an organization are directly involved in the implementation of strategy and the way that they are organized is thus crucial to effective implementation. The importance of this match between strategy and structure was emphasised by Alfred Chandler as early as 1962. Organizational structure can be either integrated or differentiated. An integrated organization displays a high degree of collaboration among its departments. A differentiated organization tends to be informal and considers the interpersonal interactions of its people. This distinction was called mechanistic and organic respectively by Burns and Stalker (1961). The appropriate degree of integration or differentiation can be related to the stability of the environment (Lawrence and Lorsch 1967). It is possible for an organization to be both differentiated and integrated at the same time. Peters and Waterman (1982) describe this as a "simultaneous loose-tight" configuration. Mintzberg (1979) developed a taxonomy of organizational structures that includes the following four basic categories; entrepreneurial, bureaucratic, divisional and matrix. An organization does not necessarily remain in any one of these categories. Organizational structures have to be continually adjusted to accomodate environmental changes. The organization itself undergoes change as it grows. The dynamics of organizational change has been called the organizational life cycle. The organizational structure changes from entrepreneurial to bureaucratic to divisional and finally to matrix as it moves through the phases of its life cycle (Greiner 1972). It has also been shown that an organization's structure can depend on the level of its technology. It is important in the context of the relationship between strategy and organizational structure to establish the specific conditions and processes required to effect the implementation of a given strategy. It is important also in the implementation to take into account that organizational structure is constantly adapting to external conditions and internal coalitions. Figure 2.5 shows the relationship between the determinants of organizational structure.

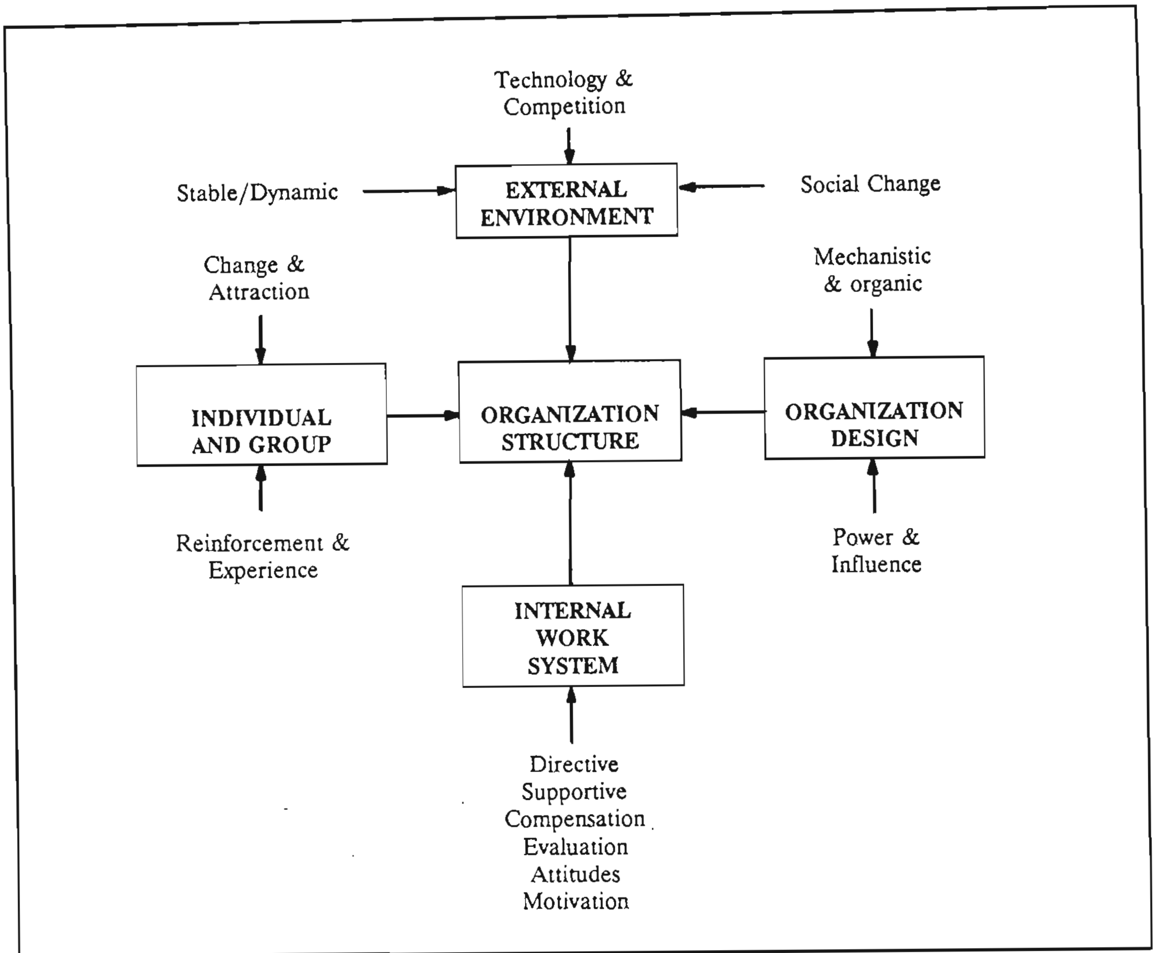


Figure 2.5 Determinants of Organizational Structure (adapted from Tosi and Hammer (1974))

2.2.4 Strategic Control

Control is the vitally important process through which managers assess whether or not the organization is moving toward its strategic objectives. It involves four basic steps:

- The establishment of standards and measures

- The measurement of performance

Newman (1975) groups control methods into three categories: steering controls, which detect performance deviations before a given operation is completed; screening controls, which ensure that specific conditions are met before an operation proceeds further; and post-action controls, which measures the results of completed actions and applies the findings to similar future activities. These three categories of control systems should not be seen as alternatives to one another. They could easily be used in combination. Steering controls are, however, particularly important since they allow corrective action to be applied early enough to prevent the failure of an action plan or to take advantage of an unexpected opportunity. Reliable and effective control systems all have the same characteristics. Stoner (1982) suggests that an effective control system should be:

- Accurate
- Timely
- Objective and Comprehensible
- Focused on Strategic Control Points
- Economically realistic
- Organizationally realistic
- Coordinated with the organization's work flow
- Flexible
- Prescriptive and Operational
- Acceptable to the organization's members

Anthony (1976) suggests three levels of control which he calls strategic, management and operational control. Implementation of new strategies requires control at all these levels. It is difficult to distinguish between managerial control and strategic control. The mechanisms are the same but there is an important difference: managerial control deals with the existing business and activities already past; strategic control is forward oriented, it frequently deals with new business or with modifications to the existing business that are still to be made. Operational control is concerned with the day to day operations in the various functional areas of the organization. It focuses on structured and repetitive activities that are measurable in terms of specific results.

Controlling the execution of strategy is made difficult by short-term problems that tend to cause a neglected attention to strategy and also by dynamic modifications to the strategy itself. Fortunately, formal mechanisms such as steering controls provide a practical means for regulating strategic action.

This brief section on strategic control concludes the discussion of the process of strategic management. The discussion is not meant to be a definitive treatise on strategic management. The focus has been on the most important aspects of strategic management in order to emphasis its procedural nature and to provide the background necessary for the understanding of the framework used for the development of the support system. Also, since the emphasis has been on strategic management as a process, the difference in focus that the process assumes when used at different levels in the organization has not been made explicit. This refers to the hierarchy of strategies discussed earlier. In other words, for example, strategic analysis at the organization wide level assumes a different focus to strategic analysis at the business level. The strategic management process, however, remains the same. Many organizations make use of the procedural quality of the strategic management process as a powerful prescriptive methodology that facilitates the systematic formulation, execution and control of strategy. In addition, many organizations exhibit characteristically similar strategic behaviour within a given set of environmental conditions. Since exhibited strategic behaviour is derived from a relationship between strategy (the content of strategic management) and strategy formulation, implementation and control (the process of strategic management), it needs to be examined further.

2.3 Strategic behaviour

Strategic Behaviour can be defined as consistent and recurring patterns of strategic competitive activity (Galbraith and Schendel 1983). These patterns can be viewed as typologies or archetypes of strategy and have been the subject of much research. Miles and Snow (1978) view strategy as a process of adaptation involving three problems. The entrepreneurial problem (the choice of a product-market domain), the engineering problem (the choice of technologies for production and distribution) and the administrative problem (selection of areas for future innovation and rationalization of structure and process). On the basis of their research studies, Miles and Snow suggested four strategic types or patterns of adaptation. These types are the defenders, prospectors, analyzers and reactors. The first three enjoy similar degrees of success while the last type is a strategic failure. Snow and Hambrink (1980) comment that in the Miles and Snow typology, the focus is primarily on strategy itself and not the process used to formulate and implement strategies. This process of strategy-making has been the focus of research, first by Mintzberg (1973), who suggested three modes of strategy-making and five patterns in strategy formation (Mintzberg 1978) and later by Miller and Friesen (1978, 1980) who suggested ten archetypes of strategy formulation. The Miller and Friesen archetypes consist of six successful and four unsuccessful archetypes. Vesper (1979) suggested a continuous spectrum of seven archetypes ranging from Multiplication (an "easy" strategy) to Liquidation (a "hard" strategy). Some researchers have also suggested that archetypes exist in subareas of strategic management such as new venture strategy (McDougall and Robinson, 1990; Vesper, 1980). Several researchers have commented on the strategy/strategy-making dilemma (Camillus 1981, Venkatraman and Camillus 1984). Segev (1987) examined the relationship between strategy, strategy-making and performance and found that the Miles and Snow prospector, analyzer and reactor types are related to the Mintzberg entrepreneurial, planning and adaptive types. In another view, Hrebiniak and Joyce (1985) suggest that organizational adaptation is an ongoing, multi-directional relationship in which organizations neither mechanistically react to environmental forces nor exercise unrestricted free will. Strategic behaviour therefore is only one dimension. The other dimension which must be examined is whether managerial choice or environmental forces determine an organization's success and survival. Bedeian (1990) suggests that strategic choice, environment and behaviour are indispensably linked. Mintzberg and Waters (1989) represent this linkage in a continuum with the planned or deliberate strategy at the one end, the pure emergent strategies at the other, and a variety of real-world strategies in between. They emphasize that an emergent strategy does not mean chaos but "unintended order". The Mintzberg and Waters work can be related to the Miller and Friesen (1982) research on structural change and performance in the sense that quantum structural changes in an organization must be deliberate whereas incremental structural changes can be largely emergent.

The relationship between strategic behaviour and the intention of the research in this thesis can be identified in the following description of strategic behaviour. This description is taken from the views of Galbraith and Schendel (1983) and extended to include the views of Mintzberg and Waters (1989).

> A consistent pattern or combination of managerially controllable and environmentally imposed decision components representing scope, resource deployments and competitive advantages; and the direction in which these components are shifting over time.

In view of this description of strategic behaviour, as long as a given system can provide the support for identifying these decision components and optimizing and controlling any strategy that is formulated and implemented based on these decision components, the system will be capable of supporting any type of strategic behaviour or archetype. This capability of the proposed knowledge-based support system becomes evident later as the design and the development of the system is discussed.

CHAPTER 3

The practice of strategic management

The concept and practice of strategic management allows an organization to endure the effects of change and to maintain a consistency in its action. A sound strategic management process helps to ensure that all the organizational components are working toward the same objectives instead of drifting off in different directions. A sound strategic management process gives direction to diverse activities even though the conditions under which those activities are carried out are always changing. Rue and Holland (1986) list the benefits of practising strategic management as achieving

- Consistency of action
- Raised managerial consciousness
- Multilevel involvement

3.1 An evaluation of current criticisms

Many empirical studies have been conducted to measure the relationship between performance and the practice of strategic management. The studies by Thune and House (1970), Herold (1972), Karger and Malik (1975a), Karger and Malik (1975b), Robinson (1982) and others have all indicated that a positive relationship exists between the performance of an organization and its practice of strategic management.

Very recently, however, the concept of strategic management has come under harsh criticism for not delivering the same levels of success it had generated in the past. Strategic failures are becoming common and management scepticism of the concept and function of strategic management seems to be growing. It is clear from the examination of the concept and process of strategic management in the previous chapter that the problem lies not with the analytical validity of the concept but rather in the nature of its execution or the practice of strategic management. This becomes evident as the criticisms of some well known researchers and practitioners are examined. Since not all these criticisms are aimed at the same area of strategic management, and since some areas receive more than one criticism, it will be convenient to discuss each area separately. A survey of the available literature has generated the following "problem" areas:

- Organizational response rate
- Bias in strategy formulation
- Narrow focus
- Planning procedure
- Misapplication of strategic concepts
- Organizational fit
- Balance between creativity and control
- Implementation

Organizational response rate

In the 1950's, the strategic problem was to decide "What business are we in? "; this meant finding a profit producing match for the firm and its markets and reflected the optimism about the environment. In the 1970's, many firms had difficulties in finding attractive growth opportunities which matched their internal qualities. Structure became important and the Strategy-Structure relationship proposed by Chandler as early as 1962 was given a new meaning. This new perception was that the transformation of the internal configuration was as much part of the strategic problem as finding a new product-market strategy. The scarcity of strategic resources in the mid 1970's added further complexity to the problem. This made entrepreneurs aware of the fact that apart from the front interface between the firm and its markets, there also existed a back interface between the firm and its sources of supply and these two had to be reconciled in relation to the internal configuration of the organization. In the 1980's all these factors were compounded by fierce international competition and the introduction of socio-political variables in the management of the firm which generates both internal and external power struggles. Also, technological advances have developed a rate of change in certain sectors of the environment much greater than the rate at which organizations can respond. Ansoff (1969) calls this the "lag" response and states that such organizations characteristically fail to anticipate environmental changes which call for a modification in strategy. When deterioration of strategy results in a decline of profit, the organization seeks remedies, first through changes in operations, secondly through reorganization, only lastly does the focus shift to strategy.

Stubbart (1985) is more explicit: he states that the difficulties of a chaotic environment are de-emphasised in favour of approaches consistent with synoptic rationality and that proponents of strategic management rarely give advice on how to deal with ambiguity, uncertainty and complexity.

Bias in strategy formulation

The effectiveness of strategic decision making depends largely on how thoroughly the strategic problem is formulated. Since the input to the problem formulation process often involves a great deal of uncertainty and ambiguity, it is possible that these inputs can be interpreted in a way that reflects a manager's personal conceptual framework or previous experience. Michael (1973) suggests that when environmental uncertainty cannot be minimized by organizational action, decision makers may alter their perceptions of the environment so that it appears more certain. This happens because the psychological state of uncertainty regarding an important decision is very painful. Lyles (1981) suggests that it is perhaps better to identify the fit between managerial, empirical and subjective viewpoints in making a choice about a problem's nature than to try and construct a optimal problem formulation framework. Schwenk (1985) suggests specific techniques for dealing with biases. He suggests for example, the devils advocate method for dealing with biases in the evaluation of alternatives. Stubbart (1989) states that everyone recognises that managers think, but, he asks "what kind of thinkers are thinking managers?". In other words, he is encouraging research in managerial cognition in order to resolve the problem of strategic bias. Keen and McKenney

(1974) argue that there is no "right" way of thinking or of solving problems, it is always a compromise between the demands of comprehensiveness, speed and accuracy.

Narrow focus

Many strategies are driven by specific concepts and even more are focused on only one or two aspects. for example , market share or cost. James (1984) suggests that this focus on specific issues deflects the planning function from a central strategic theme which should consider the multiplicity of problems that face the firm in a systematic manner. Fredericks and Venketraman (1988) argue that organizations do not recognise the complexity of strategic analysis and oversimplify strategic issues. Factors that are central to the firms business strength and that should be considered are technologies, products, services, the relationship with customers, suppliers, governments and the financial community and the firms financial and human resources. Competitive advantage arises out of a balance between all these factors but few organizations seem to realise this. Ohmae (1982) argues that the more severe the pressure and the more urgently a broader view is needed, the more dangerously an organization's mental vision seems to narrow down. He calls this the strategic tunnel vision through which management loses sight of the range of alternatives and rushes with ever narrowing vision to their own destruction.

Planning procedure

The process of strategic management must evolve as organizations and environments evolve. Lenz and Lyles (1985), argue that along the way, it is vulnerable to a number of forces that can influence its capacity to serve as a vehicle for organizational adaptation. Many planners have converted planning into a collecting and analyzing ritual. It can be observed with increasing frequency, that a variety of bureaucratic processes within organizations and technical developments from without are causing the process of strategic management to become too rational. In this state , the planning system seems to develop an inertia all of its own that can stifle creative thought and frustrate the most able managers. Taylor (1982) states that formal planning systems are now so much part of organizational life that the perspective of planning as a central control system tends to dominate management thinking about strategy.

Misapplication of strategic concepts

Strategic concepts are often applied across industries without a realistic appraisal of the value of the concept in different situations. The experience curve concept and portfolio theory are two commonly misapplied concepts. Mintzberg (1973) wrote: "Planning is not a panacea for the problems of strategy making. As obvious as this seems, there is little recognition of it in planning books or by planners. Instead, one finds a focus on abstract simple models of the planning process that takes no cognisance of other modes of strategy-making. Little wonder then that one finds so much frustration among planners. Rather than seeking panaceas we should recognise that the mode used must fit the situation". James (1984) argues that strategists and managers have become "mesmerized by the clinical precision of many of the concepts". Consequently, there appears to be a lack of understanding in that intra- and inter-market conditions vary both in substance and over time. Some researchers have criticised specific techniques; Coate (1983) and Derkindren and Crum (1984) criticise the value of portfolio techniques in assessing risk, resilience and other factors. Kiechel (1981) and Abernathy and Wayne (1974) criticise the misuse of the experience curve concept.

Organizational fit

The relationship between strategy and structure has been identified a long time ago. Chandler (1962) found that an organization's structure is affected by its strategy. A change in strategy is likely to result in structural change. Bower (1968) has shown that a firms administrative context has a major influence in its strategic decisions. Almost three decades later, practising strategists still ignore this relationship. Bowman (1986) has discovered that tailoring a formal planning system to its context was not of concern to corporate officers. Chakravarty (1987) found that a lack of fit between a planning system and its internal and external contexts is not a powerful determinant of how it is evaluated by top management. The strategy-structure relationship is an extremely important one and can not be ignored. In this respect, Waterman (1982) includes both strategy and structure in his seven elements of strategic fit and Scholz (1987) suggests that organizational culture is used to improve the strategic fit.

Balance between creativity and control.

Strategists are often faced with what they believe to be two conflicting goals: On the one hand, a strategy that reflects pragmatic judgments based on what is known and possible and on the other, a strategy that reflects creative thinking and innovation and challenges previous strategic assumptions. These two orientations are distinguished by Lorange (1980) as being integrative and adaptive respectively. The adaptive nurtures creativity. It helps the firm to systematically look for opportunities and threats and to come up with the best alternatives. The integrative orientation focuses on control. It narrows down options to provide for an efficient course of operation and is widely used. It reflects conventional wisdom and often opportunities are missed and the firm becomes vulnerable to competitors who are willing to pursue innovative strategies. Mintzberg (1976) argues that truly outstanding managers are no doubt the ones who can couple effective right-hemispheric processes (hunch, judgement and synthesis) with effective processes on the left (articulateness, logic and analysis). McGinnis (1984) suggests that only strategic integration, that is, the integration of analysis and intuition, can lead to success in the modern environment. McGinnis and Ackelsberg (1983) suggest that strategic planning will lead to more innovative strategies if it is approached in this integrated manner. Shank et al (1973) suggest that the degree of looseness of the linkage between long range planning and short-term budgetary control affects assertive and creative thinking in organizations.

Implementation difficulties.

There seems to be an ever growing gap between the formulators of strategy and the implementors of strategy. This gap is probably due to the nature of the strategy concept, dictating that it be a sophisticated exercise, too complex to involve lower levels of management. According to James (1984), this gap has been widened by the hiring of "whiz kids" from the business schools as strategists who know nothing about the history and culture of the organization in which they are employed or more importantly, its operations at the lower levels. As long as such a gap exists, the effectiveness of strategic implementation is questionable. This gap is also recognised by Gummerson (1974) who argues that as long as planners and implementors become alienated, there can be no effective implementation. Another implementation difficulty, according to Hobbs and Heaney (1977), is the coupling of strategic plans to operating decisions. They argue that unsatisfactory coupling to a new plan may be due to the lack of explicit decoupling from previous plans because of commitments within the organization.

It is clear from the above discussion that many of the difficulties arise out of the uncritical application of strategic management concepts or the context in which these concepts are applied rather than with the analytical validity of the concepts themselves. It is evident that the effectiveness of strategic management will be enhanced greatly, if even some of these difficulties can be resolved. The presence of these difficulties initiated the research into the construction of the support system and they will therefore be considered in chapter 5 during the analysis and development of the system. The difficulties will again be reviewed in chapter 6 when the support system is evaluated.

CHAPTER 4

Computer-based support for strategic management

Strategic management is a complex process and there are many difficulties experienced in its implementation. At the same time, it has been suggested (Turban 1987) that conventional computer systems are not capable of providing effective support when the application area is by nature highly unstructured or when the application area presents a multiplicity of variables, many of them uncertain, or both. Fredericks and Venkatraman (1988) believe that the environment within which strategic management is practised is too complex to be handled by simple frameworks and that systems with much more sophistication are required to accommodate the inherent multidimensionality of strategic problems. Stubbart (1989) suggests that research into expertise and expert systems can help managers cope with some of the complex cognitive tasks inherent in the strategic management process. Luconi et al (1986), O'Leary and Turban (1987) and Sullivan and Yates (1988), all believe that information technology has a growing role to play in strategic management. In particular, they believe that specialized knowledge-based systems can materially enhance the planning and management process. When the nature of decision making is examined in the framework of Simon (1960) together with the taxonomy of organizational decision making levels by Anthony (1965), a relationship between the structure of a decision making context and the level in the organization at which it occurs can be established (Gorry and Scott-

Morton 1971). The type of computing support that the decision making requires can then be added to this framework (Turban 1988). The table in figure 4.1 depicts the whole framework as well as examples of specific decision making areas at each level.

CONTROL / DECISION	OPERATIONAL CONTROL	MANAGERIAL CONTROL	STRATEGIC PLANNING	REQUIRED SUPPORT
STRUCTURED	Accounts Receivable	Budget Analysis	Financial Management	Management Information Systems
SEMISTRUCTURED	Inventory Control	Plant Layout	Mergers	Decision Support Systems
UNSTRUCTURED	Buying Software	Buying Hardware	New Product Development	Decision Support Systems & Expert Systems

Figure 4.1 A Framework for Decision Making Support (adapted from Turban(1988))

Some attempts at developing support systems for strategic management have been made in the past using conventional computing methods and a significant amount of research is currently being pursued by various researchers to build decision support systems and expert systems (or knowledge-based systems) for the same purpose. The next section examines the work done in this area.

4.1 A review of current computer-based approaches to strategic management support

The use of the computer to assist in the activity of managerial planning began with the application of computer models to investigate the future consequences of business decisions. Gershefski (1970) found in a survey that at least one hundred corporate models were in use in member companies of the Planning Executives Institute in the United States in 1969. Many of these models were developed using the existing general purpose languages of the time. One of the earliest attempts at supporting the strategic Management process is probably the SIMPLAN system written by Britton Mayo in 1973. The SIMPLAN system provides a totally integrated environment in which the activities of data management, modelling, report generation, graphic displays, forecasting and econometric and statistical analysis are supported. The system is used by entering commands that manipulate data in either interactive or batch mode. SIMPLAN is extremely effective in modelling relationships within a confined area such as marketing or finance.

Another model orientated system was one developed by Moses and Hamilton (1974) for large diversified organizations. It permits two types of strategic options, momentum strategies and development strategies. Momentum strategies represent a continuation of present activities in current lines of business. Development strategies reflect proposed changes in the nature or level of present activities. The model maximizes earnings per share subject to a set of goal and corporate constraints by using an integer programming algorithm to select optimal financial and investment strategies over time.

King and Rodriguez (1977) describe a strategic issue competitive analysis system (SICIS) that is used interactively by a manager to establish relationships in competitor related strategies. This system uses a tree based structure that is traversed in order to refine the attributes of a strategic issue as the user moves from one level of the tree to another. Suppose for example that a company wished to examine the possibility of a competitor introducing a new product before it has introduced its own. The SICIS system would then lead the user through the levels of the tree, identifying further issues which would have a bearing on the problem. Examples of further issues in this case would be the competitors production and financial capability and its marketing and technological capability. The user knows that he has assembled all the relevant subissues when the terminal node in the tree for a particular issue is reached. A limitation of this system is that the strategic issues and hence the tree structures are predetermined and this makes the system inflexible.

A more sophisticated system called COSMOS, for competitive scenario modelling system, was developed by King and Dutta (1980) and improved on the SICIS system by allowing the user to test alternative strategies against those that might be used by the competitor. The COSMOS system consists of a market share subsystem which relates price and quality to market share, a profit subsystem which calculates the profit contribution of an organization in any give competitive scenario and a preference subsystem which keeps track of the preference decisions of a user under trade-off conditions. The system makes use of Meta-Game analysis which models the "mutual anticipation" of the players in a game. In this case, the players are the organization and its competitors. The analysis starts with a hypothesized set of specific strategic choices made by each player in a competitive situation and examines the stability of the situation from the point of view of each competitor through a theory of rational choices. COSMOS thus improved on the SICIS system by enabling the user to deal with issues that represent the strategic use of the data rather than only relationships between data. Although COSMOS serves to compare and evaluate each strategy in a very complex and sophisticated manner, it requires that each contemplated strategy be generated by the user. In other words, the system does not support the design of alternative strategies.

Klein and Newman (1980) describe a system for assisting a user in assessing the environment. Called SPIRE for Systematic Procedure for Identifying Relevant Environments, the system relates factors outside the environment to components within the organization that would be affected by those factors and so provides a link between environmental assessment and the later stages of strategic decision making. SPIRE can thus be used in the context of developing and understanding the relationships between groups of environmental factors and the business areas that would require strategic thinking. The SPIRE system operates by storing Environmental Factor-Strategic Planning linkages in a large matrix. The entries of the matrix denote intersections between rows, which represent environmental factors and columns, which represent strategic factors. Columns and rows are then individually examined to pick out the commonly occurring linkages. The matrix is then translated into a diagrammatic form in order to improve the communicability of its results. Management and planning personnel can then examine the diagram for inconsistencies, omissions and contradictions. New environment factors can be added and the process repeated for revised analysis and results.

A system called HSJ for Hop, Skip and Jump is described by Brill et al (1982). This system uses a multicriteria linear programming model to produce alternative solutions that are generated through the interaction of the user. Each successive solution is different from the previous one and the system is thus capable of generating a domain of solutions. Although the HSJ system was tested on a problem of land use planning, its developers believe that it is applicable to any situation in which there is a lot of flexibility in the decision space or where there are many unmodelled issues. The system can be used in such situations to generate different solutions which managers evaluate in order to gain insights into the characteristics of the problem. A particular solution can also be refined and used to generate a further set of alternate solutions.

Bouwman (1983) developed a system for financial diagnosis based on the study of actual human decision making behaviour. The system performs an initial problem detection process which identifies all the symptoms that are indicative of the current state of the underlying system. The number of symptoms can be potentially large and the system then performs a data reduction process in two stages. The first stage reduces data through qualitative reasoning which essentially extracts the data judged relevant for the formulation of the diagnosis. The second stage reduces the amount of data even further by extracting only significant items such as very large increases in the data item "Sales" for example. The remaining data is used to formulate relationships between the symptoms and these relations are integrated into a problem hypothesis. The system is capable of producing an "explanatory path" that can be used to examine the reasoning underlying a particular hypothesis.

A Decision Support System that was developed specifically for supporting decisions in the strategic area is STRATPORT, a system for strategic portfolio planning developed by Larreche and Srinivasan (1981). The system, designed to assist managers in the formulation and evaluation of business portfolio strategies, uses decision calculus to construct a function that is able to simulate the effect of a strategy, for example, the development of market share. The user is allowed to change either the nature of the function or the initial parameters in order to suit the decision situation. STRATPORT also chains events together in order to develop an integrated model. For example, the development of market share requires an increase in production capacity which in turn increases inventory which uses up working capital. The flexibility that a system like Stratport provides is extremely useful in solving strategic problems but it is difficult for the user to keep track of the many parameters that need to change in order to achieve this flexibility.

Smith et al (1985) describe a decision support system that assists an insurance company to match its operations to market opportunities. The system uses a large database to hold the market research information and statistical modelling to identify how various factors affect corporate performance. The system also helps in the design of marketing experiments and promotional campaigns. An interesting aspect of the system is the integration of the decision system with a computer cartography system that is used to draw coloured maps of sales and marketing regions that offer potential for new business. The presentation of results in this form is highly desirable since it reinforces the analytical results and also encourages the involvement of non-analytical individuals who are nevertheless familiar with the business.

Cooper (1986) argues that the decision support approach to managerial problem solving makes five invalid assumptions about the managerial competence of the user. He lists these assumptions as; the user knows what problem he has, the user is able to build a model, the user has access to information, the user knows how to interpret the answers and finally, the user is computer literate. He argues further that the only way to build a system that can operate with a realistic assumption of the manager's competence is to take into account the elements of the experience and judgement that distinguishes outstanding managers. He suggests the use of artificial intelligence technology as a means of achieving this and describes an expert system based financial advisor called PFA. This system is designed to assist senior managers who are faced with the evaluation of complex business proposals. Using this system, a manager can consider alternative approaches to new product development proposals, evaluate major strategic investments and consider the consequences of cost-reduction plans. The system contains a core of financial knowledge common to all businesses and must be tailored to give specific advice to a particular company. The system generates graphics and dialogue in a format that could be readily used and not as the developers argue, using ivory tower jargon that no manager really understands.

Goul (1987) developed a prototype situation assessment expert system (SAES) that, given information about an industry, the nature of production tasks and the nature of organizational design, searches for theoretical inconsistencies between the current structure and a suggested structure. The system uses a set of representations that is easily understood by the user. These representations used are folders, file cabinets and a desk. The system displays a screen with the graphical representations of these familiar objects. Each folder consists of questions, knowledge and advice in a specific area. For example, there are folders for capacity expansion, competitive action, buyers and suppliers, market signals and others. Folders are stored in the cabinet and the desk contains useful items such as a scratchpad and a dictionary. The representations are used to emulate the situation where the user has access to the desk of an expert and is free to peruse the expert's files or to leave questions on his notepad. The knowledge used in the SAES system was provided by a professor of Strategic Management at Oregon State University. Another system that structures its knowledge from a human expert is described by Van Beek (1987). This system replicates the knowledge of a Dutch businessman in the area of new business ventures. It consists of separate modules that consider different aspects of the decision making situation. A market module estimates the size of the market at the proposed new business, a finance module produces a financing scheme for the new business and a revenue module estimates the turnover and profit. The user is however, required to provide the control of the decision making and the consolidation of the results. This gives rise to some ambiguity as to whether the system is an Expert System or an Intelligent Decision Support System.

Bohanec et al (1983) have developed a general purpose expert system for decision making called DECMAK that can be used in a narrow sense for strategic decision making. The system instantiates variables beginning at the leaves of a tree and progresses upward toward the root where the overall utility of an alternative is computed. Consider, for example, the decision situation of acquiring a new computer system. The root decision is the acquisition of the system, the level below contains nodes which contribute to the decision at the root level. In this case the nodes would be subdecision situations concerning the economic, technical and personnel aspects of the proposed system. A level below this contain the leaf variables for each of the three subdecision nodes. The Technical subdecision node would have the leaf variables of memory size, computational speed, disk capacity, and others contributing to its decision. The system makes use of production rules to arrive at the decisions at the various levels in the decision tree. The DECMAK system is a general purpose system and aspects of it can be incorporated into a knowledge-based support system.

Chandrasekar and Ramesh (1987,1988) describe a decision support system that maximizes a utility function such as market share subject to a set of constraints. The system consists of a multicriteria decision system and an expert system that work in combination in order to maximize a function and generate scenarios. The system maximizes market share, net income and share price subject to marketing, production, demand, financial and operational constraints. The decision support system acts as a front end to define, formulate and store the various decision problems. The decision support system also uses a multi-criteria linear programming model to generate solutions which are passed on to the expert system to generate scenarios. Decision makers can then examine the scenarios and make changes to the inputs to the decision support system.

Another system that integrates the use of an expert system and a decision support system is SAM, a sales mix system developed by Lee and Lee (1987). The system considers the long-term strategic impact of the current sales mix. The decision support system is used for the optimization of short-term profits while the expert system is used to help decision makers to interpret the portfolio models used. The system makes use of the Post-Model Analysis method, which is a framework that supports tradeoffs between quantitative and qualitative objective values. Since managers frequently favour quantifiable short-term objectives to unquantifiable long-term goals, the system can be useful in resolving these conflicts.

A further system that combines decision support systems and expert systems is described by Levine et al (1987). The system, called DECIDEX, enables the user to build scenarios in an interactive way. The system consists of a file processor and scenario generator that gathers data from various files about decisions and events, an archives database that contains accumulated experience from previous cases and a spreadsheet to facilitate intermediate calculations. The expert system is used monitor the user's evaluation. Since every decision can have far reaching consequences, the expert system attempts to contradict the user by firstly negating any conclusion made, and then using rules to prove that the negation is true. If a contradiction is valid, the user is able to follow the reasoning process back to the point of disagreement. The authors believe that the user is more likely to accept criticism from the expert system than from a colleague.

Moser and Christoph (1987) describe a management expert system for divestment decision making. The system, which began as an experiment, was built around a survey conducted by the authors. In this survey, strategic planners from leading firms in the US were asked to provide a list of factors that they consider when making divestment decisions. The survey not only generated all the important factors but also the relative ranking of factor importance. These factors are all incorporated into the system's knowledge base in the form of rules. The method used for acquiring the expertise is effective and according to the authors, shows promise for improving decision making in other areas such as acquisitions which also depend largely on managerial judgement.

Biswas et al (1988) describe an expert decision support system that acts as a consultant for troubleshooting production processes. The system uses a natural language front end that interacts with the user. Relations between process characteristics, problem symptoms, and cause categories based on expert knowledge is expressed as production rules in a knowledge base which are partitioned into knowledge for different production processes. A directed questioning scheme controls the user-system dialogue and the aim is to elicit general symptoms and to establish the most likely cause for an observed problem. The system uses a sophisticated inferencing scheme that is made up of four components: there is an evidence combination mechanism based on the Dempster-Shafer framework, a hypothesis selection mechanism, a query and dialogue direction mechanism and a controller for selecting the appropriate process partition in the knowledge base.

The table in Figure 4.2 shows a summary of the various systems examined together with the elements or phases of the strategic management process that each one supports. It is evident from this table that without exception, each system examined supports only a confined area of strategic management. Another important consideration that emerges from the examination of the various systems is the use of management science models in support systems generally. As examples, Moses and Hamilton use integer programming, King and Rodrigues use

ELEMENTS OF STRATEGIC MANAGEMENT							
Control	Strategy Implementation	Strategic Choice	Strategy Evaluation	Strategy Formulation	Environmental Assessment	Internal Assessment	SUPPORT SYSTEMS
						■	Mayo (Simplan,1973)
				■			Moses & Hamilton (1974)
				■			King & Rodrigues (1977)
		■	■	■			King & Dutta (1980)
					■		Klein & Newman (1980)
				■			Brill et al (1982)
■						■	Bouwman (1983)
			■	■			Larreche & Srinivasan (1981)
				■			Smith et al (1985)
			■	■		■	Cooper (1986)
				■	■	■	Goul (1987)
			■	■			Van Beek (1987)
			■	■			Bohanec (1983)
			■	■			Chandrasekar & Ramesh (1988)
			■	■			Lee & Lee (1987)
		■	■	■			Levine et al (1987)
			■	■			Moser & Cristoph (1987)
■							Biswas (1988)

Figure 4.2 A Summary of Systems and Areas Supported

decision analysis, Brill uses multicriteria linear programming while Bohanec and Chandrasekar both use multiattribute decision theory. The use of models is an inherent design feature of Decision Support Systems and Thierauf (1982) gives an exhaustive list of available models and their application in management areas. These models however, support very narrow domains of management decision making and no single model is applicable to all areas of the strategic management process. In addition, the use of many of the available models requires an understanding of advanced mathematics which managers do not often have. Decision Support Systems enable such models to be embedded in user friendly environments. Their application however, is still limited to narrow areas (Turban 1988). Blanning (1985) states that many of the management problems now being addressed by model builders and system designers cannot be solved by concentrating on objective data and ignoring the specialized knowledge and judgement of experienced managers. In addition to the systems examined, there are many other knowledge-based systems that are also only applicable in an isolated and confined domain which is often disjoint from the domain of strategic management. A comprehensive list of these systems can be found in Waterman (1986) and also in Feigenbaum et al (1988) and Ernst (1988).

4.2 Rationale for a distributed approach to strategic management support

It can be deduced from the previous discussion that there is a need for a strategic management support system and yet it is not unusual that a computer-based system for the support of the total strategic management process has not been developed. Knowledge-based systems by their very nature perform best in a restricted domain. In order for a knowledge-based system to be effective, even within a confined area, its stored knowledge must be comprehensive. A comprehensive knowledge base to support the total strategic management area therefore, would be have to be excessively large. Large knowledge bases are known to exhibit many problems (Prerau et al 1990). An obvious problem is the reduction in inference speed as the size of the knowledge base increases. As the context in which the system can operate grows, the size of the knowledge-base and the time it takes to solve a particular problem grows as well. Thus there is a trade off between speed and the generality of the system. Other problems concern the representation of knowledge. One problem that has particular relevance to the domain of strategic management is known as the frame problem (Hayes 1985). This refers to the ability of a system to infer side effects and implicit changes in its world description. Since the world description of strategic management encompasses both the organization and its operating environment, the frame problem would force a knowledge base to be exhaustive.

A way out of this impasse is partially suggested by the existence of the systems described above. Each of them effectively support decision making in a subset of the total strategic management domain. An integrated collection of such individual systems whose application domains encompass that of the total strategic management area would solve the problem completely, provided that they could be effectively coordinated and controlled. Since the problem of coordinating and controlling a network of individual intelligent systems is the central research theme in the area of distributed artificial intelligence and many useful techniques have already been developed, a workable solution becomes evident. The next section examines the domain of strategic management in order to identify natural partitions through which expertise is distributed into manageable knowledge modules.

4.3 Strategic management as a distributed problem

Elements of a system of knowledge are distributed if there is some conceptual distance between them (Bond and Gasser 1988). This distance could be spatial, where processes occur at different locations; temporal, where processes occur at different times; logical, where intermediary deductive processes are required to make the knowledge accessible; or semantic, where knowledge is clustered into specializations depending on the practical use of the knowledge. It is always possible to find one or more of these conceptual distances in organizations. Adam Smith in 1937 in his book, "The wealth of Nations" describes the distribution of labour as a means of increasing productivity. Zeleny (1987) states that the concept of the division of labour hides three separate dimensions: division of task, division of labour and the division of knowledge. More recently, Chandrasekaran (1981) observes that "social organizations from honeybee colonies to modern corporations are living examples of distributed information processing embodying a variety of decomposition and coordination". Malone (1987) suggests that in human organizations, decomposition is best achieved along either functional or product dimensions. Functional decomposition refers to grouping classes of generic tasks into individual clusters by task type. Product decomposition refers to the grouping of all tasks required to produce a particular product into individual clusters. The functional unit in an organization remains independent in all forms of organizational structure. Functional structure is perhaps the most logical form of compartmentalization because it makes efficient use of specialized resources. Other structures such as the product-market structure or even the matrix structure recognise the independence of the functional unit within the product, market or matrix compartments. The size and number of functional units in an organization depends largely on the size and complexity of the organization but most organizations have functional units in the areas of marketing, finance, production, personnel and research and development.

In the process of strategic management, many activities are performed and monitored within functional boundaries that transcend the organizational structure. For example, situation assessments are performed in functional areas separately and broad strategies are translated into functional strategies for implementation, irrespective of whether the organization has a functional, product-market or matrix structure. These boundaries form a natural and convenient partitioning over the total strategic management area and form the basis for a distributed support system. There are many advantages that can accrue from a distributed approach. The following list is adapted from Bond and Gasser (1988).

Adaptability: Logical, semantic, temporal and spatial distribution allows a distributed system to provide alternative perspectives on emerging situations, and potentially greater adaptive power.

Cost: A distributed system may hold the promise of becoming cost-effective, since it could involve a large number of simple computer systems of low unit cost.

Development and Management: If an intelligent system can be built in a distributed way, each part could be developed separately by a specialist in a particular domain.

A distributed intelligent system may be extensible.

Efficiency and Speed: Concurrency may increase the speed of computation and reasoning.

History: There may already exist a historical basis for a distributed system. This basis could be a collection of existing resources or expertise that need to be integrated.

Isolation/Autonomy: For protection and for local control, parts of a system may be separated and isolated from one another; this approach is sometimes called the "arms-length relationship".

Naturalness: Some problems are better described as a collection of separate agents; there is a better fit to a problem or domain because elements are "naturally" distributed along some of the axes of distribution.

Reliability: Distributed systems may be more reliable than centralized systems because they can provide cross-checking and triangulation of results.

Resource limitations: Individual computational agents have bounded rationality, bounded resources for problem solving, and possibly bounded influence, necessitating cooperation and coordination to solve large problems.

In this chapter, current approaches to the use of computer-based systems to support management activity have been examined and it is apparent that all the effort thus far has been directed at narrow sub-domains of the total domain of strategic management. A rationale for using a network of distributed knowledge-based systems as a solution has been presented. The design, construction and implementation of a support system using this rationale will be presented in the next and subsequent chapters.

CHAPTER 5

Distributed artificial intelligence

There is currently a great surge of research effort in the discipline of distributed artificial intelligence and many techniques have been developed to resolve the problems that arise in the control and coordination of a distributed system. Since the distributed knowledge-based support system presented in this thesis makes extensive use of some of these techniques, and also since these techniques are not as well established as other artificial intelligence techniques, it is considered appropriate that they be discussed further. The chapter begins with an overview of the current status of the field of distributed artificial intelligence with the emphasis on the techniques used for control and coordination.

5.1 An overview of distributed artificial intelligence

Most artificial intelligence research investigates intelligent behaviour for a single intelligent agent or expert. This behaviour includes heuristic problem solving, natural language understanding, vision, perception and so on. Distributed Artificial Intelligence is concerned with the coordinated behaviour of multiple, physically separated intelligent agents. Distributed artificial intelligence provides intellectual insights about organization, interaction and problem solving among intelligent agents.

The field of distributed artificial intelligence can be divided into two sub-areas. The first area involves a network of intelligent agents where each agent has sufficient problem-solving knowledge to propose a complete solution to a problem. Since the problem-solving knowledge is sufficient but not complete, the problem is not necessarily optimally solved. The second area concerns a collection of specialist agents, each of which has knowledge only of a particular aspect of the overall problem-solving situation and need to cooperate in order to arrive at a solution . The first area is referred to as Cooperative Distributed Problem Solving (CDPS) and the second area is called Multiagent Planning (MA) (Gasser 1989). Durfee et al (1987) suggest that the first area stresses **intelligent local control** while the second emphasises **intelligent network control.** The intelligent agents or knowledge sources in both areas must share knowledge not only about problems they face and solutions they reach, but also about the coordination between them. As stated by Durfee et al (1989), "Getting them to cooperate is not simply a matter of giving them a common communication language". Several useful distributed coordination and control frameworks have been developed in order for individual knowledge sources to divide control, share responsibility and knowledge, and share partial results. These frameworks can be classified into the following broad categories: (These categories are adapted from Durfee et al (1989), Bond and Gasser (1988) and Gasser (1989)).

- Multi-Agent planning

- Blackboard frameworks

- Contracting or Negotiation

- Functionally-Accurate cooperation
- Organizational structuring
- Sophisticated local control
- Theoretical frameworks
- Integrative frameworks
- Open-system frameworks

The discussion of strategic management as a distributed problem suggests that a support system for the strategic management process should consist of a network of functional area support modules. The strategic management process in practice is characterised by extensive cooperation and coordination between functional area managers. Achieving this in the support system would require a central control module to manage the cooperation, coordination and the exchange of information between modules. These requirements of the distributed support system can be summarized as follows:

Individual knowledge modules for each functional area

A control module to manage the cooperation, coordination and interchange of information between these modules

A communication mechanism for the physical transfer of information

Of the available distributed frameworks listed above, only the principles of the blackboard framework and some of the principles of the multiagent planning framework are directly applicable to the design of the distributed strategic management support system. These two frameworks will be examined closely. A brief description of the other frameworks as well as some references for each of them is presented for the sake of completeness and in order to show that they are not as readily applicable as the Multiagent and Blackboard systems.

5.1.1 Multiagent planning

Multiagent Planning frameworks use a single agent or group of agents to form a coherent plan for solving a multiagent problem. Dependencies and conflicts among the agents and knowledge of different agents are identified in advance. There are essentially two forms of multiagent planning. Centralized multiagent planning, in which one agent acts as the controller and coordinator and distributed multiagent planning where no single node has a global view of the problem solving activities of the network. Many of the multiagent paradigms are adapted from the single agent planning approaches developed earlier. Single agent planning approaches can be categorized into four distinct groups; Hierarchical planning, Non-hierarchical planning, Script based planning and Opportunistic planning.

Hierarchical planning concerns the development of plans by using different levels of abstraction. These levels form a hierarchy of representations of a plan in which the highest level is an abstraction of the plan and the lowest level is a detailed plan, sufficient to solve the problem. An abstraction level is distinguished by the granularity, or the fineness of detail of the discriminations it makes in the world (Wilkins 1987). Some known hierarchical planning systems include NOAH (Sacerdoti 1977), ABSTRIPS (Sacerdoti 1974) and SIPE (Wilkins 1987).

Non-hierarchical planning concerns the development of plans by ordering operations at a single level of abstraction. A non-hierarchical planner develops a sequence of problem solving actions that achieves a goal. Goals can be reduced to simpler subgoals, or means-end analysis can be used to reduce the differences between the current state and the desired state of the world. A disadvantage with non-hierarchical planning systems is their failure to distinguish between actions which are critical to the success of the problem solving process and those that are just details. STRIPS (Fikes and Nilsson 1971) and HACKER (Sussman 1975) are examples of non-hierarchical planning systems.

Script-based planning makes use of skeleton plans that are recalled from a store of skeleton plans instead of generating them as in the case of hierarchical planners. These stored plans contain the outlines for solving many different kinds of problems. The planning process proceeds in two steps: first, a skeleton plan is found that is applicable to the given problem and then the abstract steps in the plan are filled in with problem solving operators from the particular problem context. An example of this type of planning is found in the MOLGEN system (Stefik 1981).

Opportunistic planning methods are characterized by their flexible approach. Plans are developed in a fragmentary manner and synthesised as opportunities arise. Opportunistic planning has been developed by Hayes-Roth and Hayes-Roth (1978) who argue that it is more efficient than hierarchical planning when the planning problem is complex and also that it is closer in nature to the way in which human planners plan. An important concept in the framework of opportunistic planning is that of **island driving,** in which a problem solver finds part of a solution that he thinks is correct, an island, and extends the solution from there, possibly toward another island. In Strategic Planning, these "islands" can drastically reduce the range or solution space of the strategic problem. Opportunistic planning makes use of the blackboard framework to represent the complex control structure of human planning. The blackboard framework is discussed next.

5.1.2 Blackboard frameworks

The Blackboard framework was first introduced in the Hearsay II speech system (Erman et al 1980). Blackboard architectures incorporate a common data area or blackboard for memory and interaction among a collection of knowledge agents. This shared data area is analogous to the working memory accessed by many rules in a conventional system but is divided into levels of varying semantic abstraction. In a blackboard system, a collection of independent knowledge sources may read and write to one or more levels of the blackboard under the supervision of a control system. A Blackboard architecture is well suited to the domain of strategic planning since it treats problem solving as an incremental, opportunistic process of assembling a satisfactory configuration of solution elements. These solution elements could be actions at an organization's functional level. Blackboard systems are characterized by the three attributes that follow:

All solution elements generated during problem solving are recorded in a structured global database called the blackboard.

Solution elements are generated and recorded on the blackboard by independent knowledge sources.

On each problem solving cycle, a scheduling mechanism chooses a single knowledge source to execute its action.

These three attributes would be customized to suit the type of problem solving process for which the system is designed. For example, the separation of the blackboard into semantic levels, the exact retrieval and posting mechanism and the control procedures for scheduling, would depend largely on the nature of the task. Nii (1986) observes that the blackboard model forms a generic control architecture and cannot be seen as a methodology for a specific application. The exact specification of the blackboard architecture and control mechanisms used in the strategic management support system will be discussed during its construction in the next section.

Hayes-Roth (1988) lists the strengths of a blackboard framework as the following:

-The blackboard architecture provides extreme flexibility in system behaviour;

-Blackboard systems can follow rigorous procedural strategies;

-They can coordinate implementation of successive strategic phases with problem specific situations;

-They can interrupt, resume or terminate adopted strategies;

-They can adopt variable subsets of simultaneously applicable strategic and non-strategic heuristics;

-They can use variable rules for integrating adopted heuristics and choosing among pending problem solving actions.

In sum, blackboard systems can adapt to complex control plans whose operative strategies, heuristics, and integration and scheduling rules can change repeatedly in the course of problem solving. Many systems have been built using the blackboard framework. These include the well known speech system, Hearsay II (Erman et al 1980) and the Distributed Vehicle Monitoring Testbed (DVMT) (Lesser and Corkhill 1983).

5.1.3 Other frameworks

Contracting or **Negotiating** networks consist of problem solving agents that make use of bidding, contracting and information exchange protocols in order to allocate tasks and resolve conflicts. These frameworks capitalize on insights about human negotiation to build mechanisms that enable artificially intelligent agents to negotiate. The major difference between negotiation frameworks and multiagent frameworks is that in multiagent frameworks, each individual knowledge module's capabilities and responsibilities are identified in advance. No duplication of functions are allowed. In negotiating frameworks, modules have overlapping abilities and bidding or contracting is used to distribute tasks in the most efficient way. Relationships between modules therefore, last only for the duration of the problem solving process. In multiagent frameworks, the relationships between modules are permanent and designed into the system. Important research in this area includes the Contract-Net Protocol (Smith and Davis 1988) and Multistage negotiation (Conry et al 1988).

Functionally-Accurate cooperation (Durfee et al 1987, Lesser et al 1988) is concerned with enabling individual agents with inconsistent views and information to cooperate effectively. Inconsistencies arise out of incomplete or out of date views that an agent may have of the task or even of the other agents. In this framework, an agent's problem solving is structured so that it is not necessary for its local knowledge to be complete, consistent or up to date in order for it to contribute to the problem solving process. Agents do the best they can with their current information.

Organizational structuring (Durfee et al 1989) attempts to find a compromise between the strongly top-down view of contracting and the bottom-up view of the functionally-accurate cooperation. In both these cases, individual agents may be largely ignorant of the contribution of the other agents in the network. This ignorance can lead to excessive communication and duplication of effort. Also, individual agents may not initially know how their subproblems relate to the total network problem. In organizational structuring, agents are given information regarding the long term relationships among them. This is capable of enhancing both the contracting and the functionally-accurate cooperation approach where the alliances are temporary.

Sophisticated local control (Durfee et al 1988, Durfee et al 1989) allows an agent to "understand" the implications of its planned problem solving and communication actions on other agents and thus enables an agent to "decide" for itself when to coordinate rather than have it prescribed. Policies for communication and coordination have to be established to guide the agents. Three characteristics of such a communication policy are: Relevance; the impact of the communication on the problem solving activity of another agent, Timeliness; the need for communication in the current activity of the agent, and Completeness; the proportion of the overall solution that the communication represents.

Theoretical frameworks concentrate on developing formal models of distributed problem solving rather than on techniques for particular application domains since it is believed that rigorous models of agent reasoning and interaction can develop insights into coordination that are independent of any domain. Models for deductive belief and the nature of cooperation among others have been developed (Genesereth et al 1988, Rosenschein et al 1988, Tanney and Sandell 1988).

Integrative Frameworks provide a set of communication and consistency mechanisms that integrate a number of complimentary but heterogeneous paradigms for problem solving (Hayes-Roth 1988, Bisiani 1988, Gasser 1988).

Open system frameworks provide theoretical and practical models of self defining aggregation, communication and coordination frameworks. The emphasis is on viewing a control structure as a pattern of messages passing along a collection of computational agents rather than as a sequence of choices made by a single decision maker in a web of choice points (Hewitt 1988).

CHAPTER 6

Knowledge representation, inference and heuristic problem solving

This chapter serves as an introduction to the knowledge representation schemes and inference strategies used in knowledge-based systems. Also included is an examination of heuristic problem solving and the design of the heuristic strategy generating mechanism which initiates the problem solving process of the distributed support network.

6.1 Knowledge representation

The knowledge in knowledge-based systems is typically separated into declarative knowledge which is contained in the knowledge-base, and control knowledge which is contained in an area known as the inference engine. The inference engine is an algorithm that dynamically controls the search process in the knowledge base during a problem solving session. The separation of knowledge from control allows the knowledge required for the system to be acquired in unconnected pieces rather than in complete step by step procedures. The architecture of a typical knowledge-based system is shown in figure 6.1.

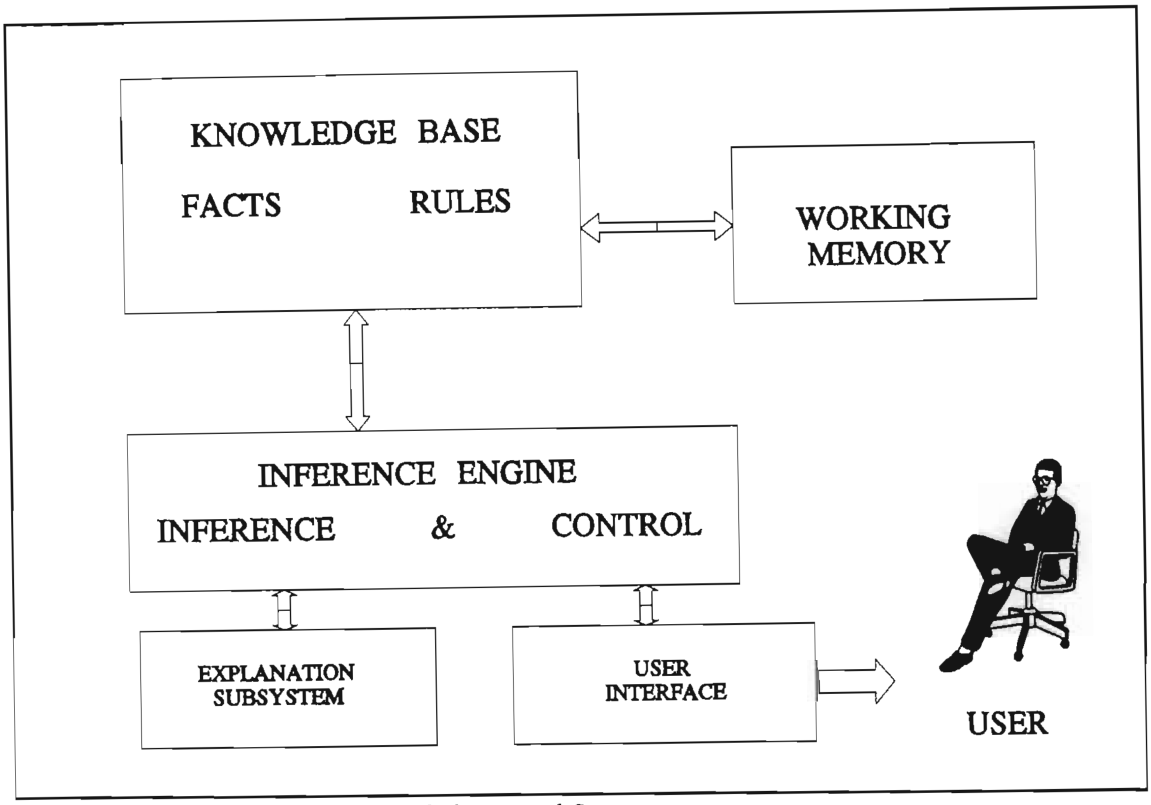


Figure 6.1 Architecture of a Knowledge-Based System

In order for a knowledge-based system to use the declarative knowledge stored in its knowledge base, a formalism for representing that knowledge must be used and in terms of criteria put forward by Fikes and Kehler (1985), the formalism used must have expressive power, understandability and accessibility. It is difficult to satisfy these criteria with a single knowledge representation scheme and many knowledge-based systems make use of a combination of two or more of the available schemes. Harmon and Sawyer (1990) suggest that a combination of rule-based and frame-based representation offers the most flexibility. This is the combination used to represent the knowledge in the distributed knowledge-based system and a brief explanation of each of these schemes follows.

6.1.1 Rule-based representation

This is the most common form of representation since the format of the rules correspond to that of rules used in conventional procedural languages. In essence, rules have the following structure

IF condition THEN action or conclusion

The condition is also referred to as the antecedent and the conclusion or action as the consequent.

An example of such a rule structure taken from the Marketing Module of the distributed system is

IF market_development is selective and
price_elasticity_of_demand is elastic

THEN price_policy is undercut

The interpretation of a rule is that if the antecedent can be satisfied, so can the consequent. When the consequent defines an action, the effect of satisfying the antecedent is to schedule an action for execution. When the consequent defines a conclusion, the effect of satisfying the antecedent is to infer the conclusion.

Problem solving using the rule-based representation involves the two stage iterative cycle of identifying a rule that bears on the problem and executing the rule. The executed rule either solves the problem or identifies another rule to be executed. There are different strategies that can be used to control the order in which rules are examined. These strategies will be examined under the section on inference below. Rule-based systems are easily implemented and can be extended to accommodate uncertain information. Hayes-Roth (1985) argues that although artificial intelligence researchers have developed several alternatives to rule-based representation, only the rule-based approach consistently produces expert problem solvers.

6.1.2 Frame-based representation

In the frame-based methodology, represented knowledge is partitioned into discrete structures called frames. Each frame has a set of individual properties called slots. Frames can be used to represent broad concepts, classes of objects or individual instances or components of objects. Frames are all joined together in an inheritance hierarchy that provides for the transmission of common properties among the frames without the need for multiple specification of those properties.

An example of a frame used to represent knowledge about investment options would take the form

FRAME: treasury bill	
SLOT	VALUE
Risk	low
Return	medium
Term	medium, long

If the treasury bill frame is part of a larger class of Government type investments, then the risk and term slots could be inherited rather than specified. Slots can also have procedural attachments that can invoke a procedure depending on the value of the slot. If the value was missing for example, a procedure to request a value from the user can be attached to the slot. Fikes and Kehler (1985) claim that frames capture the way that experts think about much of their knowledge, provide a concise structural representation of useful relations and support a concise definition-by-specialization technique that is easy for most domain experts to use.

6.2 Inference and control

Inference is the procedure used to manipulate knowledge items in the knowledge base. The inference procedure or inference engine operates between the knowledge base and the user. It guides the system in the use of the facts and rules stored in the knowledge base and also in the use of the additional information acquired from the user. The inference engine performs two functions. Firstly, it examines facts and rules stored in the knowledge base and adds new facts that it infers from these and from user input. Secondly, it decides on the order in which inferences should be made. The first task is one of pure inference while the second is essentially of control. The most commonly implemented inference strategy used in knowledge-based systems is the application of the *Modus Ponens* rule of logic. This rule simply states that if X is true and there is a rule that states : IF X THEN Y, then it can be assumed that Y is true. Control strategies can be forward chaining or backward chaining. In forward chaining, also called data-driven inference, the goal or solution is assembled as more and more facts are inferred or become available. In backward chaining, also called goal-driven inference, a goal is traced back through subgoals in order to establish a match with the given facts. In addition to the backward and forward chaining strategies, there are also the depth-first and the breadth-first search strategies. The breadth-first search examines all the antecedents of a rule before looking for more detail. Depth-first search focuses on one aspect of the problem until all the information on that aspect has been obtained. Combinations of search and chaining strategies can be used to optimize the control procedure of an inference engine. In the PROLOG inference engine used later in the development of the support system, a combination of backward chaining and depth-first inference strategy is used.

6.3 The heuristic strategy generating mechanism

Newell and Simon (1976) argue that intelligent activity, in either human or machine, is achieved through three distinct processes. These are:

-the use of symbol patterns to represent significant aspects of the problem domain,

-operations on these patterns to generate potential solutions and finally,

-a search process to select a particular solution.

In order to generate all the possible solutions, the search process must exhaust the problem state space. While exhaustive search can be applied to any problem state space, the overwhelming size of the state space for complex problems makes this approach a practical impossibility.

6.3.1 Heuristic problem solving

Strategic management is an extremely complex domain and an exhaustive search for strategic solutions would not only be impractical but would fail to capture the substance of intelligent management activity. Managerial problem solving is based on experiential and judgemental rules that guide the search process into areas that exhibit more potential than others. These heuristic rules are powerful reasoning mechanisms that selectively search a problem state space examining only areas that offer a high probability of success. Heuristic modelling (Tanimoto 1987) is the process of expressing a complex relationship between a problem state and a goal state as a network of simpler relationships or intermediate assertions. In the area of strategic management, the complex relationship between the current state of an organization and its desired future states is known as the strategic posture transformation (Ansoff 1976). In this context, we can regard the generation of generic strategies, which are intermediate assertions of strategic posture, as being heuristic. Strategic management techniques such as the Product Life Cycle theory, Experience curve theory, the PIMS findings, the Boston Consulting Group matrices, the McKinsey matrices and other similar techniques, all provide frameworks for generating generic strategies and can also be regarded as heuristic techniques. Many of these techniques however, have been criticised for not being adequate (Coate 1983, Derkindren and Crum (1984), Kiechel (1981) and Abernathy and Wayne (1974)) or for oversimplifying the process of strategic management (Stubbart 1989).

6.3.2 An integrative framework

A conceptual framework for generating strategic options that integrates the principles from the techniques mentioned above with the Structured Matching paradigm (Bylander and Johnson (1988), Chandrasekaran (1986), Chandrasekaran and Tanner (1986), Chandrasekaran and Mittal (1984)), and with formal multiattribute decision making theory (Bohanec et al 1983) is presented in this section. The implementation of the framework is discussed in the next chapter.

Structured matching is a problem solving technique that makes use of a hierarchical structure for representing related concepts. The hierarchy is made up of nodes at various levels. Each node represents a subconcept in the hierarchy and has the ability to assert a value depending on the evidence that it is presented from other nodes below. The process of assertion at an individual node of a particular value from evidence given is called simple matching. The overall assertion of a decision value for the whole framework is called structured matching. Each node can be regarded as a simple matcher. Simple matchers combine results to activate higher matchers until the root matcher outputs a decision. At the top most level of the hierarchy is the root node or root matcher which outputs a decision, and at the lowest level is the domain specific data relevant to the hierarchy. This relationship is shown in figure 6.2.

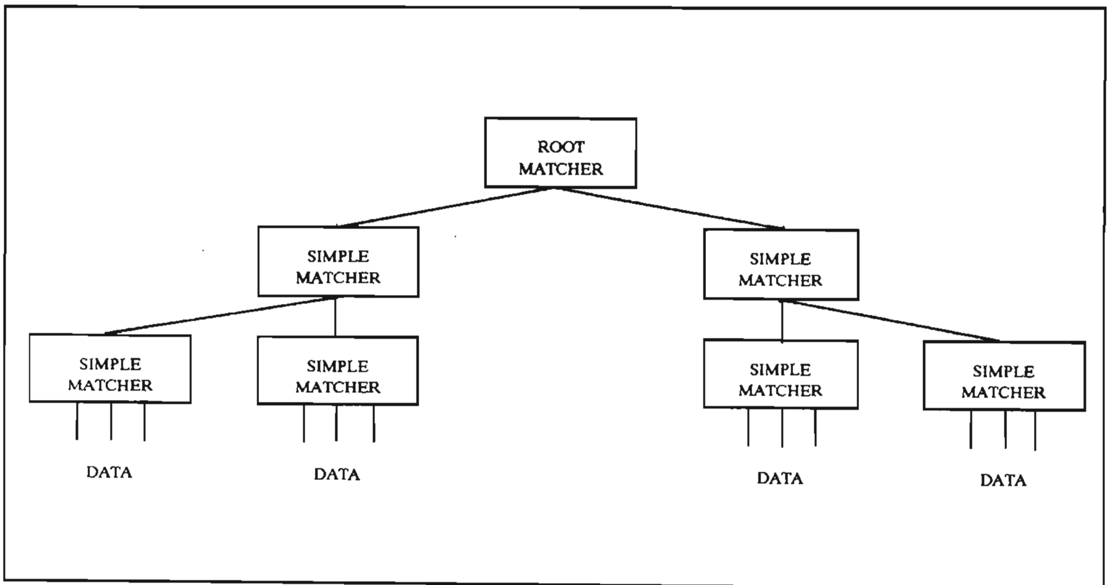


Figure 6.2 Structured Matching (adapted from Bylander and Johnson (1988))

The formal description of this process is given by Bohanec et al (1983). The structure of the matching hierarchy is described as a semantic tree given by the triple (X,F,E), where:

X is a set of performance variables $x_1,x_2,...x_n$ whose domains are $D_1,...D_n$;

F is a set of functions $f_1,...f_n$, from tuples of performance variables into performance variables;

E is a set of equations $e_1,...e_m$ $(m<n)$ of the form

$$x_i = f_i\,(x_{i1},x_{i2},...)$$

Set E satisfies the following conditions:

1. There is exactly one variable which never appears as an argument of any of the functions. This is the root variable or overall decision variable and corresponds to the root matcher in the structured matching model;
2. Each non-root variable appears as an argument of the functions exactly once (nodes do not have overlapping responsibility);
3. Each variable appears in the left-hand side of the equations at most once. The variables that do not appear on the left-hand side are called leaves and correspond to the data matchers in the structured matching model.

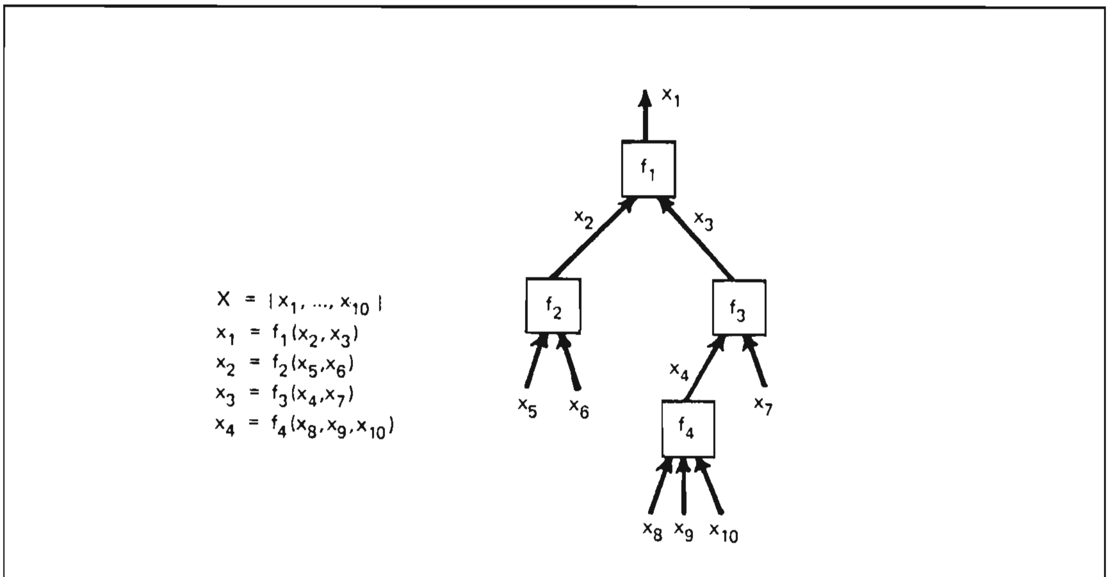


Figure 6.3 The Semantic Tree (adapted from Bohanec et at (1983))

Figure 6.3 depicts a typical semantic tree. Each function f_i represents a simple matcher and each performance variable x_i represents a piece of evidence. The idea of successively reducing the amount of data to be considered has considerable merit in strategy formulation where it is very easy to become paralysed by the amount of detail that requires scrutiny. The structured hierarchy framework is used to construct a model for the strategy formulation problem. Figure 8.3 illustrates this structure. At level 0 is the root matcher which outputs the generic strategy. At level 1 are the two simple matchers Environment and Organization. Level 2 contains the four simple matchers Environment Stability, Industry Strength, Competitive Advantage and Financial Strength. Since level 2 is the lowest level in the hierarchy, the four simple matchers at level 2 perform their matching from a combination of organizational factors. The factors used in this framework are shown in figure 6.4.

The matching or problem solving process proceeds as follows; Simple matchers gather data at the lowest level. In this case the four simple matchers at level 2 would each request the values for all the organizational factors contributing to their respective matching processes. Each matcher would then match the particular combination of organization factor values to a node value. The Environment Stability node for example would match the particular combination of environmental stability factors provided by the user to an environmental stability value for the environment within which the organization operates. Similarly, the other three nodes would assert values for the organization's level of Competitive Advantage, its Financial Strength and the Strength of the Industry within which it operates. The four node values thus generated at level 2 would then be combined

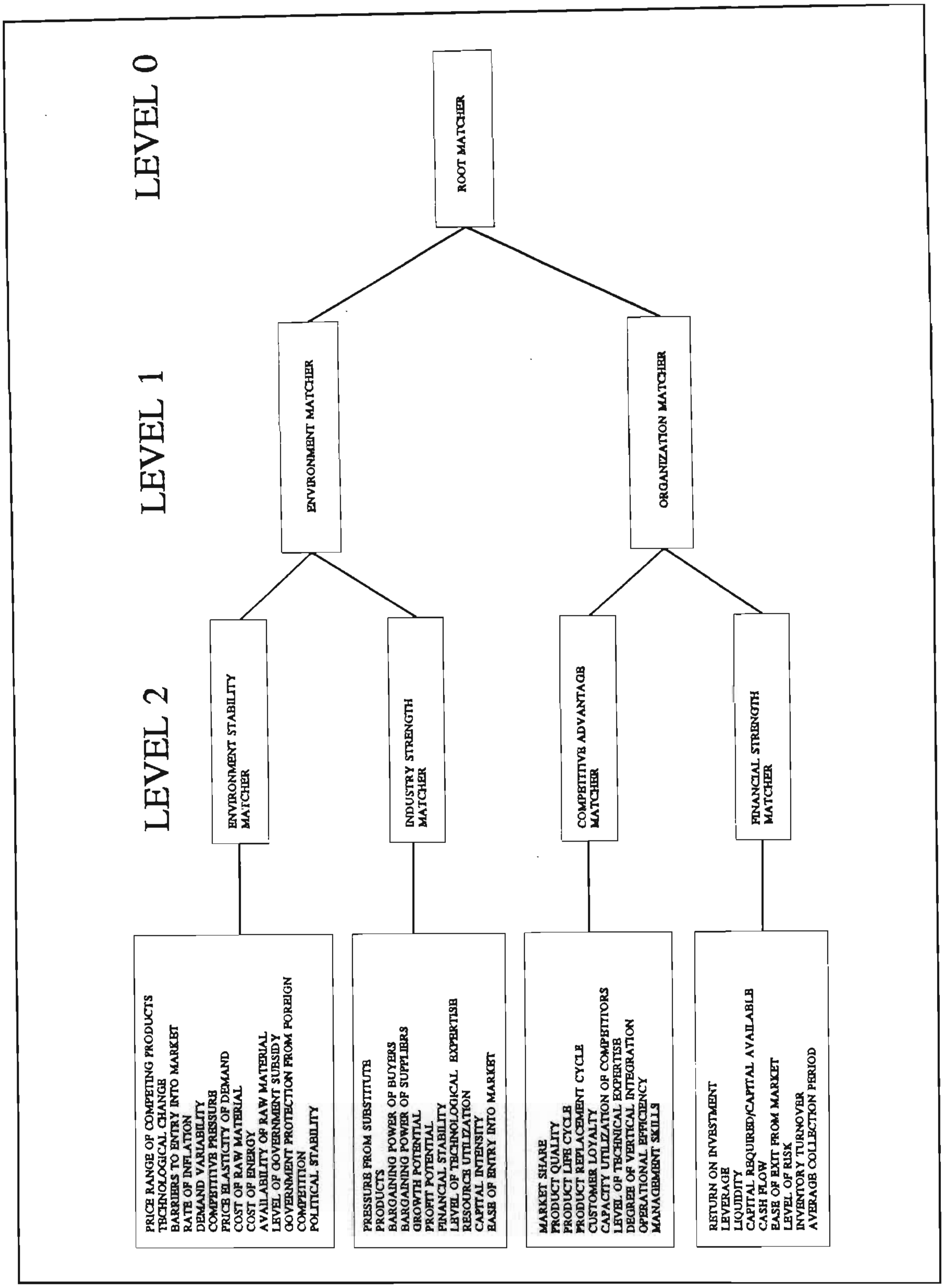


Figure 6.4 The Structured Matching Hierarchy for the Strategic Option Generator

by the matchers at level 1 to generate two node values at this higher level. The Environment node value generated would correspond to the relative strategic attractiveness of the environment and the Organization node value would correspond to the relative strength of the organization. These two node values are then combined by the root matcher to generate the root value for the hierarchy, which in this case would be a generic strategy option.

There are essentially three methods that can be used to achieve the actual matching of a combination of evidence values to a single node value. These methods are discussed individually.

Quantitative matching.

This method combines factors by using a numerical system of relative weights. Each factor in a matcher is assigned a weight which is indicative of the relative importance of its contribution to the final node value. The method of relative weights has been used before in analytical frameworks for strategy generation (Hussey 1978, Robinson et al 1978). The effectiveness of this method pivots around the assignment of weights and it is important that they are derived through consultation with experts in the industry or through other empirical means. The survey approach used by Moser and Christoph (1987) in the development of an expert system for divestment decision making can be extremely useful. In this approach, leading experts in the industry are asked in a survey to indicate the degree of importance that they place on particular strategic factor. The responses can then be formulated into a weighting system that is representative of the expertise in the whole industry.

Qualitative matching

This method allows qualitative values such as "high", "average", and "very low" among others, to be used to describe factors. The combination of these qualitative factor values is then achieved with the assistance of an expert (Bylander and Johnson (1988), Chandrasekaran (1986), Chandrasekaran and Tanner (1986), Chandrasekaran and Mittal (1984)). Consider the combination of the Environment Stability node value and the Industry Strength node value at level 2 as an illustration. The strategy expert will be asked the following question:

> If the environment stability is very high and the industry strength is average, how would you rate the attractiveness of the environment?

Similarly, in order to combine the Competitive Advantage node value and the Financial Strength node value, the expert will be asked:

> If the organization's competitive advantage is high and the financial strength is very low, how would you rate the organizations overall capability?

In this way, all the possible combinations are given a value by the expert and all the combinations together with their assigned values are stored in a table. When there is a need to match a particular combination of values, the table is searched until the combination and its corresponding result is found.

Hybrid matching.

The hybrid matching method is a combination of the quantitative and the qualitative methods and is suggested by Bohanec et al (1983). This method allows the use of descriptive values such as "high" and "satisfactory" as in the qualitative method but the values are then converted to numeric values using a compatibility function based on Fuzzy reasoning.

Each of the three methods of combination described above exhibit certain advantages and disadvantages. The quantitative method is the one which is implemented most easily but requires factor values to be numeric. This implies that there can be some loss of representational accuracy when a user has to choose a numeric value. The qualitative method corresponds very closely with the qualitative decision making behaviour of experts. The main limitation of this method is the number of combinations that must be stored when there many factor values to be combined. As an example, a node with 5 factors, each of which can assume 3 values (high, average and low) will need to search 243 combinations in order to arrive at a match. Since the nodes at level 2 of the proposed framework contain at least 8 factors, the use of this method is severely restricted. The hybrid matching method is an effective way of exploiting the advantages of both the quantitative and the qualitative methods.

The heuristic option generating mechanism is a means of reducing the overall strategic search space. Through this mechanism, the control module of the distributed system can enable the functional modules to concentrate their efforts at devising functional strategies rather than muddling through organizational and environmental data in an attempt to formulate their own strategies. This is the essence of generic strategies (Day 1984, Rowe et al 1986, Porter, 1980). Since the choice of the particular combination method in the heuristic option generator does not affect the operation of the distributed system in the experimental prototype stage, it was decided as a purely implementational consideration to use the quantitative method of combination. It is intended that the hybrid method be incorporated in future versions of the system.

6.3.3 Advantages of the framework

A list of advantages that can be derived from the use of the structured matching framework is discussed below. Since the advantages are derived largely through the use of the hierarchical structure, apart from the specific advantage of encoding of qualitative values, which is not shared by the quantitative combination method, these advantages apply to all the methods of combination equally.

Encoding of qualitative reasoning.

The use in the framework of descriptive or qualitative values such as "high", "satisfactory", "indistinguishable", "differentiated" etc, which form part of any strategic expert's vocabulary, promotes a more direct and explicit representation of the user's understanding of the problem domain. The rules of combination of matchers or performance variables are derived directly from the problem solving domain and there is therefore no need for the user or the expert to transform everyday terminology into numerical values. The structure of the framework also facilitates the systematic organization of the experts knowledge.

Implicit encoding of uncertainty

When an expert is asked to provide a suitable value for the combination of evidence, the expert's given value reflects his qualitative uncertainty judgement. When this value is used as evidence for yet a higher level of combination, its implied certainty is also combined. The hierarchical evaluation of evidence produces an overall uncertainty for the root decision. There is therefore no need for a separate uncertainty handling mechanism. As pointed out by Chandrasekaran and Tanner (1986), human problem solvers are uncertain in many situations and do not use a single method for handling different kinds of uncertainty. A global normative uncertainty handling mechanism would obscure this implicit structure.

Systematic knowledge acquisition

The hierarchical matching framework establishes a very effective semantic mapping between the problem solving formalism and the domain. This allows an expert to systematically formalise his expertise and simplifies the knowledge acquisition process in the following way. First, the data or evidence that is relevant to the problem is listed and then the data is grouped according to the subdecisions that the expert considers. For each data group, a simple matcher is formulated by querying the expert's response to the different combinations of data or evidence listed. In this way, the expert's judgement on the decomposition is also implicitly encoded into the framework. Higher level matchers are formulated by considering one level or subdecision at a time until finally, the root matcher can be formulated. The whole hierarchy can then be tested and refined.

Ease of explanation

The exact combination of evidence that gives rise to a value in a given simple matcher can be stored when that matcher is activated. These stored combinations form a chain of reasoning from the root matcher down to the lowest level. When an explanation is required at a node, the stored combination can be retrieved and translated. When a overall explanation is required, the chain of stored combinations can be retrieved and translated.

Computational tractability

The hierarchical matching framework avoids the common problem of having to consider a combinatorially increasing number of patterns. By using simple matchers as an aggregation of lower level matchers or data, the number of patterns that need to be considered become manageable. Also, since these matchers are arranged in a hierarchy, interdependence between matchers and the consequent feedback loops that arise are avoided. It is possible that for some simple matchers in the hierarchy, certain combinations of evidence are not relevant or may even be absurd. This would further reduce the number of possible patterns.

CHAPTER 7

System design : architecture and operation

7.1 System architecture

The distributed knowledge-based system for strategic management is modelled on the blackboard framework. A control knowledge source makes use of the blackboard to integrate and control a set of separate, domain specific knowledge sources. Each knowledge source is an expert in an organizational functional area and the experts cooperate opportunistically within the blackboard framework. The system architecture is shown in figure 7.1. A brief description of the knowledge sources or modules and a discussion of their major roles in the network follows. Extensive details of each module will be discussed during the construction and implementation of the system.

The control module.

The control module acts as the strategy formulation expert and also as the manager of the network. As the strategy formulation expert, it controls the direction and format of the network problem solving process. It contains knowledge about the strategic management process and it also contains meta-knowledge, which is knowledge about how the rest of the system's knowledge is distributed through the network. This meta-knowledge allows the control module to decide that interest rates concern the financial expert, product cost concerns the production expert and so on. The control module also performs the important function of strategy evaluation. As the network controller, the control module controls the execution of individual modules as well as the management of the status of the blackboard.

The scanning module.

The scanning sub-system acts as the machine interface between the network and the organization. The scanning module monitors a set of strategic factors and reports all variances to the control module via the blackboard. It performs a simple but nevertheless important role in the network. The module is non-intelligent in that it reports all variances. The control module decides on the severity of an occurred variance.

The functional knowledge modules.

There are currently four functional modules in the network. Each module contains conceptual knowledge of the domain area in general and also of specific policies of the organization in that area. The domain areas are Marketing, Finance, Production and Organizational. Each module has sufficient domain and control knowledge in order to function as a stand alone expert or knowledge-based system. The individual knowledge modules are discussed in detail later.

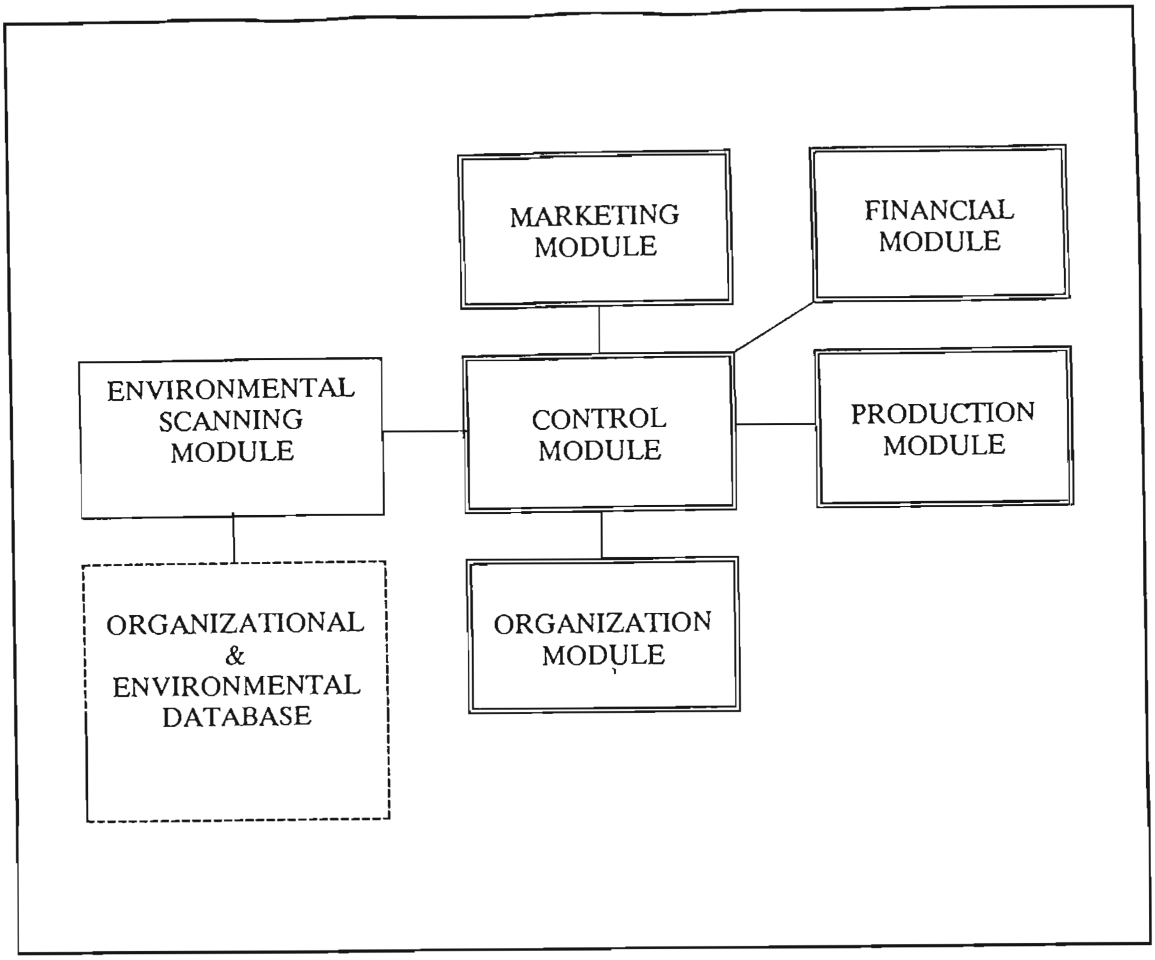


Figure 7.1 The System Architecture

7.2 Operational overview

The support system may be used in two ways. Firstly as a strategic management support system in which case it would operate in a control mode, and secondly as a consulting system in which case it would operate in a diagnostic mode. In the control mode, the support system is continually active either in controlling the implementation of operational plans which have been translated from previous strategic plans or in the formulation of new strategies. Each knowledge source is responsible for maintaining a set of strategic variables in its own domain. Variables are categorised as either internal or external depending on whether the entity that a variable relates to is changed from within or outside of the organisation's boundary. As long as the values of these variables remain within predefined limits, there is a balance between the organisational ability, environmental pressure and a chosen strategy. Values for the internal variables are held in the organisational database which is constantly updated through the organisation's information system. External variables are updated through manual input on a regular basis. All variables are monitored by the scanning subsystem. When the value of a variable changes, the scanning subsystem communicates this change to the control module. The control module decides on the degree of severity of the variance (and others which may occur simultaneously), assigns priorities and then decides on which modules need to be called in order to resolve the problem. It then posts a request with parameters describing the nature of the variance on the blackboard and activates the appropriate expert module or knowledge source. The individual knowledge source assesses the impact of the change in relation to the present strategic posture and communicates the result back to the control module via the blackboard. If the result concerns other knowledge sources, these are then activated by the control module. The process continues until a final result is obtained that is consistent with all the experts individual results. If two or more experts put forward recommendations that are conflicting, the control module can resolve the conflict by choosing the recommendation with the highest utility value or by modifying and reposting variables on the blackboard so that the individual experts reassess their respective recommendations and in so doing resolve the conflict themselves after a number of cycles. The control mode is similar in nature to the parallel decision-making model of Ansoff (Ansoff 1969). In the consulting or diagnostic mode, the control module elicits information from the user which it then uses to assess the strategic posture of the organization. It then uses a powerful heuristic mechanism to suggest shifts in the posture. Depending on the assessment, a shift can imply growth, turnaround or divestment. These shifts are suggested to the individual knowledge sources which test their validity and then translate them into functional strategies or action plans.

CHAPTER 8

System design : communication and control

8.1 The system blackboard

The blackboard does not exist as a physical entity in the system but rather as a communication mechanism through which the knowledge sources communicate both their requests and their findings. All individual knowledge source activity is initiated from the blackboard and all conclusions or results from knowledge sources are directed to the blackboard. In this application, the blackboard is in the control of the strategy formulation and control knowledge source. The system blackboard is divided into three main areas as shown in figure 8.1.

These three areas are used for static knowledge, dynamic knowledge and control knowledge respectively. Static knowledge is the domain specific knowledge that is relevant to the problem and normally remains relatively stable during the solution process. In the system blackboard, the static knowledge area holds the collection of organizational data that supports the strategic planning process. Dynamic knowledge is knowledge that is generated during the execution of the system. It consists typically of new facts, hypotheses and suggestions that are made by the knowledge sources. In the system blackboard, the dynamic knowledge is divided into the heuristic suggestion area and the functional strategy area. The heuristic suggestion area contains the suggestions made by the strategy formulation expert which are used by the functional knowledge sources to restrict their search spaces. The functional strategy area contains all the functional strategies, which are the solutions to a strategic problem, that are generated by the individual sources. Control knowledge is knowledge about the current state of the network itself and also of the status of the problem solving. In the system blackboard, the control knowledge is made up of a set of requests which form a dynamic queue. The requests are either from the control module to a functional module or vice-versa. The control module extracts from this request list a single request which it then

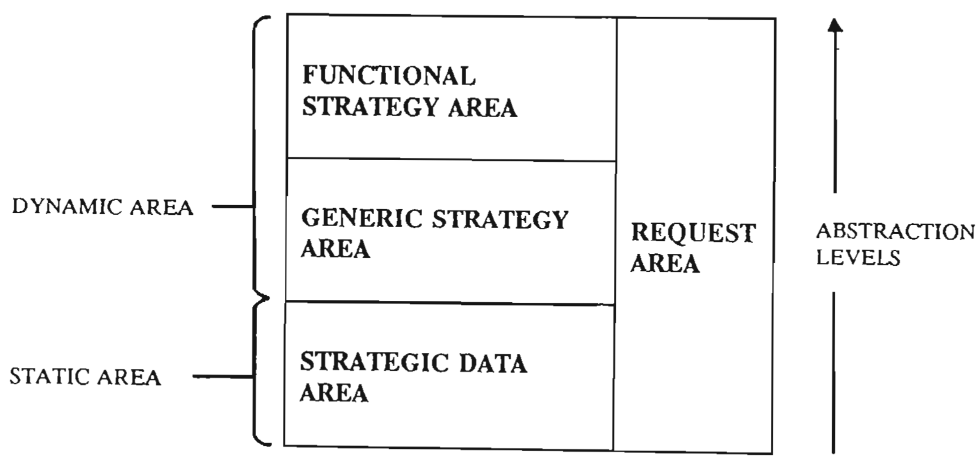


Figure 8.1 The System Blackboard

converts into a call to an individual module. The responsibility of keeping the blackboard "clean", that is, erasing old or unwanted entries or archiving previous entries rests with the control module. This is an essential activity since the blackboard tends to become cluttered after a reasonable amount of network activity and this can lead to a degradation of the network efficiency.

8.2 Scheduling and control

Network control can be achieved by selecting an individual knowledge source and calling on it to execute inside a problem solving cycle, or it can be achieved by placing knowledge on the blackboard that will cause a knowledge source to execute on its own. The support system uses the strategy formulation knowledge source as the network controller and therefore makes use of the former method. The network as a whole makes use of three control mechanisms: Goal-Driven control, which is the control exerted on the network to attain a network-wide or global system goal; Request-Driven control, which is the control exerted on the network by inter knowledge-source requests, and Event-Driven control, which is the control exerted on the network due to the occurrence of certain events. Since the two modes of operation of the support system exhibit different control requirements, these will be discussed separately. We will make use of the terms support mode control and diagnostic mode control to distinguish the two.

The support mode control concerns the control of the network when the system functions as a full support system. In this mode, the goal-driven function of control is the classical strategic management function of monitoring and controlling of strategic and functional plans. The goal of the network is to ensure that the implemented strategy adheres to certain performance limits that were used in the formulation of the strategy. Variances that exist obviously affect the strategic posture as a whole and must be accommodated at the strategic level. Variances are translated into network action by the event-driven control mechanism. A variance is regarded by the scanning subsystem as a strategic event that triggers the network into a resolution process. The event-driven control function is to alert the control module into initiating the network. Individual knowledge sources would then attempt to reduce the variance or the effects of it and failing this, to reevaluate the strategy.

The diagnostic mode control concerns the control of the network when the system is used to assess an organizations strategic posture and to suggest alternative strategies. In this mode there is no event-driven control exerted on the network at all. The goal-driven control function is to ensure that a set of strategic options is generated and that these options are translated into functional plans for evaluation.

Both modes of operation makes extensive use of the request-driven control mechanism. This mechanism allows the control module as well as other modules to alter the direction of the problem solving process in a dynamic way by posting requests on the blackboard. These requests may be for further information or for initiating the activation of other modules. There may be many such requests on the blackboard at any one time and in a serial network, that is a network in which the knowledge sources cannot be executed in parallel, these requests need to be serviced in some sort of order. This is accomplished by establishing a schedule of ready-to-be-called modules. This schedule must be flexible enough to be dynamically modified since the execution of one module may cause others that were ready to execute to be no longer required or, the execution of one module may cause others that were not executable, to become ready to execute. Also, there may be more than one consecutive request for the same module, and the schedule must allow a single activation call with all the requests consolidated rather than allow more than one consecutive call to the same module.

CHAPTER 9

Implementation

The three previous chapters were all devoted to developing conceptual design frameworks for the distributed knowledge based support system. This chapter and chapter 10 presents the implementation of these frameworks in the form of an experimental prototype. In terms of the developmental classification suggested by Waterman (1986), an experimental prototype is a limited implementation of a system that displays credible performance on the entire problem. In this case, the implementation of the distributed system is limited only in the sense that the functional modules, with the exception of the marketing module, contain sufficient knowledge to test the capability of the network in respect of distributed problem solving. The marketing module is developed more extensively in order to illustrate the idea that individual knowledge modules can be used as standalone knowledge-based advice systems in their respective domains.

The language used for the development is Prolog. Specifically, the Turbo Prolog package, a typed prolog compiler which is microcomputer based, is used. Since the discussion of the system implementation is illustrated through extracts of Prolog code, it will be useful to examine briefly the nature and inferencing procedure of a Prolog program. A Prolog program is a set of specifications in the first-order predicate calculus describing objects and relations in a problem domain. A Prolog predicate is used to describe the generic form of an object and clauses are used to hold the actual occurrences. Clauses can be factual or inferential. Factual clauses, also known as facts, describe what is known to be true and inferential clauses, also known as rules, describe the relationships between objects. Facts need not be verified by the Prolog inferencing procedure while rules have to be proven true. The Prolog inference procedure is driven by a given goal. A goal has the form

$$\begin{aligned}\text{GOAL if } & \text{SUBGOAL}_1 \text{ and/or} \\ & \text{SUBGOAL}_2 \text{ and/or} \\ & \ldots\ldots \\ & \text{SUBGOAL}_n.\end{aligned}$$

The Prolog inference procedure will attempt to satisfy GOAL by proving that all the SUBGOAL_i's are true. If the subgoals are proven true, the goal is assumed true. A process known as backtracking maintains a pointer wherever there is more then one solution that can be generated. The inference procedure uses this pointer to generate alternative solutions in its reasoning process. The Turbo Prolog environment contains many useful built-in predicates that can be used to facilitate screen design and list processing.

This chapter presents the implementation of the control module and chapter 10 presents the implementation of the individual functional modules.

Implementation of the control module

The Control Module serves as the overseer of the problem solving network. It controls the format and direction of the problem solving process by executing a series of procedures. The function of these procedures become evident when the goal that drives the control module is examined. This goal takes the form;

Solve IF GetValues AND
Generate_Strategy AND
Confer AND
Evaluate_Strategy AND
Present_Strategy AND
Conclude.

The goal Solve is made up of five subgoals or prolog procedures, each of which must be satisfied. The subgoal Getvalues controls the user interface and guides the user in supplying the required values for the strategic factors. The subgoal Generate_Strategy controls the heuristic strategy option generator and generates a generic strategy appropriate to the combination of factor values supplied. Confer controls the process that allows each functional module to investigate the functional implications of the generic strategy proposed by the Generate_Strategy subgoal. Through the Confer procedure, the control module dynamically schedules the execution of functional modules and controls the interchange of information on the blackboard. The subgoal Evaluate_Strategy examines the functional action plans proposed by the functional modules in relation to an evaluating scheme and either accepts or rejects these plans. The plans are rejected if the subgoal Evaluate_Strategy fails, and the prolog backtracking mechanism automatically restarts the Confer procedure. If the plans are accepted, the Present_Strategy subgoal presents the results of the network problem solving process to the user. Concludes terminates the diagnostic session of the system.

The implementation of the various functions of the control module will be presented in the order in which they are performed in the typical problem solving cycle represented by the Solve goal.

9.1 Implementation of the user interface

The function of the user interface in the diagnostic prototype is to obtain the required factor values from the user in the simplest way. Two introductory screens are used to introduce the system and a series of question screens then follow. There are 42 questions in 4 categories. These categories are Environment Stability, Financial Strength, Industry Strength and Competitive Advantage. A frame structure is used to hold each question and a recursive prolog procedure is used to control the questioning and to store the responses. The frame structure is represented by the following prolog predicate;

Q(Qnum,Categ,Fact,[ExplainList],[OptionList])

Where Q is the predicate identifier

Qnum is the question number

Categ is the category name

Fact is the factor at which the question is aimed

ExplainList is a list of explanation clauses which assist the user in understanding the nature of the question

OptionList is a list of responses from which the user makes his choice

An example of a question clause follows;

```
Q(12,"ENVIRONMENTAL STABILITY","TECHNOLOGICAL CHANGE",
    "This factor involves both the rate as well as the",
    "degree of technological changes in your immediate",
    "environment."
    "If sudden rapid changes are common in your",
    "environment, rate this factor VERY HIGH ",
    ["VERY LOW","LOW","AVERAGE","HIGH",VERY HIGH"])
```

Samples of screens and the complete prolog source code for the user interface can be found in appendices A, B and C.

9.2 Implementation of the heuristic strategy option generator

The theoretical framework and justification for the heuristic strategy option generator has been discussed in the previous chapter. At the heart of the framework is the concept of the structured matcher. The matching process matches or assembles various combinations of attribute values of strategic factors at different levels. The heuristic strategy option generator is implemented using a quantitative matching process throughout the hierarchy. In this method of implementation, the user's responses are converted to numeric values that are combined using an evaluating function as the matching mechanism. The evaluating function is formulated as follows;

$$\text{MatchValue} = F(\text{factor1}, \text{factor2}, \ldots \text{factorN})$$

Using the Financial Strength matcher at level 2 as an example, the evaluating function takes the form

$$FSM = w_1 F1 + w_2 F2 + \ldots + w_9 F9$$

F1 to F9 are the factors that contribute to the result of the Financial Strength Matcher and w_1 to w_9 are the relative contributions made by each factor to the overall result. In other words, the function returns a weighted average of the individual factors. In this form, the numerical matching method of using weights for each factor resembles very closely the method used for constructing the various portfolio grids such as the Boston Consulting group's Growth Share Matrix, the Shell Directional policy Matrix or the General Electric Market Attractiveness Matrix. The problem with these techniques, as with the numerical implementation of the matching process, is the assignment of the weights for each factor. The weights have to be assigned objectively by an expert who understands the industry extremely well or distortions can arise (Hussey 1978, Robinson et al 1978). The weighting assignments also need to vary across different industries since certain factors exhibit different degrees of prominence in different industries. This problem is circumvented in the prototype by assigning equal weights to all the factors since it is intended that an expert will provide the relative weights in the production version of the system or that a qualitative matching method will be implemented instead.

The weighted values obtained from the four matchers at level 2 are used in the evaluating functions at level 1 as follows;

$$\text{MatchVal1} = m_1\text{FSMVAL} - m_2\text{ESMVAL} \quad \text{and}$$

$$\text{MatchVal2} = n_1\text{CAMVAL} - n_2\text{ISMVAL}$$

m and n are the respective weights at level 1.

It can be seen that the value MatchVal1 is purely the weighted difference between the Financial Strength matched value and the Environmental Stability matched value. Similarly, the value of MatchVal2 is the weighted difference between the Competitive Advantage matched value and the Industry Strength matched value. MatchVal1 and MatchVal2 are therefore the results of matching an organization's financial strength against the environmental stability and matching an organization's competitive strength against the industry strength. This is reasonable since a company's financial strength is important when there are adverse economic conditions such as high inflation or high interest rates. A strong financial position acts as a cushion in such times. In better economic conditions, a financially strong company is able to diversify into more attractive industries or to invest aggressively in its current industry. A company lacking financial strength has more tolerance in a stable environment while a lack of financial strength in a turbulent environment can lead to disaster. In a similar way, a company's competitive position, whether in market share, product cost or expertise, will allow it to maintain a high profit margin in a healthy industry and a reasonable profit margin in a declining industry. Marginally profitable firms will find it difficult to survive in such an industry. A strong industry however, provides momentum to expanding markets and allows even marginal competitors to find niches. An industry with low strength intensifies competitive rivalry and companies in such an industry are forced to protect their competitive positions.

At level 0, the values of MatchVal1 and MatchVal2 are used by the system to generate a strategic vector on a two dimensional framework illustrated in figure 9.1. The position of the vector indicates the strategic posture of the organization and also dictates the strategic options open to it. The use of a vector to establish strategic position has been used before by Ansoff (1976) and is also used in the Strategic Position and Action Evaluation technique (Rowe et al 1986).

9.3 Implementation of Distributed Network Control

The control of the distributed network embodies three separate functions. These are, the control of information flow between the control module and functional

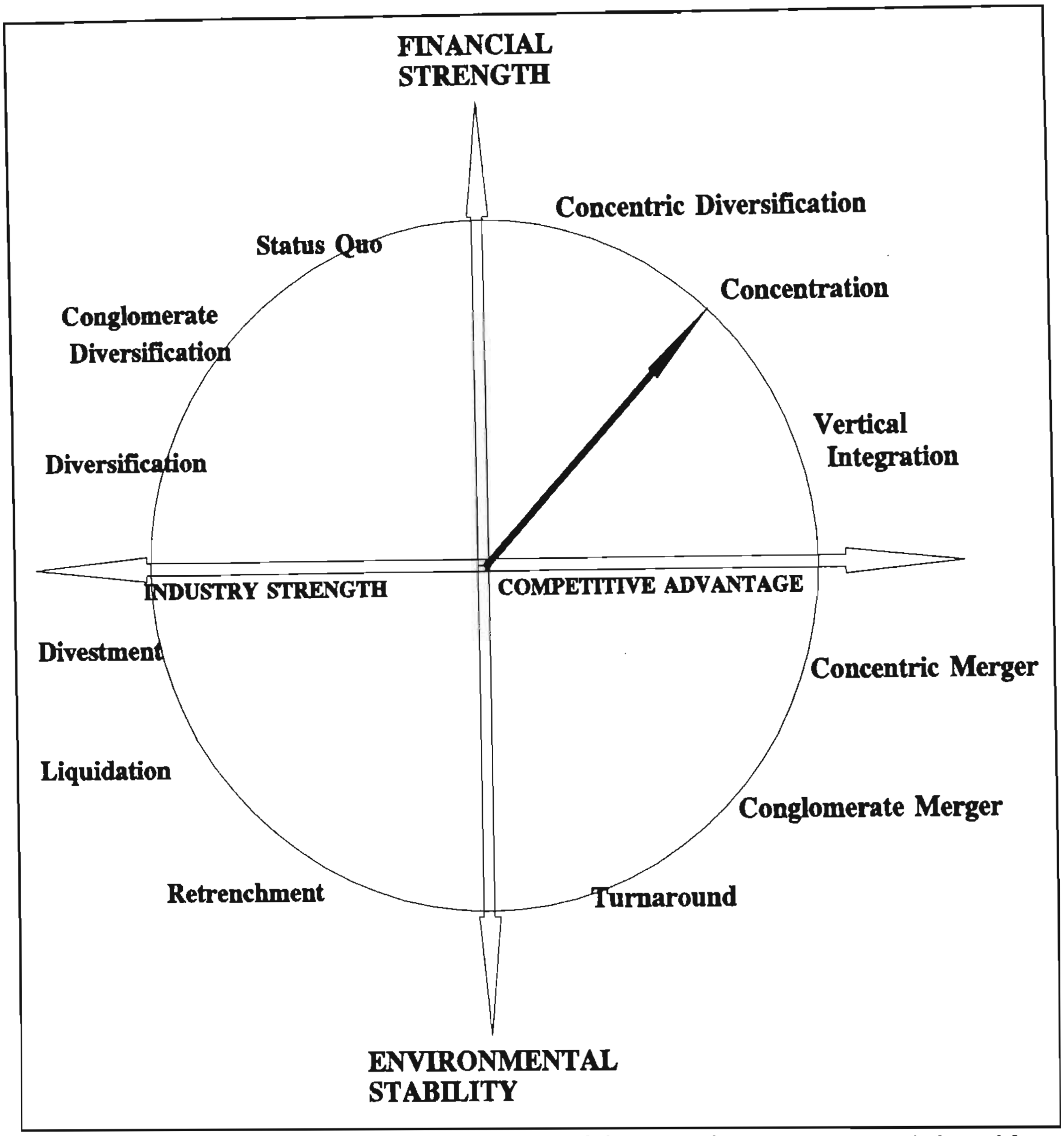


Figure 9.1 The Strategic Option Generating Grid and the Strategic Posture Vector (adapted from Rowe et al (1986))

modules, the decomposition of problems into smaller tasks for distribution and the order of scheduling functional module execution. The implementation of these three functions are discussed in turn.

9.3.1 Control of Information Flow

The mechanism used to control and facilitate the flow of information in the network is the blackboard. The blackboard is a communication and storage mechanism which is accessible by all the modules and which is divided into different levels. Prolog has an internal database which can be modified during execution time and can also be stored and retrieved. This forms a convenient implementation of the blackboard. The different levels can be distinguished by using a separate predicate for each level. At the static level, which holds organizational data, the predicate has the form;

Factval(FactorName,value)

An example of such a clause is Factval("Leverage","LOW").

When the user has responded to all the questions, there are 42 Factval clauses held in the static area of the blackboard.

The dynamic level of the blackboard is further divided into a generic strategy level and a functional strategy level. The generic strategy level is used by the control module to post the strategies that it generates through the heuristic mechanism. The functional modules examine the generic strategies and translate these into functional plans which are posted at the functional level. At the generic level, the control module posts clauses conforming to the predicate

Recommend(Strategy)

An example of this predicate is the clause Recommend("Turnaround").

At the functional level, the individual modules post the results of their translation of the generic strategies using the following format;

Plan(Factor,Action)

Factor is the particular organizational factor that is being referred to by the functional module and action is the proposed modification of Factor. An example of such a clause is Plan("ProdRange","DEC"). This example, which suggests a reduction in the product range, could be one of the action plans proposed by the marketing module corresponding to the Turnaround strategy.

The third level of the blackboard is used to hold control information for the scheduling mechanism. This information is in the form of request clauses that are inserted into the blackboard at the control level by those functional modules that require assistance or additional information. Requests are held in the following format

Request(CallMod,DestMod,Factor,Action,Ref,Status)

CallMod identifies the module issuing the request, DestMod is the module to which the request is directed, Factor and Action are as before, Ref is a request reference number and Status indicates the status of the request. A status value of "U" denotes unresolved and a status value of "OK" or "NotOK" denotes a resolved request. When the control module assembles requests into a queue, it examines the status value in each request and ignores requests that have already been resolved. An example of a request is

Request("MARK",,"PRICE","DEC",1,"U").

This is a request from the marketing module requesting that the control module investigate the possibility of a reduction in product price. The DestMod is left blank since the individual modules do not have knowledge of each others expertise. The control module, through its decomposition procedure, decides on the module to which it can best delegate the resolution of the request and fills the DestMod slot before the delegated module is called. If the request can only be resolved by more than one module, the control module issues as many requests as the decomposition procedure generates. Since the scheduling mechanism uses the clauses in the request area of the blackboard to construct an execution queue, an since there are no clauses in this area at the start of network interaction, the control module must insert a list of special requests to initiate the cooperative problem solving process. These requests follow the same format as the normal request with the exception that the Factor, Action and Ref slots are not used. The use of the request area to create an execution schedule is discussed fully in the section on scheduling later in this chapter.

9.3.2 Problem decomposition

When an individual functional module encounters a subproblem during its problem solving activity that is outside its domain of expertise, it would issue a request to the control module for assistance. It is the function of the control module to redirect these requests to the appropriate modules. A major problem for the control module in the execution of this function is "knowing" which module to call for a given request. A simple and effective way to overcome this problem is to maintain a list that links all the relevant organizational data items with the modules responsible for them. Such a list represents Meta-level knowledge since it represents knowledge about the use of the distributed expertise in the most efficient way. When a request that can be resolved by a single module is received, the control module need only scan the list in order to identify the module best suited to resolving the request. A problem arises when a request is received that cannot be resolved by one module alone. Such a request has to be decomposed into subrequests that can be resolved by individual modules. This decomposition process can be implemented by organizing the decomposition relationships into a taxonomy as follows.

The fundamental unit of the decomposition taxonomy is a Meta-Knowledge frame. The prolog representation of the Meta-Knowledge frame is

MFrame(Problem,PRef,DecompList,Dmodule)

where:

MFrame is a label distinguishing the Meta-Knowledge frames from other frames in the program;

Problem is the label identifying the problem that this instance of the frame is representing;

PRef acts as a reference number for the problem represented by this frame and is used to establish priorities in the problem solving process;

DecompList is a list of all the subproblems that Problem can be decomposed into;

Dmod is the Domain module responsible for solving Problem and is only present in a frame if the DecompList contains a single element, or if it contains more then one element, then all these elements are the responsibility of the same domain module.

The following scenario illustrates the use of this taxonomy;

Suppose that a user has supplied all of the 42 organizational factors required by the level 2 matchers and that the control module, through its heuristic mechanism asserts concentration as a strategic option. It would then need to broadcast this option to the functional modules in the network in order for them to investigate the implications of the proposed strategy on a functional level. For example, the marketing module would attempt to translate the concentration strategy into marketing action plans. One marketing option in a concentration strategy is to increase market share. Market share can be increased by stimulating primary market demand which expands the total market or by stimulating selective demand which increases market share within the existing market. A marketing action plan of reducing product price or increasing advertising can achieve both these. Since product price is outside the domain of the marketing module, it will request the control module to investigate the feasibility of price reduction. The control module has to refer this request to the appropriate module or modules and makes use of the meta-knowledge frame taxonomy search to decide which module or modules are appropriate. The search begins by finding a frame which has price as the label in the problem slot.

MFrame("Price",1,["Cost","Margin"],)

The PRef slot is arbitrarily set to 1 and the domain slot is empty since DecompList contains more than one element. This frame represents the decomposition of the price problem into the two subproblems of cost and margin. The search then continues by finding a frame for each of the elements in the DecomList. These are found as

MFrame("Cost",1,["ProdCost","Ohead"],)

MFrame("Margin",1,["Margin"],FIN)

The first frame further decomposes the cost problem into the two subproblems of production cost and production overhead. The second frame asserts that margin cannot be decomposed further and that it is the responsibility of the FIN or Financial module. The control module continues the search by finding frames with Prodcost and Ohead as labels in the problem slot. This produces the following frames

MFrame("Prodcost",1,["ProdCost"],PROD)

MFrame("OHead",1,["OHead"],FIN)

Since both these frames contain only one element in their respective DecomLists, the search terminates and the control module posts a request to the PROD or production module to investigate the reduction in product cost. The production module contains rules that relate product cost to raw material and labour costs and so is able to function independently in solving this subproblem. The control module also posts a request to the FIN or financial module to investigate the possibility of a reduction in profit margin and production overhead. Both the financial and the production modules communicate the results of their investigations to the control module. Both the requests derived from the decomposition have the same PRef number as the original request and the scheduling mechanism uses this number to keep them in the same logical group.

9.3.3 Control of dynamic scheduling

Dynamic Scheduling begins with the execution of the subgoal Confer. Before this, the control module elicits information from the user and generates its own generic strategic option. The Confer procedure initiates network activity by posting a proposed strategic option and establishing a queue of Ready-to-be-called modules. The queue is represented by a prolog list and is constructed by examining all the requests held in the control level of the blackboard. The Confer procedure terminates when there are no unresolved requests on the blackboard. When network activity is first started, the queue is constructed from special requests inserted into the blackboard by the control module. There is an initial special request for each functional module in the network. Once a queue has been constructed, the control module calls the functional module represented by the first entry in the queue. When the call terminates, that is, when the functional module has completed its task, the control module then reconstructs the queue and the process is repeated. Reconstructing the queue each time a functional module call is terminated, ensures that the scheduling mechanism makes use of the most current problem solving knowledge available. This is necessary since at any stage, a called module may issue a request and suspend its problem solving activity until the request is resolved. The module chosen for investigating this new request must be inserted at the head of the queue and called. On its termination, the original module which is waiting for the response is called and continues its task.

As an illustration of the dynamic scheduling mechanism, suppose that the control module inserts the clause Recommend("Concentration") at the generic strategy level of the blackboard. To initiate the network, the control module also inserts the following requests in the request area

Request("CM","MARK",,,,"U")

Request("CM","PROD",,,,"U")

Request("CM","FIN",,,,"U")

Request("CM","ORG",,,,"U")

The scheduling mechanism constructs a list from these requests as follows

["MARK","PROD","FIN","ORG"]

and executes the head of the list. The marketing module is called. It examines the blackboard and picks up the generic strategy of Concentration. Using its own knowledge it then investigates the increase of market share by lowering the product price. Price is outside its domain and it inserts a request for assistance at the top of the request area as follows;

Request("MARK",,"PRICE","DEC",,"U")

Request("CM","MARK",,,,"U")

Request("CM","PROD",,,,"U")

Request("CM","FIN",,,,"U")

Request("CM","ORG",,,,"U")

The control module attempts to fill in the DestMod slot by executing the decomposition procedure. Through the decomposition procedure, it generates three requests which are added to the request list thus

Request("CM","PROD","ProdCost","DEC",1,"U")

Request("CM","FIN","Margin","DEC",1,"U")

Request("CM","FIN","OHead","DEC",1,"U")

Request("CM","MARK",,,,"U")

Request("CM","PROD",,,,"U")

Request("CM","FIN",,,,"U")

Request("CM","ORG",,,,"U")

The scheduling mechanism now constructs an execution queue as follows;

["PROD","FIN","MARK","PROD","FIN","ORG"]

It Calls the Production module to investigate the reduction of Prodcost. The production module traces ProdCost through its own rules to Material and Labour costs. If a reduction in ProdCost is possible, the Production module would modify the request area as follows;

Request("CM","PROD","ProdCost","DEC",1,"OK")

Request("CM","FIN","Margin","DEC",1,"U")

Request("CM","FIN","OHead","DEC",1,"U")

Request("CM","MARK",,,,"U")

Request("CM","PROD",,,,"U")

Request("CM","FIN",,,,"U")

Request("CM","ORG",,,,"U")

The constructed execution queue at this stage appears as;

["FIN","MARK","PROD","FIN","ORG"]

The Finance module is now called and the process continues until all the requests are resolved. When this occurs, the strategic action plans generated can be evaluated.

9.4 Strategy evaluation and the termination of the problem solving process

The control module initiates the problem solving process in the network by generating a generic strategy from factor values supplied by a user and requesting individual modules to investigate the generic strategy in terms of their own functional knowledge. It is also the responsibility of the control module to terminate the process when an acceptable solution is generated. In order to classify a generated solution as acceptable, each solution is evaluated using an adapted version of the Tilles evaluation criteria presented in chapter 2. The evaluation is performed through the Evaluate_Strategy subgoal which executes its own subgoals as follows;

```
Evaluate_Strategy    IF    ConsistencyOK,
                           AppropriateOK,
                           RiskOK.
```

The Evaluate_Strategy subgoal succeeds if all the subgoals succeed.

The ConsistencyOk subgoal examines the proposed plans for internal consistency. It does this by examining all the clauses in the plan area of the blackboard. If there is more than one plan with the same proposed factor but with conflicting actions, the plan is not consistent. Consider the following two plan clauses.

```
Plan("Price","DEC")
```

Plan("Price","INC")

The first clause is generated by the marketing module in order to effect an increase in market share and the second is generated by the production module in order to effect an increase in profitability. There is clearly a conflict and the subgoal ConsistencyOk fails, causing the Evaluate_Strategy subgoal to fail and the network problem solving process is restarted.

The AppropriateOK subgoal examines the implications of the proposed strategies to establish whether they are appropriate in respect of the organizational resources. Tilles refers to appropriateness in terms of financial resources, personnel resources and physical resources. In the implementation of the prototype, the AppropriateOK evaluates only the financial implications of the proposed strategy. It does this by accumulating all the expenditure to be incurred by the proposed strategies, and compares this to the funds available. Since the level of funds available is not a factor in any of the matchers and therefore not accessible, the control module requests this value from the user independently. If the requirements exceed the funds available, the user is prompted for a value of augmented debt (additional debt that can be incurred because of favourable leverage). If the requirements exceed the sum of funds available and augmented debt, the AppropriateOk subgoal fails.

The RiskOK subgoal compares the ratio of resources committed to the proposed strategy to the total resources and matches this value against the matched value of the Environment Stability Matcher. For simplicity, the RiskOk subgoal only fails if the Environmental Stability value is lower than the ratio. It is intended that a more sophisticated risk and resilience analysis procedure be incorporated in the production version of the system. When the Evaluate_Strategy subgoal is satisfied, the Present_Strategy assembles the proposed plans into a report which is then printed. The Conclude procedure writes the blackboard to a disk file and terminates the program.

CHAPTER 10

Implementation of the functional modules

The distributed network contains four functional modules that act as independent experts in the domains of marketing, production, finance and organization. This chapter describes the implementation of each of these modules. The modules are not developed as comprehensive knowledge-bases since the motivation for developing the prototype network is the need to study the operation and investigate the performance of the distributed support framework. In this respect, the evaluation of the efficiency of the network interaction and the effectiveness of the cooperative problem solving process can be accomplished by implementing each module so that it contains only the knowledge necessary for it to cooperate in the network. Each module has two types of knowledge in its knowledge-base. There is control knowledge which the module uses in order to manage the essential blackboard access and retrieval functions and to integrate the communication activity with its own problem solving activity. There is also domain knowledge which is used to translate generic strategies into functional action plans. The knowledge in each module is represented as either rules or frames or a combination of rules and frames and each module is compiled into an executable file. This allows the control module during its own execution to call each module through a system call.

In the prototype implementation, the marketing module is developed more comprehensively in order to illustrate the particular benefit of using a distributed system that each individual knowledge base can be used as a standalone system in its own area. The implementation of each module is discussed in terms of the techniques used to represent control knowledge and domain knowledge. Some rules or frames are included to illustrate the inference process or the nature of the knowledge representation technique. Relevant extracts of the Prolog source code can be found in the appendix for further reference.

10.1 The marketing module

The marketing module implemented in the prototype participates in the cooperative problem solving process of the network as the marketing strategy expert and also acts as an advice system in two areas of marketing. These two areas are the screening of potential products in new product development and the choice of advertising media.

10.1.1 Control knowledge

The marketing module functions both as a network module and as an independent knowledge base. These two functions present different programming and execution requirements. In its function as the network marketing expert, the marketing module does not require a user interface and the very first action that it must perform is to scan the blackboard. As an advice system, the first action is to present the user with a menu of its capabilities. In the implemented prototype, the options are new product screening and advertising media selection. Since the module is called in executable form from either the control module or from the normal operating system environment, the command line passing facility is used in order to accommodate these two different modes of operation of the same module. This is achieved as follows:

The name of the marketing module in its executable form is "MARK". When it is called from the control module, the call used is "MARK NET". When it is called as an advice system, the call used is "MARK ADVICE". The Prolog predicate COMLINE(X) stores the command line parameter with which the program is called and can be used to invoke the relevant sections of the program as the following goals illustrate

```
NETWORK    IF  COMLINE(X) AND
               X = "NET" AND
               Other subgoals to perform network functions.

STANDALONE IF  COMLINE(X) AND
               X = "ADVICE" AND
               Other subgoals to perform advice functions.
```

Access to the blackboard is achieved through the use of the Prolog Consult and

Save predicates which enable the module to load a stored blackboard into its working memory as an internal database and also to rewrite the blackboard with the requests that it has itself inserted. The clauses contained in the Prolog internal database are regarded no differently by the inference process and this facilitates the integration of blackboard access and problem solving in the following way: if during its search through the subgoals of a goal, the Prolog inference mechanism has a need to instantiate a variable contained in a clause whose predicate is defined in the internal database, the blackboard is automatically accessed.

10.1.2 Domain knowledge: marketing strategy

The domain knowledge in the marketing module concerns the logical translation of generic strategic options into marketing action plans or programs. Every strategy that is generated by the control module must be analysed in terms of its impact on the marketing policies and their options listed below.

Market Policies

Geographic Coverage: International, National, Regional, Local

Number of Markets: Many, Few, One

Nature of Market: Consumer, Industrial, Government

Market Similarity: Related, Unrelated

Market Development: Primary Demand, Selective Demand

Product Line Policies

Breadth of Product Line: Full, Partial, Single Product

Customization: Standard, Modifications, Custom

Distribution Policies

Nature of Distribution: Competitive, Complimentary

Distribution Chain: Wholesalers, Retailers, Direct Selling

Selectivity: Intensive, Selective, Exclusive

Pricing Policies

Level: Undercut, Match, Overprice

Credit: Purchase, Financing

Promotion and Advertising Policies

Emphasis: Push, Straddle, Pull

Media: Newspapers, Radio, TV, Movies, Billboards

In most cases, a strategic option will have an effect at least on some of the policy areas listed above. Each policy option is held as a clause and rules are formulated to match clauses to strategic options. Clauses are defined through the predicate

SOption(Policy,Action)

Examples of clauses are

SOption("ADEmphasis","PUSH")

SOption("Price","UNDERCUT")

Examples of rules are

SOption("Price","UNDERCUT") IF

SOption("MarkDev","SELECTIVE") AND

Factval("Price Elasticity of Demand","Elastic").

SOption("MarkDev","SELECTIVE") IF

Recommend("Concentration") AND

NOT(Factval("Product Life Cycle","Decline")).

The second rule matches a selective market development option to the generic concentration strategy. The first rule matches a reduction in price as an option for selective market development. Other options for selective market development such as increased advertising or financing or improvements in quality are also stored in clauses and can be generated automatically by the prolog inferencing mechanism by making use of the fail predicate. The fail predicate forces backtracking to a subgoal which can generate alternative solutions.

The factval clauses are introduced in rules to test for anomalous situations. For example, when a company has high competitive advantage and financial strength in a stable environment, the control module would suggest concentration which is an aggressive growth strategy. Increasing market share is the commonly accepted method of growth within such a strategy. An anomaly exists, however, if the product and its corresponding market is in the decline stage of its life cycle. In such a case, increasing market share is not a feasible option and diversification would be more appropriate. This anomaly is catered for by the factval clause in the second rule which would cause the rule to fail in the context of a declining market. Similarly, a price reduction would not increase market share unless the market demand is elastic and the factval clause in the first rule ensures that this is the case before the rule is allowed to succeed.

10.1.3 Domain knowledge: new product screening

Many organizations rely on new product development and marketing for their long-term success. New product development can be the key to successful implementation of marketing strategies such as product line extension and diversification. Product development, however, is expensive and involves a high degree of risk. The marketing module in its function as a marketing expert, attempts to reduce this risk by screening new product ideas and evaluating the feasibility of further development. The screening process is achieved by asking the user to rate 17 factors in the four categories of Marketability, Durability, Production and Growth. The factors, which are adapted from a screening process devised by O'Meara (1961), are;

Marketability Factors

Relation to present channels of distribution

Relation to present product lines

Quality/Price relationship

Number of sizes and variations

Merchandisability

Effects on sales of present products

Durability Factors

Stability

Breadth of market

Resistance to cyclical fluctuations

Resistance to seasonal fluctuations

Exclusiveness of design

Production Factors

Equipment required

Production knowledge required

Raw material availability

Growth Factors

Market placement

Expected competitive position

Expected availability of end users

Each factor is stored in a frame similar to the strategic factor frame used in the control module. An example of the frame corresponding to the Equipment Required factor in the Production category is;

Q(12,"PRODUCTION","EQUIPMENT REQUIRED",
"The new product can be produced with:",
"A: Equipment that is presently idle",
"B: Present equipment but production shared with existing products",
"C: Largely present equipment but some new equipment is necessary",
"D: Largely new equipment but some present equipment can be used",
"E: New equipment altogether",
["A","B","C","D","E"]).

The system rates "A" as 5, "B" as 4, "C" as 3, "D" as 2 and "E" as 1. An average value is obtained for the whole scheme. A rating of 5 denotes a highly desirable product; 4, a desirable product; 3, a risky product and 2 and 1, as undesirable products. The frames for the other factors can be found in the appendix.

10.1.4 Domain knowledge: media selection

Advertising is an important aspect of marketing. Even a perfect product at an affordable price will not be successful unless information about its availability and its benefits are advertised. Media selection is an important aspect of advertising. Media selection attempts to find an optimum match between media audiences and delivery environments on the one hand and consumer and product factors on the other. The media selection advice function of the marketing module assumes an existing product and a known demographic profile of the intended market.

The selection process begins by prompting the user to respond to a series of market factors. Each factor is presented with a list of options from which the user makes a choice. The factors together with their corresponding options are;

Product Type:	Convenience, Impulsive, Shopping, Speciality
Customer Type:	Teenager, Young-Single, Married-Nochildren, Married-Children, Elderly-Retired
Target Market:	General, Selective
Geographic Reach:	Local, Regional, National
Buying Decision:	Rational, Irrational
Advertising Requirements:	Audio-Visual, Detail-Info, Awareness, Repetition

Each response is stored in a Factval clause as before and a series of production rules are then used to map combinations of the above factors into the media types RADIO, TV, NEWSPAPERS, MAGAZINE. There are altogether 6 rules in the prototype. An example of a rule is;

```
MEDIA("RADIO")  IF   Factval("Product_Type","Convenience) AND
                     Factval("Target_Market","Selective") AND
                     Factval("Customer-Type","Teenager") AND
```

Factval("Reach","Local") AND

Factval("Buy","Irrational") AND

Factval("Advert","Repetition").

10.2 The financial module

The primary function of the financial module in a strategic context is to provide the financial support for the functional strategic plans formulated by the other modules. This function, often referred to as Strategic Funds Programming is concerned with providing the most effective financial structure for the organization to achieve its strategic objectives. In performing this function, the financial module must establish the strategic requirements of the other modules and examine this in relation to the funds generated through the organizations's normal operations in order to establish the net funds flow following relationships. If the funds generated balance the funds required then the financial module need only consider the effective deployment of funds. In the more likely event that the required funds and the available funds are not the same, the financial module must consider the following options.

If additional funds are required, is it to be generated by;

Increased external debt or additional equity

Decreased dividend payments

Sale or Liquidation of assets or businesses

Acquisition of cash rich businesses

If there is a surplus of funds, is it to be used for;

Repurchase of equity or repayment of debt

Increased dividend payments

Acquisition of cash needing businesses

Investments in working capital or fixed assets

A second function of the financial module is more directly related to some of the generic strategic postures generated by the control module. In this function, the financial module adopts an operating strategy to correspond with the generic strategy. The Turnaround strategy for example, could be translated into cost-reduction, asset reduction and revenue-increasing strategies. These in turn could be decomposed into the following operating decisions;

Reduction in inventories including Work-in-Process

Reduction in receivables

Reduction in expenditure

Stretching payables

Cost reduction is also investigated for its impact on product prices through fixed overhead costs. The possibility of a product price decrease through reduced fixed costs is referred to the financial module by the control module on behalf of the marketing module. In the implementation of the prototype, a set of rules that match operating options to generic strategies perform the secondary function. The financing function is not implemented since there are no quantitative details available in the prototype system for computing the exact requirements and the consequent funding.

10.3 The production module

The production module is required to translate generic strategies into production action plans. These plans concern;

- Manufacturing Policies
    - Level of automation
    - Level of integration
    - Plant size
    - Plant location
    - Nature of equipment
    - Capacity
- Production Policies
    - Inventory levels
    - Quality control
- Product Policies
    - Nature of design

Again, rules are used to link appropriate operational actions to strategic options. A market development strategy for example, would require the product design to be improved, a differentiation strategy would require the product quality to be improved and a turnaround strategy would require product ranges to be pruned. Product price through its variable cost component is also a concern of the production module and it can be investigated through improved purchasing, improved process control or more efficient equipment.

10.4 The organization module

The organization module is required to ensure that the organizational structure corresponds to the chosen strategy. Each strategy can be examined in terms of the following policies;

Coordination
Authority
Measurement and evaluation
Rewards
Recruitment
Training
Promotion
Leadership style

In the prototype however, the organization module makes recommendations regarding training and leadership styles only. Training can be linked to quality control and production efficiencies. The organization module would suggest training as a option to reduce product price if the work pace is slow or if there are many rejects or if there is excessive downtime. The leadership style is matched to the strategic option through rules structured from a framework by Lynch and Rock (1980). In terms of this framework for example, a harvesting strategy can be effectively implemented by "critical administrators". These are highly conservative, risk averse, autocratic and minimally participative individuals. Growth strategies, on the other extreme, can be effectively implemented by "entrepreneurs", who are risk accepting, highly venturesome, innovative, charismatic and minimally controlling.

CHAPTER 11

Evaluation

The evaluation discussed in this chapter embraces two distinct considerations. Of primary concern to the central research theme of this thesis is the evaluation of the utility of the system or the evaluation of the idea that distributed knowledge bases can be applied in the area of strategic management support. This is generally known as the performance evaluation (Gaschnig et al 1983) and is only achieved through the second consideration, the technical evaluation which concerns the evaluation of the prototype system in terms of its adherence to design criteria. These two aspects of the evaluation will be treated separately. Gaschnig et al (1983) raise several issues regarding the evaluation of an expert system. While these issues concern the evaluation of **fully configured** and **single, stand-alone expert** systems, two of them, namely, the need for an objective standard and realistic standards of performance are relevant to the testing and evaluation of the distributed prototype. This is discussed further.

The need for an objective standard and realistic standards of performance. Evaluation of new techniques and methodologies require some type of standard with which results can be compared. This standard can either be a correct solution to a problem in some objective sense or what a human expert presented with the same information available to the program says is the correct answer. Gaschnig et al point out that it is difficult in most domains to decide what level of performance qualifies as being "expert". As the system is implemented as an experimental prototype, the evaluation emphasis at this stage of its development is on the utility of its architecture. The specific strategic performance of the system can only be tested for consistency within the limited knowledge stored in the knowledge bases of the individual modules. The system is evaluated through the use of two distinct sets of case data. Firstly, for the technical evaluation, generated cases are used to show internal consistency of the stored knowledge and to validate the communication and coordination mechanisms of the system. In addition, for the performance evaluation, selected written cases are used to illustrate the strategic performance of the system.

11.1 Technical evaluation

Commonly applied code-based criteria such as statement coverage or branch coverage that are used for evaluating traditional software are not applicable to logic programming languages because of the lack of control-flow and data-flow concepts in these languages. Testing criteria for logic programming languages must therefore be specifically designed to facilitate objective measurement. The most effective procedure for systems with a finite output space with discrete outputs is known as equivalence partitioning (Francia and Sung 1991). Since the prototype satisfies this requirement, this procedure was used in the technical evaluation. In the equivalence partitioning method, test case data is generated and used to exercise all the possible sets of conclusions of the system and to invoke all sequences of reasoning. A generated test case is a set of artificial data, created solely to test particular aspects of the distributed system's functionality (Nielson and Walters 1988). The aspects of functionality of the prototype to be discussed are its **reasoning ability**, the **adequacy of the knowledge representation used** and the **effectiveness of the cooperation between the participating knowledge modules.** The data from forty generated test cases were used to test the mapping from the strategic factors to the strategy option grid and the resulting network activity. The case which generated the most network activity is used in the following discussion. The set of strategic factor values and the resulting response from the system for this case are shown in figures 11.1 and 11.2. Representative examples of cases that map to the other quadrants of the strategic option grid can be found in appendix D.

11.1.1 Reasoning

The prototype exhibits a range of reasoning behaviour. This behaviour varies from the control module's heuristic reasoning for developing generic strategies, its reasoning for evaluating strategy and its taxonomic reasoning for decomposing problems to the domain reasoning of each functional module. In each case, the reasoning is predictably accurate since the size of the system facilitates the use of tracing during construction to ensure this. This accuracy can be maintained in the fully configured system if the extensions to the knowledge bases are made in stages and regression testing is used at every stage. Regression testing involves the use of a standard set of test data to ensure that each successive version of a prototype

VALUE	STRATEGIC FACTOR
L	Price range of Competing Products
L	Technological Change
L	Barriers to Entry
A	Rate of Inflation
A	Demand Variability
L	Competitive Pressure
L	Price Elasticity of Demand
H	Cost of Raw Material
A	Cost of Energy
A	Availability of Raw Material
VL	Level of Government Subsidy
VL	Government Protection from Foreign Competition
A	Political Stability
A	Pressure from Substitute Products
A	Bargaining Power of Buyers
A	Bargaining Power of Suppliers
H	Growth Potential
A	Profit Potential
A	Financial Stability
A	Level of Technological Expertise
A	Resource Utilization
L	Capital Intensity
A	Ease of Entry into Market
H	Productivity
H	Market Share
H	Product Quality
A	Product Life Cycle
H	Product Replacement Cycle
H	Customer Loyalty
H	Capacity Utilization of Competitors
A	Level of Technical Expertise
L	Degree of Vertical Integration
H	Operational Efficiency
A	Management Skills
H	Return on Investment
A	Leverage
H	Liquidity
L	Capital Required/Capital Available
H	Cash Flow
A	Ease of Exit from Market
A	Level of Risk
H	Inventory Turnover
L	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High**

Figure 11.1 Factor Values used in System Test

can at least duplicate the results of the previous one. The area that could experience some degradation in a fully configured system is the decomposition mechanism. The hierarchy of organizational concepts used by the mechanism to

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION AUG 90

CASE *XYZ Computer Co*

SCORES	FS	3.66
	ES	2.38
	CA	3.50
	IS	3.09

VECTOR POSITION 1
VECTOR SLOPE 72

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*average*
ENVIRONMENT TURBULENCE IS	*low*
COMPETITIVE ADVANTAGE IS	*high*
FINANCIAL STRENGTH IS	*high*

INDICATED STRATEGIC POSTURE IS *Growth/Concentration*

FUNCTIONAL RESULTS

MARKETING

Market	*Same*
Development	*Selective*
Pricing	*Undercut*
quality	*improve*

PRODUCTION

Product Cost decrease by buying up
efficiency up
quality control up

FINANCE

Growth by *investment up*
acquisition in same industry

ORGANIZATION

Control	*low*
effectiveness	*high*

Figure 11.2 System Results corresponding to test values

decide responsibilities can become very complex if all the concepts and subconcepts used in strategic management are stored and this can have an impact on the inference speed. Although the speed of inference in a strategic management support system is not as critical as in a weapons control system for example, inference speed can nevertheless be improved through the use of heuristic focus control mechanisms (Pearl et al 1982, Yang et al 1988).

11.1.2 Knowledge representation

The prototype system makes use of two well known and widely used knowledge representation techniques namely production rules and frames. The control module makes use of both rules and frames and the functional modules in their present configuration make use of rules only. These representation techniques proved to be both efficient and adequate in the prototype. The frame structure is an extremely flexible representation technique. It can be used purely for storing a set of aggregate concepts and data as in the storing of the questions in the user interface. It can also be used as a mechanism for storing hierarchical relationships as is evident in its application to the decomposition procedure. Frames can also be used in the functional modules to represent hierarchies. In the financial module for example, frames can be used to represent the hierarchical structure of ratios in the Du Pont return on assets relationship. Slots can be used to hold historical and industry measures for the comparative evaluation of each ratio (Ram 1989). Also, the procedural attachment feature of a frame structure can enable a frame to retrieve a value if it is missing. This is known as knowledge directed information retrieval and can form an intelligent and implicit interface between the knowledge base and the organizational database (Mittal et al 1984). Frames can exhibit some limitations in interpretation especially in the ambiguity between definitional and factual interpretations (Brachman 1983). This ambiguity arises because the interpretation is entirely dependent on the inferencing procedure and it is the inferencing procedure that must decide whether a slot value is a fact or a definition. This problem can be avoided in simple taxonomies. Rules currently provide the easiest form of representing knowledge. They are simple to construct and can be applied to many areas in strategic management since experts tend to express most of their problem-solving expertise in terms of situation-action rules (Hayes-Roth 1985). Rule based reasoning can also be strengthened by the use of uncertainty handling procedures within the rules themselves. The rules used throughout the prototype system do not make provision for the inclusion or the combination of uncertainty but this can be added at any stage of the system's development. Many techniques have been developed and tested to include uncertainty management in Prolog rule and frame based systems. These include the use of standard confidence measures (Marcus 1986) and also fuzzy relationships and ambiguous sets (Suites 1988, Leung et al 1989).

11.1.3 Control and cooperation

The extent and the frequency of the interaction between the control module and the individual modules can be deduced from the partial transcript of the network activity shown in figure 11.3. This transcript provides a trace of the first 5 cycles of the network activity corresponding to the combination of input values shown in figure 11.2. It is evident that even with limited knowledge in the functional modules, there is still a relatively high degree of interaction. The control module

CYCLE	REQUEST B/B	DYNAMIC QUEUE	MODULE CALLED	MODULE ACTIVITY	GENERIC B/B	FUNCTIONAL B/B	REQUESTS		
							FROM	TO	REQST
0	empty	empty	none	control module prompts user to input factor values	growth/ concentration	empty	CM CM CM CM	MK FN PR OR	Consid Gen. Option
1	CM, MARK CM, FIN CM, PROD CM, ORG	[M, F, P, O]	MARK	Marketing executes to translate generic strategy option			MK	CM	Price Reduce
2	MARK, CM CM, MARK CM, FIN CM, PROD CM, ORG	[M, F, P, O]	NONE	Control module decomposes price into prodcost and overheadcost			CM CM	PR FN	Pcost Ohead
3	CM, PROD CM, FIN CM, MARK CM, FIN CM, PROD CM, ORG	[P, F, M, F, P, O]	PROD	Prod investigates reduction in price		Qcontrol Up Buying Down Efficiency Up			
4	CM, FIN CM, MARK CM, FIN CM, PROD CM, ORG	[F, M, F, P, O]	FIN	fin investigates reduction in price					
5	CM, MARK CM, FIN CM, PROD CM, ORG	[M, F, P, O]	MARK	Mark accepts price input and continues execution		Share UP by Price Down	MK	CM	quality increas

Figure 11.3 Transcript of Network Activity

calls the appropriate functional modules who in turn are able to access the blackboard and exercise their knowledge. This interchange demonstrates the extremely important point that the network is capable of cooperative behaviour and that it will do so at whatever degree of sophistication the modules are configured. This is because the execution of reasoning procedures within each module is independent of the control and communication system of the network. If the control module calls an appropriate functional module at an appropriate time in the problem solving cycle, whether the functional module executes a single rule or a sophisticated chain of reasoning is irrelevant. The cooperation depends on the soundness of the control module's decomposition procedure and the ability of each individual module to communicate with the control module through the blackboard. It may seem that the efficiency of the network could be improved by enabling each functional module to communicate with each other rather than through the control module. This would require each functional module to store meta-level knowledge or knowledge of the capabilities of all the other modules. Besides the duplication of knowledge in the network that this would effect, the control module would lose the control of the network. There would also not be a trace record of the problem solving activity unless all modules were to use the same blackboard which counteracts the distribution of network knowledge.

11.2 Performance evaluation

While the evaluation of the prototype system's performance requires technical criteria, the primary consideration in the performance evaluation of the system is whether or not the problem solving task is enhanced by the system in a significant way. As the individual knowledge-bases in the prototype do not contain sufficient deep knowledge, selected documented cases are used in the performance evaluation. It is understood that the use of documented cases presents certain problems as noted by Miller and Friesen (1978). Two of these problems relate specifically to the evaluation of the prototype. The first is that different cases supply different types of information and information on certain variables are supplied for some cases and not for others. The second problem concerns the levels of abstraction involved in the use of case data. Case writers interpret real situations and researchers interpret case data which can generate distortions in the data and anomalies in evaluation. To minimize the possibility of distortion in interpretation, the cases used in the performance evaluation were chosen on the basis of the amount of data available that could be used by the system directly. Also, factors that are required by the system which are not disclosed in a particular case are set to neutral. In other words, the absence of a factor does not affect the reasoning process. As an example, if a case does not disclose the factor "Bargaining power of suppliers", the system would not use the factor in its reasoning process rather than treat the factor as zero. Another factor that was taken into account in selecting the test cases was the amount of additional information on the industry that was given and whether or not actual events following the case situations could be found in the literature. This is important and is required in order to compare the system strategy proposal to the actual strategy pursued by the companies described in the cases. Significant differences arising out of such a comparison can be used as a basis for knowledge refinement in subsequent versions of the prototype. Four cases that satisfied the above requirement were eventually selected and used in the testing. The actual case material can be found in appendix E. Only the interpreted factor values required by the system and the system response are used in the following discussion.

CASE VALUE	APPLE COMPUTERS STRATEGIC FACTOR
H	Price range of Competing Products
VH	Technological Change
L	Barriers to Entry
N	Rate of Inflation
L	Demand Variability
VH	Competitive Pressure
H	Price Elasticity of Demand
L	Cost of Raw Material
L	Cost of Energy
H	Availability of Raw Material
N	Level of Government Subsidy
L	Government Protection from Foreign Competition
VH	Political Stability
A	Pressure from Substitute Products
N	Bargaining Power of Buyers
N	Bargaining Power of Suppliers
VH	Growth Potential
VH	Profit Potential
H	Financial Stability
VH	Level of Technological Expertise
H	Resource Utilization
H	Capital Intensity
H	Ease of Entry into Market
VH	Productivity
VH	Market Share
A	Product Quality
VH	Product Life Cycle
L	Product Replacement Cycle
H	Customer Loyalty
H	Capacity Utilization of Competitors
VH	Level of Technical Expertise
L	Degree of Vertical Integration
H	Operational Efficiency
A	Management Skills
H	Return on Investment
H	Leverage
VH	Liquidity
H	Capital Required/Capital Available
H	Cash Flow
A	Ease of Exit from Market
H	Level of Risk
H	Inventory Turnover
N	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High, N-Neutral**

Figure 11.4 Factor Values for Apple Computers

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION

CASE *APPLE COMPUTER COMPANY*

SCORES	FS	3.66
	ES	2.90
	CA	4.00
	IS	2.09

VECTOR POSITION 1
VECTOR SLOPE 23

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*average*
ENVIRONMENT TURBULENCE IS	*high*
COMPETITIVE ADVANTAGE IS	*very high*
FINANCIAL STRENGTH IS	*high*

INDICATED STRATEGIC POSTURE IS *Concentration/Vertical Integration*

FUNCTIONAL RESULTS

MARKETING

Market	*Same*
Development	*Selective*
Quality	*Improve*

PRODUCTION

Product Cost decrease by buying up
efficiency up

FINANCE

Growth by *investment up*

ORGANIZATION

Control *high*

Figure 11.4 System Results for Apple Computers

CASE VALUE	HERSHEY FOODS STRATEGIC FACTOR
A	Price range of Competing Products
L	Technological Change
H	Barriers to Entry
N	Rate of Inflation
L	Demand Variability
H	Competitive Pressure
H	Price Elasticity of Demand
H	Cost of Raw Material
L	Cost of Energy
H	Availability of Raw Material
N	Level of Government Subsidy
N	Government Protection from Foreign Competition
VH	Political Stability
H	Pressure from Substitute Products
L	Bargaining Power of Buyers
H	Bargaining Power of Suppliers
L	Growth Potential
H	Profit Potential
H	Financial Stability
A	Level of Technological Expertise
H	Resource Utilization
H	Capital Intensity
L	Ease of Entry into Market
H	Productivity
A	Market Share
H	Product Quality
A	Product Life Cycle
H	Product Replacement Cycle
H	Customer Loyalty
H	Capacity Utilization of Competitors
H	Level of Technical Expertise
L	Degree of Vertical Integration
H	Operational Efficiency
H	Management Skills
A	Return on Investment
VH	Leverage
VH	Liquidity
H	Capital Required/Capital Available
VH	Cash Flow
L	Ease of Exit from Market
A	Level of Risk
H	Inventory Turnover
L	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High, N-Neutral**

Figure 11.6 Factor Values for Hershey Foods

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION

CASE *HERSHEY FOODS*

SCORES	FS	3.88
	ES	2.92
	CA	3.50
	IS	3.00

VECTOR POSITION 1
VECTOR SLOPE 62

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*high*
ENVIRONMENT TURBULENCE IS	*average*
COMPETITIVE ADVANTAGE IS	*high*
FINANCIAL STRENGTH IS	very *high*

INDICATED STRATEGIC POSTURE IS *Concentration/Concentric Diversification*

FUNCTIONAL RESULTS

MARKETING

Market	*Same/New*
Development	*Selective/Primary*
Pricing	*Undercut*

PRODUCTION

Product Cost decrease by buying up
efficiency up

FINANCE

Growth by *investment up*
acquisition in same industry

ORGANIZATION

Figure 11.7 System Results for Hershey Foods

CASE VALUE	DELOREAN MOTOR COMPANY STRATEGIC FACTOR
A	Price range of Competing Products
N	Technological Change
H	Barriers to Entry
N	Rate of Inflation
L	Demand Variability
VH	Competitive Pressure
H	Price Elasticity of Demand
H	Cost of Raw Material
L	Cost of Energy
H	Availability of Raw Material
N	Level of Government Subsidy
L	Government Protection from Foreign Competition
VH	Political Stability
H	Pressure from Substitute Products
L	Bargaining Power of Buyers
H	Bargaining Power of Suppliers
L	Growth Potential
L	Profit Potential
L	Financial Stability
H	Level of Technological Expertise
H	Resource Utilization
H	Capital Intensity
VL	Ease of Entry into Market
A	Productivity
L	Market Share
L	Product Quality
N	Product Life Cycle
A	Product Replacement Cycle
L	Customer Loyalty
L	Capacity Utilization of Competitors
H	Level of Technical Expertise
L	Degree of Vertical Integration
L	Operational Efficiency
L	Management Skills
N	Return on Investment
VL	Leverage
L	Liquidity
L	Capital Required/Capital Available
L	Cash Flow
L	Ease of Exit from Market
H	Level of Risk
N	Inventory Turnover
N	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High, N-Neutral**

Figure 11.8 Factor Values for Delorean Motors

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION

CASE *DELOREAN MOTOR COMPANY*

SCORES	FS	2.44
	ES	3.00
	CA	2.50
	IS	3.45

VECTOR POSITION 3
VECTOR SLOPE 210

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*high*
ENVIRONMENT TURBULENCE IS	high
COMPETITIVE ADVANTAGE IS	*low*
FINANCIAL STRENGTH IS	*low*

INDICATED STRATEGIC POSTURE IS *Divestment/Liquidation*

FUNCTIONAL RESULTS

MARKETING

Market	*Harvest/Retain*
Development	*None*

PRODUCTION

Product Line	*Discontinue*
Capacity	*Cut*

FINANCE

Growth by	*Defer investment*
	liquidate

ORGANIZATION

Personnel	*Defer promotion*
	Retire/Retrench

Figure 11.9 System Results for Delorean Motors

CASE VALUE	DELTA AIRLINES STRATEGIC FACTOR
L	Price range of Competing Products
A	Technological Change
VH	Barriers to Entry
N	Rate of Inflation
H	Demand Variability
H	Competitive Pressure
H	Price Elasticity of Demand
VH	Cost of Raw Material
N	Cost of Energy
H	Availability of Raw Material
L	Level of Government Subsidy
N	Government Protection from Foreign Competition
VH	Political Stability
VH	Pressure from Substitute Products
H	Bargaining Power of Buyers
N	Bargaining Power of Suppliers
H	Growth Potential
L	Profit Potential
L	Financial Stability
A	Level of Technological Expertise
L	Resource Utilization
VH	Capital Intensity
VL	Ease of Entry into Market
H	Productivity
L	Market Share
A	Product Quality
N	Product Life Cycle
H	Product Replacement Cycle
A	Customer Loyalty
A	Capacity Utilization of Competitors
A	Level of Technical Expertise
L	Degree of Vertical Integration
H	Operational Efficiency
H	Management Skills
L	Return on Investment
H	Leverage
H	Liquidity
H	Capital Required/Capital Available
H	Cash Flow
L	Ease of Exit from Market
H	Level of Risk
N	Inventory Turnover
N	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High, N-Neutral**

Figure 11.10 Factor Values for Delta Airlines

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION

CASE *DELTA AIRLINES*

SCORES	FS	3.22
	ES	3.00
	CA	3.10
	IS	3.63

VECTOR POSITION 2
VECTOR SLOPE 157

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*very high*
ENVIRONMENT TURBULENCE IS	*high*
COMPETITIVE ADVANTAGE IS	*high*
FINANCIAL STRENGTH IS	*high*

INDICATED STRATEGIC POSTURE IS *Status Quo/Focus*

FUNCTIONAL RESULTS

MARKETING

Market	*Same*
Development	*Selective*

PRODUCTION

FINANCE

Growth by	*investment up*

ORGANIZATION

Figure 11.11 System Results for Delta Airlines

11.2.1 Discussion

The following table summarizes the results generated by the system for all four cases.

Case	Strategy suggested by system	Actual event
Apple Computers	Concentration/Vertical Integration	Concentration/Growth/ Focus
Delorean Motor	Divestment/Liquidation	Liquidation
Hershey Foods	Concentration/Concentric Diversification	Concentric Diversification
Delta Airlines	Status Quo/Focus	Focus/Growth

The system produces reasonably accurate generic options, as can be seen from the table. This is not in itself remarkable since most undergraduate students of strategy would suggest the same or similar options for the selected cases. It is important however, that the generic option generated by the control module is correct as the translation of this to functional plans is dependent on it. From the responses, it is evident that the prototype is not able to provide functional plans which are concise. In some instances, a specific functional area is excluded altogether. This is because the specific knowledge that maps the suggested strategic option to the operating plan in that functional area is nonexistent or deficient and can be remedied through refinement of the knowledge bases in subsequent iterations of the prototyping process. The functional plans that are generated, although vague, are accurate in terms of the overall strategy to be followed. This is important as it illustrates the fact that the options generated by the cooperating knowledge bases are consistent and that additional domain knowledge can enhance the output of each functional module. The use of documented case studies identified two problems inherent in the design of the system that are not evident when generated test cases are used. The first problem arises out of the use of a discrete set of input factors. In documented cases, as would be the case in reality, a lot of information is given that is not used by the system through the factors. Some of this information may have an impact on the chosen strategy. As an example, consider the factor "availability of raw material" in the Hershey Foods case. The factor can be set to "high" since Hershey holds at least 40 million kilograms of cocoa beans and 1500000 litres of milk in storage. The factor can also be set to "low" since cocoa beans are only grown in West Africa and South America and crops are subject to drought, brush fires and high winds. Also if soil, moisture and temperature conditions are not exactly right, considerable variations occur in the flavour. If the factor is set to low, the system assumes that it is difficult for all firms in the industry to obtain raw material and this reduces the industry strength. If the factor is set to high, the system assumes the opposite and increases the industry strength. In this case, the competitive advantage that Hershey has built up over the years in providing a buffer stock of raw material and also by being actively involved in crop forecasting operations, is not reflected in the system's reasoning. This type of problem can be fixed through the use of additional factors, in this case, "availability of raw material to competitors". The second problem experienced with the system is the level at which it is used. The system is designed as a business level support system although a set of such systems could communicate to form a corporate level system. At the business level, the system is unable to distinguish between the performances of different products in the same market. As an example, for Hershey Foods, "Kit Kat" is of a better quality and is more popular than "Hershey Almond". When the system suggests selective market development, it cannot be product specific. This is also evident in the Apple case. The quality of the Apple III was obviously poor, and caused much customer dissatisfaction. On the other hand, the Macintosh was an excellent machine. Since the system uses the factor "product quality" as one of the indicators of competitive advantage, it is inaccurate to "average" the quality over many products. The system, should suggest that the Apple III and the Apple Lisa be discontinued but it cannot distinguish between the different products. The system also cannot distinguish between different markets. Since most markets are segmented, the value of the "market share" factor can be inaccurate. Apple, for example, sell to home users, business users, educational and technical users and the market share for each segment is different. Since the value used by the system is the total market share in terms of number of machines, the different emphasis in marketing plans is not considered. Similarly, Delta airlines have a tremendous opportunity in developing the "frequent flier" segment of their market. Although the system suggests selective market development, which it infers from a rule linking the generic strategy of focus with the factors market share, market growth potential and competitive pressure, it cannot be more concise in terms of the particular market segment that can be developed. This is essentially a deficiency in the marketing module and not the whole system. The problem can be solved through the use of the concepts inherent in methods such as the BCG portfolio matrix (Hax and Majluf 1983a) or the General Electric Business Screen (Hax and Majluf 1983b). A set of factors relating to the product market relationships in a given business can be used by the marketing knowledge base to establish different market strategies for each product. This can then be communicated to the financial module to allocate separate budgets for each plan. The following section highlights the major problems of the system and serves as a technical and performance evaluation summary. Suggested extensions which can solve some of the problems identified are also included.

11.3 Limitations and extensions

The limitations inherent in the distributed system are largely implementational. Some of the limitations can be resolved by extensions and subsequent refinements of the prototype while others would require further research. The important limitations are summarized below together with the suggested extensions that can resolve them. The extensions that require further research are summarized again in the next chapter.

11.3.1 Knowledge limitations

The knowledge bases in each of the functional domains of marketing, finance, production and organization contain knowledge sufficient to allow the modules to participate in the problem solving activity of the distributed network. This impoverished knowledge causes the system to behave as a mediocre student of strategic management rather than as a strategy expert. This in itself is not a serious limitation since the extensions to the knowledge bases can be achieved by increasing the number of rules or frames and adding more discriminating reasoning procedures. The principal limitation in this area is the acquisition of specific "how-to-do" knowledge. There is a lack of literature specifically in the area of translation of strategic options to functional action plans. In specific industries, this expertise can be supplied by human experts but a general framework which would be invaluable in such a system, has yet to be researched and formulated. Another area that can be explored is an interface to a database such as the PIMS (Schoeffler and Badler 1981) which could provide empirical validation for strategic and action plan linkages. The control module also relies heavily on human expertise for the tractability of its propositions. The essence of its heuristic strategy generating mechanism is in the weighting of strategic factors and extensive industry research is needed in order to overcome the problems currently experienced (Hussey 1978, Robinson et at 1978). Another limitation of the prototype system is that it does not make explicit provision for uncertain information. The matching process used in the heuristic strategy option generator accommodates uncertainty implicitly but the individual functional modules do not share this facility. This does not impact the constrained area of operation of the prototype but it is nevertheless an important requirement in a working system. The methods of introducing uncertainty into the reasoning process using Bayesian uncertainty, confidence measures and fuzzy and ambiguous sets have been mentioned earlier but there is still scope for integrating these methods into the managerial domain. Finally, as there are no explanation clauses contained in the knowledge bases of the prototype, the system is not capable of justifying or explaining its reasoning. This is an important feature since managers may wish to challenge the systems reasoning and use it as a sensitivity analysis tool. The explanation facility can be added to the system at the final knowledge refinement stage of the prototype and may be accomplished in an elementary way by adding explanation slots to existing frames as procedural attachments which can then retrieve the appropriate explanation, or a sophisticated explanation facility can also be implemented by extending the work done thus far in explanation systems (Chandrasekaran et al 1989, Slagle and Wick 1989).

11.3.2 Reasoning limitations

The type of knowledge-based reasoning used throughout the prototype system is known as single context reasoning and functions on the basis of complete information availability. The decisions or strategic options are arrived at only if the appropriate information is available. If a piece of information is missing, the system will arrive at a solution which does not take the missing piece of information into account. The validity of this solution then depends on the relative importance of the missing information. Also, the Prolog inferencing mechanism is a monotonic reasoning mechanism which means that if the missing information is received and it consequently invalidated the conclusion or goal, previous conclusions or sub-goals on which the final conclusion was based could still be regarded by the system as valid. Although this can be circumvented by controlled reasoning which implies that the Prolog inferencing mechanism must be modified to allow a composite depth-breadth first search procedure, a more effective solution would be to extend the reasoning to a multiple world context. In such a system, different contexts are stored for each outcome in the absence of vital information and the most correct context is used when the information becomes available. This reasoning allows the process to continue normally in the absence of information and is more representative of human reasoning. Closely allied to the multiple context based reasoning and which can be immensely useful are truth maintenance systems (Doyle 1979, Filman 1988). Since the Prolog language is based on the predicate calculus, another area that could be explored is the extensions to the predicate calculus through circumscription, a formal method for non-monotonic reasoning (McCarthy 1980). The prototype system does not have a conflict resolution procedure that will enable it to resolve the conflicts that can arise when individual modules propose different allocation plans for the same resource or when two modules propose opposite actions. The control module regards this as inconsistent during its evaluation and restarts the formulation process. While this is adequate as long as there is some user intervention to prevent repetition, a more powerful procedure would enhance the system's effectiveness. The work done by Fraser et al (1989), in which a conflict resolver modelled on the delphi method is developed, could form the basis for research in this area.

11.3.3 Design limitations

The prototype system has been designed for implementation on a microcomputer system and some functions such as the blackboard mechanism and the module calling mechanism were not explicitly designed but adapted in order to take advantages of the special capabilities of the development software used. Specifically, the Prolog internal database was used as the blackboard mechanism and the Prolog external system call was used to execute functional modules. Although this proved to be adequate at the prototype level, it may become inefficient in larger systems for the following reasons:

The Prolog internal database can be stored and retrieved as a virtual disk file and this formed the communication mechanism in the prototype. With more knowledge and intense interaction between the individual modules, the blackboard will be accessed more often and the overall increase in access time will degrade the network. This can be resolved by using an area of main memory as the blackboard and developing low level machine routines that will enable each module to access this area.

In the prototype system, the control module is always resident and each individual functional module is called in its compiled form through the Prolog system call. This means that when a functional module halts its problem solving activity to initiate a request, it must terminate in order to allow the control module to call another module to respond. When the responding module terminates, the first module is called again and begins execution from the beginning. The difference being that in the second execution cycle, the module does not halt because of some new piece of evidence stored on the blackboard as a result of its previous request. This redundant processing will become a serious limitation in a large system and can be resolved in two ways. Firstly, the working memory of an executing module, that is, all its instantiated facts as well as a pointer to its inference point, can be dumped to a virtual disk or stored in a private and protected area of main memory upon its termination. Subsequent calls would then enable processing to continue from the previously stored state rather than from the beginning. This facility is quite easily implemented and in many shell systems is referred to as a "mid-run dump". Another approach to resolving this problem is to implement all the modules in a concurrent system on a parallel machine such as the transputer or on a series of independent machines. This could become an extremely interesting and invaluable area for future research.

11.3.4 Application limitations

The distributed system is designed and developed as a support system for strategic management at the business level. In other words, the system is intended to support the strategic management of a business operating in a single industry. The extension of the system to enable it to support strategic management at the corporate level presents an interesting area for future research since it can be accomplished by using a distributed network of distributed systems. Each business in the corporate portfolio can then be supported and represented by a distributed system. A set of distributed systems can then communicate and cooperate under the supervision of a corporate control module in order to manage the corporate strategy function. Such a system can also be useful as a model for studying the communication, power distribution and coalition phenomena in large organizations.

11.4 Potential benefits of the prototype

Since the motivation for building the system emanated from the desire to enhance the effectiveness of strategic management by resolving certain difficulties currently experienced in its practise, it is appropriate to conclude the evaluation of the prototype on its **potential ability** to resolve those difficulties. Although the word potential is used to indicate that some of the benefits claimed can only be derived from a fully configured system, other benefits can be derived from the prototype directly, or from the very nature of artificially intelligent systems. Consider as examples, freedom from managerial bias, broader focus and prevention of misapplication of concepts. Even the most elementary rule-based system can exhibit these qualities if the knowledge acquired and represented is free from bias and misinterpretation.

11.4.1 Prevention of bias in strategy formulation

The input to the strategy formulation process always involves uncertainty and ambiguity and is often interpreted in a way that reflects a manager's personal conceptual framework or experience. Decision makers have been known to alter their perceptions of the environment to make it appear more certain (Michael 1973). The computer based system is not subject to any experiential bias, nor is it affected by environmental uncertainty in a psychological way. This ensures that both the strategy formulation and equally importantly, the strategy evaluation is performed in an objective way. Also, the inference control mechanism of the system does not favour a particular functional area and all the functional options receive equal consideration.

11.4.2 Prevention of narrow focus

James (1984) has pointed out that a focus on specific issues such as cost deflects the planning function from a central strategic theme. A combination of structured knowledge and inferencing in the system precludes the possibility of a narrow focus on one specific issue. The cooperation of the individual modules allows the systematic exploration of the multiplicity of problems that confront the organization.

11.4.3 Prevention of misapplication of concepts

James (1984) and Mintzberg (1973) have both argued that managers become entranced by the clinical precision of certain concepts and apply them rigidly to all situations. The computer system is not preoccupied with a specific concept and will apply conceptual knowledge according to the context of the problem. In other words, situational factors determine the use of a concept rather than one concept being applied to all situations. The appropriateness of specific concepts such as the experience curve and the product life cycle are embedded in knowledge structures such as rules and are exercised only when the situation under consideration exhibits the acceptable characteristics.

11.4.4 Improved organizational fit

Three decades after Chandler (1962) established the strategy-structure relationship, practising strategists still ignore it. In the distributed system, the presence of a dedicated organizational module network indicates that organizational factors are regarded as importantly as the other functional area factors of the organization. The organizational module is concerned with aligning the organizational structure with the chosen strategy so that the implementation of it can be effective. Organizational models contained in the organization module can identify potential problems areas and resistance to change that a proposed strategy would bring about and these could be resolved before implementation.

11.4.5 Improved balance between creativity and control

Lorange (1980) distinguishes between adaptive and integrative organizations. Adaptive organizations nurture creativity and generate many options before making a decision. Integrative organizations focus on control and conventional wisdom and seldom encourage innovation. The distributed system contains knowledge bases which represent knowledge of strategic management that reflects the pragmatic judgement of what is known and what is possible. In this way, the system can be viewed as an integrative system incapable of supporting creativity. If however, creativity is seen as a form of rationality in which all options, irrespective of their number are considered (Rich 1986), then the system encourages creativity. This is due to the backtracking mechanism which is embedded in the system's inferencing procedure and which automatically generates every conceivable alternative, some of which may challenge previous assumptions. In this way, the system forces the user to examine a multitude of options which would normally be discarded at the early stages of strategy formulation.

11.4.6 Improved organizational response rate

The computer-based system is not subject to the inertia inherent in physical organizational systems and is therefore capable of generating many strategic alternatives in much less time than a human planning system. This allows time for many options to be fully examined and evaluated before implementation. The system is also computationally efficient and the communication between the various modules as well as access to the organizational database prevents the delays in information transfer inherent in conventional systems. In the fully configured system, the environmental scanning module will pass on strategic information to the control module on a real-time basis which will allow changes to strategic plans to be considered immediately. This will enable the organization to take advantage of opportunities sooner and thus enhance its competitive position.

11.4.7 Improved implementation

The system considers all the factors that are crucial to successful implementation. The most important of these is the balance in resource allocation. Resources are often committed to one area of the organization while others are neglected. This is either as a result of managerial bias or because the complexity of the situation does not allow the impact of the various combinations of resource allocation to be considered. In its fully configured state, the system will be capable of optimizing the best combination of resource allocation in order to achieve the chosen strategy while at the same time considering the ongoing needs of the organization. Also, the system is capable of monitoring plans in order to ensure that they are not neglected since in many cases, management is preoccupied with the smooth and efficient execution of current operations to the extent that the implementation of a new strategy is regarded as interference. By providing feedback on a continuous basis to the management at the operational level on current as well as strategic progress, the system can encourage a balanced focus and so help to resolve the coupling-decoupling problem. The system is also able to monitor strategic progress on an organizational level. It achieves this by scanning the organizational database or by requesting specific information and it can then draw attention to variances both favourable and unfavourable. In this way, it acts as an organization wide steering control mechanism and shifts the control emphasis from post-action control to steering control.

CHAPTER 12

Conclusion

This chapter forms a summary of the contents of the whole thesis and includes a discussion of the contributions made by the research in the fields of Strategic Management and Artificial Intelligence. The areas for future research arising out of this research as well as a brief conclusion is presented at the end.

12.1 Summary

Strategic management is both a complex and an important management function in any organization. It is complex because of the multiplicity and uncertainty of its inputs and it is important because it provides a basic understanding of how the organization will compete in its environment. There is also strong empirical evidence to suggest that the practice of strategic management can improve the long-term performance of an organization. The effectiveness of strategic management has however been severely criticised in recent years because of difficulties experienced in its practice. These difficulties arise out of the overwhelming number of options and variables that must be considered. These difficulties become more acute as environments grow more turbulent. Managers have turned to computer-based systems for support and although a considerable amount of research has been pursued, the systems arising out of this activity has been confined to a limited area of the problem. A system to support the total strategic management process has not yet been developed mainly due to the size and complexity of the application area. The research presented in this thesis is an attempt to provide such support through the use of a distributed knowledge-based system. The distributed approach allows the problem area to be compartmentalized into natural partitions and thus reduces the problem of size. The nature of knowledge-based systems, especially the use of heuristic methods and symbolic reasoning, enables it to be applied more effectively to the complexity than conventional procedural systems. The distributed approach also allows access to powerful methods such as the blackboard control system and the centralized multi-agent system which were both developed for use in the area of distributed artificial intelligence. The thesis is essentially organized in two parts. The first part of the thesis is devoted to a detailed examination of the application area, its problems and the status of current research. The remainder of the thesis concerns the design, development and evaluation of the prototype system.

12.2 Research contributions

12.2.1 Contributions to distributed artificial intelligence

In contrast to the tremendous amount of research activity in the application of artificial intelligence to business described in the literature (Feigenbaum and Nii 1989, Beheshtian-Ardekani and Salchenberger 1988, Waterman 1986, Rauch-Hindin 1985, Reitman 1985, Blanning 1985, Andreole 1985) there has been a limited amount of research in the application of distributed artificial intelligence to business problems (Bond and Gasser 1988). Some of this research has been focused on plan construction and optimization but even these have had limited success (Fikes and Hayes-Roth 1989). The development and application of the distributed support system described in this thesis makes a significant contribution to the research in this area through the following:

Unique and innovative application of available techniques

Through the application of distributed artificial intelligence to the area of strategic management, this research has demonstrated that many seemingly esoteric techniques can be applied successfully in important areas where the benefits are tangible. The area of strategic management has a high potential payoff and the application system helps to resolve many of the difficulties currently being experienced. The research also demonstrates that powerful techniques such as the blackboard control system and dynamic scheduling can be implemented on a small scale, making it accessible to many researchers and practitioners with limited resources.

Development of useful techniques

The research has produced two very powerful and useful procedures that have a wide range of applicability. The first technique is the problem decomposition mechanism. The problem of problem or task decomposition is inherent in all distributed systems and very few experimentally validated techniques exist (Bond and Gasser 1988). The decomposition mechanism based on taxonomic reasoning that is used in the prototype can be adapted to other systems. The technique can also be used as a basis for investigating the question of automated decomposition, currently an unresolved problem in distributed artificial intelligence. The second technique which has other potential applications is the heuristic matching algorithm. The technique is based on powerful formal decision making theories and can be applied to other decision making situations displaying a hierarchical structure such as hypothesis testing or diagnostic problem solving. The heuristic matcher is a simple method for encoding the qualitative decision making judgements of decision makers that facilitates knowledge acquisition, explanation and the representation of uncertainty.

Development of a distributed shell

The prototype system can be used as a distributed shell if the strategic management domain knowledge is removed. In this form, it forms a skeleton network with only the task decomposition and the communication and control facilities present. Domain specific knowledge and domain dependent meta-level knowledge can then be inserted into the empty knowledge bases to enable it to be used in any situation displaying a distributed structure or involving cooperative problem solving. A medical diagnosis performed by many specialists or a product designed by many engineers are examples of the range of its application.

Extension of distributed artificial intelligence research

Virtually all researchers in the area of distributed artificial intelligence have assumed that the knowledge sources in their domains are benevolent or have common or non-conflicting goals (Genesereth et al 1988, Genesereth and Rosenchein 1985). Research work has thus concentrated on how knowledge sources can avoid interference (Georgeff 1984). The distributed support system developed in this research makes explicit accommodation for conflict which arises in the real world situation that it models. Organizations display many cross-functional conflicts and this is especially evident in strategy formulation (Rue and Holland 1986). The prototype system therefore provides an appropriate basis for extending distributed artificial intelligence research into the area of non-benevolent cooperation. Another research extension that the work in this thesis can initiate is the issue of organizational self-design and automated learning, currently regarded as an open problem (Bond and Gasser 1988). The prototype system with its control and functional modules and the channels of communication between them forms an organizational model. This model can serve as a framework on which established organizational learning theories can be tested. The work of Cyert and March (1963) and Shrivastava (1983) have shown that organizational learning and organizational adaptation is influenced by the sharing of knowledge, beliefs and assumptions among individuals. Since these issues are considered independently and in a benevolent context in current distributed artificial intelligence research, the organizational theories can provide a means of integrating them through the model.

12.2.2 Contributions to strategic management

The research supporting the design and the development of the prototype distributed support system was motivated by both the need to resolve certain difficulties in the practice of strategic management and the desire to provide support for the complex decision making activity that it represents. Both these have been satisfied by the performance of the prototype system and the research therefore makes a significant contribution to the effectiveness of strategic management in this regard. This and other contributions that are made as a result of the research are discussed below.

Total computer-based support for strategic management

The distributed support system is an innovative approach to the provision of computer support in the total area of strategic management. Decision support systems and knowledge base support systems have in the past focussed on isolated areas of strategic management. Decision support systems have been used to support the quantitative aspects of decision making situations and managers were required to provide the linkages between the qualitative criteria and the quantitative analysis. Knowledge-based systems have been applied to narrow sub-domains of the general management area such as marketing, finance and production. The distributed support system in its fully configured state will be capable of supporting the strategic management process from organizational analysis to implementation and control. The system is also a means of representing and preserving an organization's planning expertise.

Resolution of practical difficulties

The application of the distributed support system could help to resolve many of the difficulties currently experienced in the practice of strategic management and in this way it makes a major contribution to both the effectiveness and the image of strategic management. This contribution is made through an improvement in organizational response rate, the reduction of managerial bias in plan formulation and resource allocation, an improved balance between creativity and control, appropriate use of strategy concepts, a more lateral focus in strategic choice, improved organizational fit and improved implementation.

The advancement of strategic management practice

The system has been designed to be implemented on a microcomputer. In this format it can act as a portable strategic planning assistant to advance and promote the practice of strategic management in small and medium sized businesses. Not all companies have a planning department and some smaller companies even lack planning expertise altogether. The distributed support system can be used in a diagnostic mode as a strategic management consultant to develop and evaluate strategies. Small business plays an important role in the economies of many nations and it has been found that small businesses that engage in strategic management achieve superior performance (Ackelsberg and Arlow 1985). The distributed support system can also be used to encourage planning in medium sized organizations, especially in countries like South Africa where many companies only practise basic financial planning and budgeting

(Archer and McIntosh 1986).

Advancement of strategic management education

The thesis provides a systematic analysis of a wide range of perspectives of the concept of strategic management and also of a wide range of criticisms. This can be useful to reinforce the understanding of the complex nature of strategic management in a teaching context. Also, the inherent capability of the system to explain its own reasoning through the explanation clauses embedded in its knowledge structures, allows it to be used as a strategic management teaching tool. This can enforce a systematic and structured approach to case analyses and also encourage an open minded and unbiased perspective in future strategists. The system can also be used by senior and middle managers to study the market and operational changes in order to become more intimately involved with the operational problems of line managers.

Organizational modelling

The distributed system forms an organizational model which displays functional units, channels of communication, control systems and environmental interaction. The blackboard can be extended to record the extent, frequency and direction of the communication activity and these values could be used to compute various ratios such as the ratio of communication activity to processing activity for example. Since these values can be influenced through modifications in the control and structure of the network, important relationships such as the tradeoff between production costs and coordination costs (March and Simon 1958, Malone 1988) and the tradeoff between network performance and member satisfaction (Turoff and Hiltz 1982, DeSanctis and Gallupe 1987) can be studied.

12.3 Future research

Many useful and interesting areas for future research were uncovered in the evaluation of the prototype system. These areas are summarized below.

12.3.1 Empirical studies

The weights used by the heuristic strategy option generator are indicators of the relative importance of strategic factors in a given industry. If these weights can be determined by empirical investigation, the system's recommendations could be used reliably by all companies in that industry. This study would be similar to the PIMS study in the United States. Additional studies can also be undertaken to investigate the correlation of these weights across industries. In other words, studies are required to answer the following two questions:

> In a given industry, can the recommendations of the system be accepted as being empirically valid? ; and, are the recommendations given for a company in one industry equally valid for a company with similar attributes in another industry?

12.3.2 Knowledge representation and reasoning

The scope and power of the system's reasoning can be enhanced by extending it to a multiple context system. This will enable the system to accommodate the absence of information in a more realistic manner. The use of multiple worlds will also allow the effects of environmental forces such as competition to be more accurately represented. The use of truth maintenance or non-monotonic reasoning can be investigated by extending the Prolog inference mechanism through formal methods such as circumscription. The implementation of the qualitative method in the hierarchical matching framework also presents a challenging research area. The investigation of techniques to reduce the number of combinations or innovative methods for approximating qualitative reasoning can make a contribution to many areas in artificial intelligence research.

12.3.3 Conflict resolution

Conflict resolution is an important requirement in any cooperative environment. Some methods have been developed to resolve conflict in human cooperative systems and there is considerable scope in adapting these to distributed knowledge-based systems. The research in distributed artificial intelligence is currently focussed on benevolent cooperation. The incorporation of conflict resolution mechanisms in problem solving networks will extend this research to non-benevolent cooperation. The Delphi system is an example of a method which can be used but there is still considerable research scope in the area of consistency maintenance and goal modification. Conflict resolution mechanisms can also be applied to the general area of Group Decision Support Systems.

12.3.4 Distributed distributed systems

Distributed systems such as the strategy support system can themselves be part of a larger distributed system. For example, a network of business level strategy support systems can be placed in a distributed network to form a corporate level strategy support system. The communication, scheduling and control requirements become extremely complex since there are hierarchies of control and conflict levels. The development of such a system presents an interesting research challenge.

12.3.4 Parallel systems

Very large distributed management support systems provide an excellent application area for the discipline of parallel distributed problem solving. The implementation of the prototype support system as a concurrent system provides a workable introduction to research in this area and can be used as a basis for the construction of a parallel distributed knowledge-based system shell.

12.4 Conclusions

This thesis has presented an innovative approach to computer-based support for the complex area of strategic management. The analysis of the application area has generated many useful insights into the concepts of strategic management and has also emphasized its importance. The research has shown that a distributed knowledge-based system is well suited to support the nature and the complexity of the strategic management area and that at the same time it is capable of resolving some of the difficulties currently experienced. The prototype system that was developed has produced very favourable results and it is hoped that its success on this small scale will motivate future research.

REFERENCES

Abernathy, W. and Wayne, K., (1974), Limits of the learning curve, Harvard Business Review, 60 (3), 71-79.

Ackelsberg, R. and Arlow, P., (1985), Small businesses do plan and it pays off, Long Range Planning, 18 (5), 61-67.

Ackoff, R.L., (1970), A Concept of Corporate Planning, Wiley, USA.

Andreole, S.J., (1985), The promise of Artificial Intelligence, Journal of Systems Management, July, 8-17.

Andrews, K.R., (1980), The Concept of Corporate Strategy, Richard D Irwin, Illinois.

Ansoff, H.I. (1969), Business Strategy, Harmondsworth, Middlesex UK.

Ansoff, H.I., Declerck, R.P. and Hayes, R.L., (1976), From Strategic Planning to Strategic Management, in Ansoff, H.I. (Ed), From Strategic Planning to Strategic Management, John Wiley, London.

Ansoff, H.I. (1988), The New Corporate Strategy, John Wiley, NY.

Anthony, R.N., (1965), Planning and Control Systems: A Framework for Analysis, Harvard Graduate School Press, Cambridge Mass.

Archer, A.A. and McIntosh, J.H, (1986), The state of the art in strategic planning in South African companies, South African journal of Business management, 17 (2), 101-107.

Behestian-Ardekani, M. and Salchenberger, L.M., (1988), An Empirical study of the use of Business Expert Systems, Information and Management, 15, 183-190.

Bedeian, A.G., (1990), Choice and Determinism: A Comment, Strategic Management Journal, 11 (7), 571-573.

Bisiani, R., (1988), A Software and Hardware environment for developing AI Applications on Parallel Processors, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 451-456, California, Morgan Kaufman.

Biswas, G., Oliff, M. and Sen, A., (1988), An Expert Decision Support System for Production Control, Decision Support Systems, 4, 235-248.

Blanning, R.W., (1985), Expert Systems for Management: Research and Applications, Journal of Information Science, 9, 153-162.

Boehm, B.W., (1988), A Spiral Model of Software Development and Enhancement, Computer, May, 61-72.

Bohanec, M., Bratko, I. and Rajkovic, V., (1983), An Expert System for Decision Making, in Sol, H.G. (Ed), Processes and Tools for Decision Support, 235-249, Amsterdam, North-Holland.

Bond, A.H. and Gasser, L., (1988), Readings in Distributed Artificial Intelligence, California, Morgan Kaufman.

Bouwman, M.J., (1983), Human diagnostic reasoning by Computer: An Illustration from financial analysis, Management Science, 29 (6), 653-672.

Bower, J.L., (1968), Managing the Resource Allocation Process, Cambridge Mass, Harvard University Press.

Bowman, E.H., (1986), Concerns of the CEO, Human Resources Management, 25 (2), 267-285.

Brachman, R.J, Fikes, R.E. and Levesque, H.J., (1985), Krypton: A functional approach to Knowledge Representation, in Brachman, R.J and Levesque, H.J. (Eds), Readings in Knowledge Representation, 413-429, Morgan Kaufman, California.

Brill, E.D., Chang, S. and Hopkins, L.D., (1982), Modelling to generate alternatives: The HSJ approach, Management Science, 28, 221-235.

Burns, T. and Stalker, G.M., (1961), The Management of Innovation, London, Tavistok.

Bylander, T. and Johnson, T.R., (1988), Structured Matching, Technical Report, Laboratory for Artificial Intelligence Research, Ohio State University.

Camillus, J.C., (1981), Corporate Strategy and Executive Action: Transition Stages and Linkage Dimensions, Academy of Management Review, 6 (2), 253-259.

Chakravarty, B.S., (1987), On Tailoring a Strategic Planning System to its Context: Some Empirical Evidence, Strategic Management Journal, 8, 517-534.

Chandler, A.D., (1962), Strategy and Structure, MIT Press, Cambridge Mass.

Chandrasekar, G. and Ramesh, R., (1987), Microcomputer Based Multiple Criteria Decision Support System for Strategic Planning, Information and Management, 12, 163-172.

Chandrasekar, G. and Ramesh, R., (1988), An Integrated Framework for Decision Support in Corporate Planning, Decision Support Systems, 4, 365-375.

Chandrasekaran, B., (1981), Natural and Social System Metaphors for Distributed Problem Solving, IEEE transactions on Systems, Man and Cybernetics, 1 (1), 1-5.

Chandrasekaran, B., (1986), Generic Tasks in Knowledge-Based Reasoning: High Level Building Blocks for Expert System Design, IEEE Expert, Fall, 23-30.

Chandrasekaran, B. and Mittal, S., (1984), Deep vs Compiled Knowledge approaches to Diagnostic Problem-Solving, in Coombs, M.J. (Ed), Developments in Expert Systems, 23-34, Academic Press, London.

Chandrasekaran, B. and Tanner, M.C., (1986), Uncertainty handling in Expert Systems: Uniform vs Task-Specific Formalisms, in Kanal, L.N. and Lemmer, J.F. (Ed), Uncertainty in Artificial Intelligence, 35-46, Elsevier, Holland.

Chandrasekaran, B., Tanner, M.C. and Josephson, J.R., (1989), Explaining Control Strategies in Problem Solving, IEEE Expert, Spring, 9-24.

Coate, M.B., (1983), Pitfalls in Portfolio Planning, Long Range Planning, 16 (3), 47-56.

Conry, S.E., Meyer, R.A. and Lesser, V.R., (1988), Multistage Negotiation in Distributed Planning, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 367-384, California, Morgan Kaufman.

Cooper, P., (1986), Expert Systems in Management Science, in Bertold, T., (ed), Expert Systems and Knowledge Engineering, 61-71, Elsevier, Holland.

Cyert, R.M. and March, J.G., (1963), A Behavioural Theory of the Firm, Prentice-Hall, Englewood Cliffs, N.J.

Day, G.S., (1984), Strategic Market Planning: The pursuit of Competitive Advantage, West Publishing, Minnesota.

Derkindren, F.G.J. and Crum, R.L., (1984), Pitfalls in Using Portfolio Techniques: Assessing Risk and Potential, Long Range Planning, 17 (2), 129-136.

DeSanctis, G. and Gallupe, R.B., (1987), A Foundation for the study of Group Decision Support Systems, Management Science, 33 (5), 589-609.

Doyle, J., (1979), A Truth Maintenance System, Artificial Intelligence, 12 (3), 231-272.

Drucker, P., (1954), The Practice of Management, New York, Harper and Row.

Durfee, E.H., Lesser, V.R. and Corkhill, D.D., (1987), Cooperation through Communication in a Distributed Problem Solving Network, in Huhns, M.J. (Ed), Distributed Artificial Intelligence, 29-58, Pitman, London.

Durfee, E.H., Lesser, V.R. and Corkhill, D.D., (1988), Coherent Cooperation among Communicating Problem Solvers, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 268-284, California, Morgan Kaufman.

Durfee, E.H., Lesser, V.R. and Corkhill, D.D., (1989), Trends in Cooperative Distributed Problem Solving, IEEE transactions on Knowledge and Data Engineering, 1 (1), 63-83.

Erman, L, Hayes-Roth, F., Lesser, V. and Reddy, D., (1980), The Hearsay II speech understanding system: Integrating knowledge to resolve uncertainty, Computing Surveys, 12 (2), 213-253.

Ernst, C.J., (1988), Management Expert Systems, Addison-Wesley, UK.

Fahey, L., King, W.R. and Narayanan, V.K., (1981), Environmental Scanning and Forecasting in Strategic Planning: The state of the art, Long Range Planning, 14, 32-39.

Feigenbaum, E., McCorduck, P. and Nii, H., (1988), The rise of the Expert Company, Macmillan, London.

Fiksel, J. and Hayes-Roth, F., (1989), Knowledge Systems for Planning Support, IEEE Expert, Fall, 17-23.

Fikes, R. and Kehler, T., (1985), The Role of Frame-Based Representation in Reasoning, Communications of the ACM, 28 (9), 904-920.

Fikes, R.E. and Nilsson, N.J., (1971), Strips: A new approach to the application of theorem proving to artificial intelligence, Artificial Intelligence, 1 (2), 251-288.

Filman, R.E., (1988), Reasoning with Worlds and Truth Maintenance in a Knowledge-Based programming environment, Communications of the ACM, 31 (4), 382-400.

Francia, G.A. and Sung, A.H, (1991), An approach to testing expert systems, Proceedings of the first world congress of Expert Systems, Florida, USA.

Fraser, N.M, Hipel, K.W., Kilgour, D., McNeese, M.D. and Snyder, D.E., (1989), An Architecture for integrating Expert Systems, Decision Support Systems, 5, 263-276.

Fredericks, P. and Venketraman, N., (1988), The Rise of Strategy Support Systems, Sloan Management Review, Spring, 47-54.

Galbraith, C. and Schendel, D., (1983), An Empirical Analysis of Strategy Types, Strategic Management Journal, 4 (2), 153-173.

Gaschnig, J., Klahr, P., Pople, H., Shortliffe, E. and Terry, A., (1983), Evaluation of Expert Systems: Issues and Case Studies, in Hayes-Roth, F., Waterman, D.A. and Lenat, D.B. (Eds), Building Expert Systems, 241-282, London, Addison-Wesley.

Gasser, L., (1989), Distributed Artificial Intelligence, AI Expert, July, 26-33.
Genesereth, M.R., Ginsberg, M.L. and Rosenschein, J.S., (1988), Cooperation without Communication, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 220-226, California, Morgan Kaufman.

Georgeff, M.P., (1988), Communication and Interaction in Multi-Agent Planning, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 200-204, California, Morgan Kaufman.

Gershefski, G.W., (1970), Corporate Models: State of the Art, in Schreiber, A.N. (Ed), University of Washington Press, Seattle.

Gilmore, F.F. and Brandenburg, R.G., (1962), Anatomy of Corporate Planning, Harvard Business Review, November-December, 61-69.

Gorry, G.A. and Scott-Morton, M.S., (1971), A Framework for Management Information Systems, Sloan Management Review, Fall, 55-70.

Goul, M., (1987), On Building Expert Systems for Strategic Planners: A Knowledge Engineers experience, Information and Management, 12, 131-141.

Greiner, L.E., (1972), Evolution and Revolution as Organizations Grow, Harvard Business Review, 50 (4), 37-42.

Gummerson, B., (1974), Organizing for Strategic Management: A Conceptual Model, Long Range Planning, April, 13-18.

Guth, W. and Taguiri, R., (1965), Personal values and Corporate Strategy, Harvard Business Review, 43 (5), 123-132.

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

Harmon, P. and King, D., (1985), Expert Systems: Artificial Intelligence in Business, John Wiley, NY.

Harmon, P. and Sawyer, B., (1990), Creating Expert Systems, New York, John Wiley.

Hax, A.C. and Majluf, N.C., (1983a), The use of the Growth-Share Matrix in Strategic Planning, Interfaces, 13 (1), 46-60.

Hax, A.C. and Majluf, N.C., (1983b), The use of the Industry Attractiveness-Business Strength Matrix in Strategic Planning, Interfaces, 13 (2), 54-71.

Hayes, P.J., (1985), Some Problems and Non-Problems in Representation Theory, in Brachman, R.J. and Levesque, H.J. (Eds), Readings in Knowledge Representation, 3-22, Morgan Kaufman, California.

Hayes-Roth, B., (1988), A Blackboard Architecture for Control, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 505-540, California, Morgan Kaufman.

Hayes-Roth, B. and Hayes-Roth, F., (1978), Cognitive Processes in Planning, Technical Report R-2366-ONR, Rand Corporation, California.

Hayes-Roth, F., (1985), Rule-Based Systems, Communications of the ACM, 28 (9), 921-932

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

Herold, D.M., (1972), Long Range Planning and Organizational Performance, Academy of Management Journal, March, 91-102.

Hewitt, C., (1986), Offices are Open Systems, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 321-328, California, Morgan Kaufman.

Hobbs, J.M., and Heaney, D.F., (1977), Coupling Strategy to Operating Plans, Harvard Business Review, May-Jun, 119-126.

Hofer, C.W. and Schendel, D., (1978), Strategy Formulation: Analytical Concepts, West Publishing, St Paul.

Hrebiniak, L.G. and Joyce, W.F., (1985), Organizational Adaptation: Strategic Choice and Environmental Determinism, Administrative Science Quarterly, Sept, 336-349.

Hussey, D.E., (1978), Portfolio Analysis: Practical Experience with the Directional Policy Matrix, Long Range Planning, 11, 2-8.

James, B., (1984), Strategic Planning Under Fire, Sloan Management Review, Summer, 57-61.

Johnson, G. and Scholes, K., (1984), Exploring Corporate Strategy, Englewood Cliffs NJ, Prentice Hall.

Karger, D. and Malik, Z., (1975a), Does Long-Range planning Improve Company Performance?, Management Review, September, 27-31.

Karger, D. and Malik, Z., (1975b), Long Range Planning and Organizational Performance, Long Range Planning, December, 60-64.

Keen, P.G.W. and McKenney,J.L., (1974), How Managers' minds work, Harvard Business Review, May-June, 79-90.

Kiechel, W., (1981), The decline of the experience curve, Fortune, 5 October, 139-146.

King, W.R. and Dutta, B.P., (1980), A Competitive Scenario Modelling System, Management Science, 26, 261-273.

King, W.R. and Rodriquez, J.I., (1977), Competitive Information Systems, Long Range Planning, 10, 59-64.

Klein, H. and Newman, W., (1980), How to use Spire: A systematic Procedure for Identifying Relevent Environments for Strategic Planning, Journal of Business Strategy, Summer, 32-45.

Larrech, J. and Srinivasan, V., (1981), Stratport: A Decision Support System for Strategic Planning, Journal of Marketing, 45 (4), 39-45.

Lawrence, P.R. and Lorsh, J.W., Organization and Environment, Homewood, Irwin.

Leaung, K.S., Wong, W.S.F., Lam, W., (1989), Applications on a novel fuzzy expert system shell, Expert Systems, 6 (1), 2-10.

Lee, J.K. and Lee, H.G., Interaction of Strategic Planning and Short-Term Planning: An Intelligent DSS by the Post-Model Analysis Approach, Decision Support Systems, 3, 141-154.

Lenz, R.T. and Lyles, M.A., (1985), Paralysis by analysis: Is your Planning System becoming too rational?, Long Range Planning, 18 (4), 64-72.

Lesser, V.R and Corkhill, D.D., (1983), The Distributed Vehicle Monitoring Testbed: A Tool for Investigating Distributed Problem Solving Networks, AI Magazine, 4 (3), 15-33.

Levine, P., Maillard, J.Ch. and Pomerol, J.Ch., (1987), Decidex: A multi-Expert system for Strategic Decisions, in Sol, H.G. et al (eds), Expert Systems and Artificial Intelligence in Decision Support Systems, 247-255, Dordrecht, D.Reidel Publishing.

Lorange, P., (1985), Corporate Planning: An Executive Viewpoint, Englewood Cliffs NJ, Prentice Hall.

Luconi, F.L., Malone, T.W. and Scott-Morton, M.S., (1986), Expert Systems: The next challenge for managers, Sloan Management Review, Summer, 3-13.

Lyles, M., (1981), Formulating Strategic Problems: Empirical Analysis and Model Development, Strategic Management Journal, 2, 61-75.

Lynch, C.H and Rock, R.H., (1980), Human Resources Planning, in Albert, K.J. (Ed), Handbook of Business Problem Solving, McGraw-Hill, NY.

Malone, T.W., (1987), Modelling Coordination in Organizations and Markets, Management Science, 33 (10), 1317-1322.

March, J.G. and Simon, H.A., (1958), Organization, New York, Wiley.

Marcus, C., (1986), Prolog Programming, Addison-Wesley, USA.

Mayo, R.B., (1979), Corporate Planning and Modelling with Simplan, Reading Mass, Addison-Wesley.

McCarthy, J., (1980), Circumscription: A form of non-monotonic reasoning, Artificial Intelligence, 13, 27-39.

McDougall, P. and Robinson, R.B., (1990), New Venture Strategies: An Empirical Identification of eight Archetypes of Competitive Strategies for Entry, Strategic Management Journal, 11 (6), 447-467.

McGinnis, M.A., (1984), The Key to Strategic Planning: Integrating Analysis and Intuition, Sloan Management Review, Fall, 45-52.

McGinnis, M.A. and Ackelsberg, M.R., (1983), Effective Innovation Management: Missing Link in Strategic Planning?, The Journal of Business Strategy, 4 (1), 59-69.

Michael, D., (1973), On Learning to Plan and Planning to Learn, Jossey-Bass, San Francisco.

Miles, R.E. and Snow, C.C., (1978), Organizational Strategy, Structure and Process, New York, McGraw-Hill.

Miller, D. and Friesen, P., (1978), Archetypes of Strategy Formation, Management Science, 24 (9), 921-933.

Miller, D. and Friesen, P., (1980), Archetypes of Organizational Transition, Administrative Science Quarterly, 25, 268-299.

Miller, D. and Friesen, P., (1982), Structural Change and Performance: Quantum versus Piecemeal-Incremental Approaches, Academy of Management Journal, 25 (4), 867-892.

Mintzberg, H., (1976), Planning on the left side and managing on the right, Harvard Business Review, July-August, 49-58.

Mintzberg, H., (1973), Strategy Making in Three Modes, California Management Review, 44-53.

Mintzberg, H., (1978), Patterns in Strategy Formulation, Management Science, 24 (9), 934-948.

Mintzberg, H. and Waters, J.A., (1989), Of Strategies, Deliberate and Emergent, in Asch, D. and Bowman, C. (Eds), Readings in Strategic Management, London, Macmillan.

Mittal, S., Chandrasekaran, B. and Sticklen, J., (1984), Patrec: A Knowledge-Directed Database for a Diagnostic Expert System, IEEE Computer, September, 51-58.

Moser, J. and Christoph, R., (1987), Management Expert Systems: A Framework for Development and Implementation, Information Processing and Management, 23 (1), 17-23.

Moses, M. and Hamilton, W., (1974), A Computer-Based Corporate Planning System, Management Science, October, 42-59.

Narchal, R.M., Kittapa, K. and Bhattacharya, P., (1987), An Environmental Scanning System for Business Planning, Long Range Planning, 20 (6), 96-105.

Newell, A. and Simon, H., (1976), Computer Science as Empirical Enquiry, Symbols and Search, Communications of the ACM, 19 (3), 113-126.

Newman, W.H., (1975), Constructive Control, Englewood Cliffs NJ, Prentice-Hall.

Nielson, N.R and Walters, J.R., (1988), Crafting Knowledge-Based Systems, John Wiley, USA.

Nii, H.P., (1986), Blackboard Systems, The Blackboard model of Problem Solving and the evolution of Blackboard Architectures, AI Magazine, 7 (3).

O'Leary, D.E. and Turban, E., (1987), The organizational impact of Expert Sytems, Human Systems Management, 7, 11-19.

O'Meara, J.T., (1961), Selecting Profitable Products, Harvard Business Review, January-February, 84-85.

Ohmae, K., (1982), The Mind of the Strategist: Business Planning for Competitive Advantage, Harmondsworth, Middlesex UK.

Pearl, J., Leal, A. and Saleh, J., (1982), Goddess: A goal-directed decision structuring system, IEEE transactions on Pattern Analysis and Machine Intelligence, May, 250-262.

Peters, T.J. and Waterman, R.H., (1982), In Search of Excellence, Harper Row, NY.

Porter, M.E., (1980), Competitive Strategy: Techniques for analysing Industries and Competition, Free Press, London.

Prerau, D.S., Gunderson, A.S., Reinke, R.E. and Adler, M.R., (1990), Maintainability techniques in Developing Large Expert Systems, IEEE Expert, June, 71-79.

Radford, K.J., (1980), Strategic Planning: An Analytical Approach, Reston Publishing Inc, Virginia.

Ram, V., (1989), Expert Systems for Strategic Financial Planning, Proceedings of Conference on Expert Systems in Finance, Pretoria, RSA.

Rauch-Hindin, W.B., (1986), Artificial Intelligence in Business, Science and Industry, Prentice-Hall, Englewood Cliffs, NJ.

Reitman, W., (1984), Artificial Intelligence Applications for Business, Ablex Publishing, NJ.

Rich, E.A., (1986), Rationality and Creativity in Artificial Intelligence, in Bertold, T. (Ed), Expert Systems and Knowledge Engineering, 7-16, Elsevier, Holland.

Robinson, R.B., (1982), The importance of Outsiders in Small Firm Strategic Planning, Academy of Management Journal, March, 80-93.

Robinson, S.J.Q., Hichens, R.E. and Wade, D.P., (1978), The Directional policy Matrix: Tool for Strategic Planning, Long Range Planning, 11, 8-15

Rosenschein, J.S. and Genesereth, M.R., (1988), Deals among Rational Agents, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 227-234, California, Morgan Kaufman.

Rowe, A.J., Mason, R.O. and Dickel, K.E., (1986), Strategic Management and Business Policy: A Methodological Approach, Addison-Wesley, USA.

Rue, L.W. and Holland, P.G., (1986), Strategic Management: Concepts and Experiences, USA, McGraw-Hill.

Sacerdoti, E.D., (1974), Planning in a Hieararchy of Abstraction Spaces, Artificial Intelligence, 5, 115-135.

Sacerdoti, E.D., (1977), A Structure of Plans and Behaviour, New York, Elsevier.

Schoeffler, S. and Badler, G., (1981), PIMS: Some research findings, Cambridge Mass, Strategic Planning Institute.

Scholz, C., (1987), Corporate Culture and Strategy: The Problem of Strategic Fit, Long Range Planning, 20 (4), 78-87.

Shank, J.K., Niblock,E.G. and Sandalls, W.T., (1973), Balance Creativity and Practicality in Formal Planning, Harvard Business Review, January-February, 87-94.

Shrivastava, P., (1983), A Typology of Organizational Learning Systems, Journal of Management Studies, 20 (1), 7-28.

Schwenk, C.R., (1988), The Cognitive Perspective on Strategic Decision Making, Journal of Management Studies, 25 (1), 41-55.

Schwenk, C.R., (1985), Management Illusions and Biases: Their Impact on Strategic Decisions, Long Range Planning, 18 (5), 74-80.

Segev, E., (1987), Strategy, Strategy-Making and Performance in a Business Game, Strategic Management Journal, 8, 565-577.

Simon, H., (1960), The New Science of Management Decision Making, Harper and Row, New York.

Slagle, J.R. and Wick, M.R., (1989), An Explanation facility for Today's Expert Systems, IEEE Expert, Spring, 26-36.

Smith, L.D., Blodgett, J., Janson, M. and Bartle V., (1985), Decision Support for Marketing Research and Corporate Planning, Information and Management, 8, 133-145.

Smith, R.G. and Davis, R., (1983), Negotiation as a metaphor for Distributed Problem Solving, Artificial Intelligence, 20 (1), 63-109.

Snow, C.C. and Hambrink, D.C., (1980), Measuring Organizational Strategies: Some Theoretical and Methodological Problems, Academy of Management Review, 5 (4), 527-538.

Stefik, M., (1981), Planning with Constraints (Molgen Part1), Artificial Intelligence, 16, 111-139.

Steiner, G.A. and Miner, J.B., (1982), Management Policy and Strategy, New York, Macmillan.

Stoner, J.A.F., (1982), Management, Englewood Cliffs NJ, Prentice Hall.

Stubbart, C.I., (1989), Managerial Cognition: A missing link in Strategic Manage ment Research, Journal of Management Studies, 26 (4), 325-347.

Stubbart, C.I., (1985), Why we need a revolution in Strategic Planning, Long Range Planning, 18 (6), 68-76.

Suites, D.B., (1988), Sometimes true and Unequivocally Indeterminate, Computer Language, August, 39-43.

Sullivan, C.H. and Yates, C.E., (1988), Reasoning by Analogy: A Tool for Business Planning, Sloan Management Review, Spring, 55-60.

Sussman, G.J., (1975), A Computer Model of Skill Acquisition, New York, Elsevier.

Tanimoto, S., (1987), The Elements of Artificial Intelligence, Computer Science Press, Maryland.

Tanney, R.R. and Sandells, N.R., (1988), Strategies for Distributed Decision Making, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 236-247, California, Morgan Kaufman.

Taylor, B., (1982), New Dimensions of Corporate Planning, in Taylor, B. and Hussey, D. (Eds), The Realities of Planning, 1-48, Oxford, Pergamon.

Thierauf, R.J., (1982), Decision Support Systems for Effective Planning and Control, Englewood Cliffs NJ, Prentice-Hall.

Thune, S.S. and House, R.J., (1970), Where Long Range Planning Pays Off, Business Horizons, August, 81-87.

Tilles, S., (1963), How to evaluate Corporate Strategy, Harvard Business Review, 41 (4), 111-121.

Tosi, H.L. and Hammer, W.C., (1974), Organizational Behaviour and Management, Chicago, St Clair Press.

Turban, E., (1988), Decision Support and Expert Systems: Managerial Perspectives, Macmillan, New York.

Turoff, M. and Hiltz, S.R., (1982), Computer Support for Group versus Individual Decisions, IEEE Transactions on Communications, 30 (1), 82-90.

Van Beek, J.J.J., (1987), Analysis of Potential for new places of Business, in Sol, H.G. et al (eds), Expert Systems and Artificial Intelligence in Decision Support Systems, 292-299, D.Reidel Publishing, Holland.

Venkatraman, N. and Camillus, J.C., (1984), Exploring the concept of Fit in Strategic Management, Academy of Management Review, 9, 513-525.

Vesper, V.D., (1979), Strategic Mapping: A Tool for Corporate Planners, Long Range Planning, 12 (6), 75-92.

Vesper, K.H., (1980), New Venture Strategies, Englewood Cliffs NJ, Prentice-Hall.

Waterman, R.H., (1982), The seven elements of Strategic Fit, Journal of Business Strategy, 2 (2), 69-73.

Waterman, D., (1986), A Guide to Expert Sytems, Addison-Wesley, Reading Mass.

Weitzel, J.R. and Kerschberg, L., (1989), Developing Knowledge-Based Systems: Reorganizing the system developing life cycle, Communications of the ACM, 32 (4), 482-488.

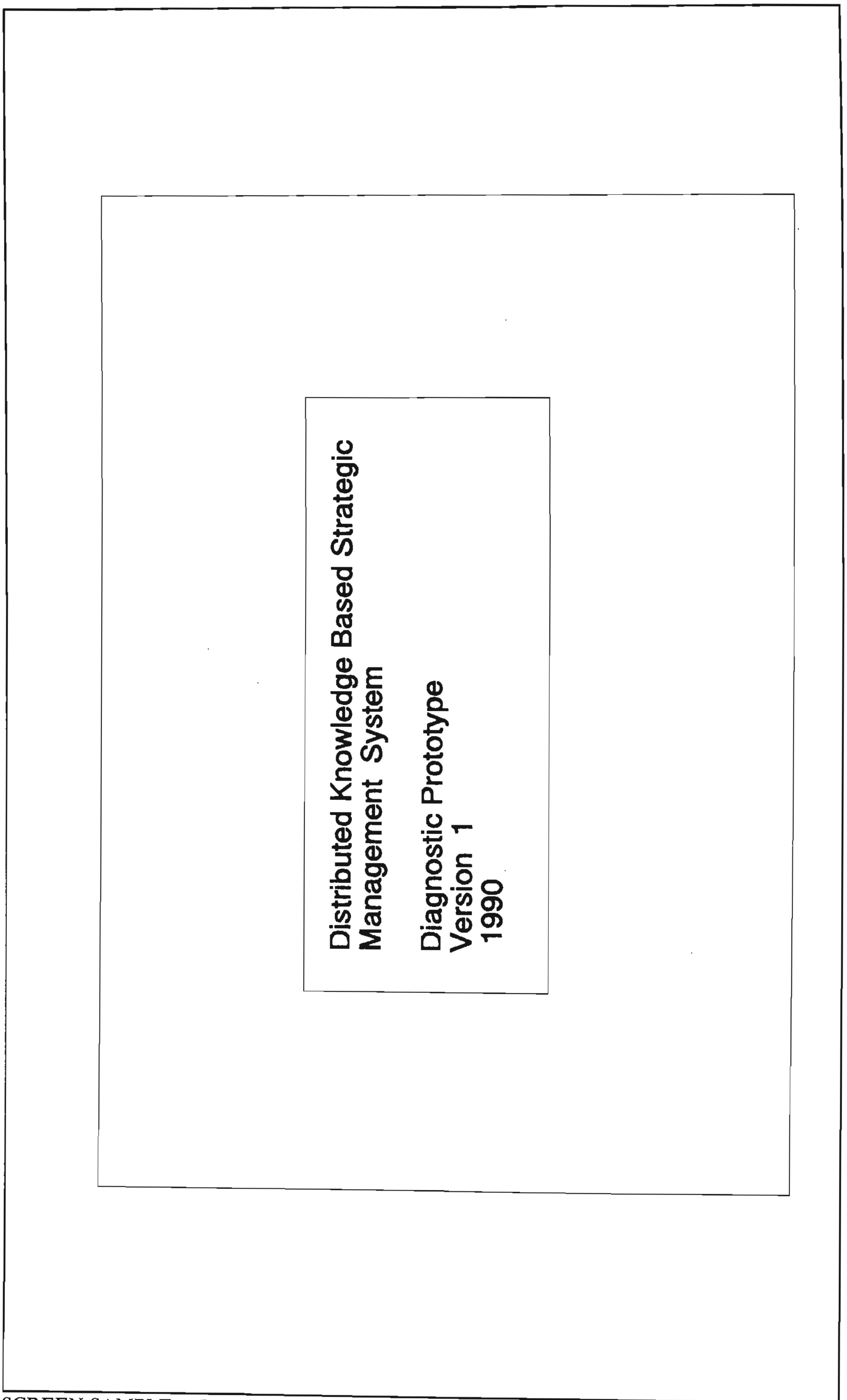
Wilkins, D.E., (1987), Hierarchical Planning: Definition and Implementation, in Du Boulay, B., Hogg, D. and Steels, L. (Eds), Advances in Artificial Intelligence, Elsevier, Holland.

Yang, J.D., Huhns, M.N. and Stephens, L.M., (1988), An Architecture for Control and Communications in Distributed Artificial Intelligence Systems, in Bond, A.H. and Gasser, L., Readings in Distributed Artificial Intelligence, 606-616, Morgan Kaufman, California.

Zeleny, M., (1987), Management Support Systems: Towards integrated knowledge management, Human Systems Management, 7, 59-70.

APPENDIX A

Screen Samples



SCREEN SAMPLE 1: Introductory Screen 1

SCREEN SAMPLE 2: Introductory Screen 2

In this diagnostic version of the system, you will be asked a series of questions in each of the following four categories

ENVIRONMENTAL STABILITY
FINANCIAL STRENGTH
INDUSTRY STRENGTH
COMPETITIVE ADVANTAGE

Please try to be as objective and as realistic as possible when responding

SCREEN SAMPLE 3: Factor Input Screen used by the Control Module

CATEGORY : INDUSTRY STRENGTH
QUESTION : 22
FACTOR : BARGAINING POWER OF SUPPLIERS

This is the power that suppliers can assert on the company because there are no substitute for their products, or because the industry supplied is not an important customer, or because the suppliers have the potential to integrate forward

VERY HIGH
HIGH
AVERAGE
LOW
VERY LOW

CATEGORY : PRODUCTIVE ABILITY
QUESTION : 6
FACTOR : EQUIPMENT REQUIRED

A : product will require new equipment altogether
B : largely new equipment but some present equipment
C : largely present equipment but some new equipment
D : present equipment but shared with existing products
E : present equipment that is presently idle

A
B
C
D
E

SAMPLE SCREEN 4: Factor Input Screen used by the Marketing Module

APPENDIX B

Prolog Source Code
The Control Module

```
/************************************************************
                DISTRIBUTED KNOWLEDGE BASED SUPPORT
                CONTROL MODULE
                VEVEK RAM
                JULY 1990
************************************************************/

include "tdoms.pro"     /* the include combines predefined  */
include "tpreds.pro"    /* domains, predicates and the menu */
include "menu2.pro"     /* program code at execution time   */


DOMAINS
  numberlist=integer*
  qnum      =integer
  categ,fact,exp1,exp2,exp3,exp4,exp5,exp6 = string

DATABASE
  stop(string)

DATABASE - factbb          /*static area of blackboard*/
  envscore(integer)
  finscore(integer)
  indscore(integer)
  cadscore(integer)
  factval(string,integer)

DATABASE - requestbb        /*request area of blackboard*/
  request(string,string,string,string,integer,string)

DATABASE - functionalbb              /*functional strategy area*/
  plan(string,string)

DATABASE - genericbb        /*generic strategy area*/
  strategy(string)

PREDICATES
  ask(numberlist,integer)
  q(qnum,categ,fact,exp1,exp2,exp3,exp4,exp5,exp6,stringlist)
  introscreen
  cat1
  cat2
  cat3
  cat4
  posture(integer,integer,integer,integer)
  quesnum(string,integer)
  check(stringlist)
  locate
  decomp
  splitqueue
  endofcycle
  consistencyok
  growthok
  riskok
  appropriateok
  getvalues
  generate_strategy
```

```
 confer
 evaluate_strategy
 present_strategy
 conclude

GOAL                          /* main goal starts the process*/
                    getvalues,
                    generate_strategy,   /* purpose of each subgoal*/
                    confer,
                    evaluate_strategy,   /* is explained in Chap9  */
                    present_strategy,
                    conclude.

getvalues :-        introscreen,
                    cat1,
                    cat2,
                    cat3,
                    cat4.


generate_strategy :- envscore(J),ES=J/13,
                    finscore(K),FS=K/9,
                    cadscore(L),CA=L/10,
                    indscore(M),IS=M/11,
                    Vcomp=FS-ES,Hcomp=CA-IS,
                    posture(Vcomp,Hcomp,Pos,Deg),
                    fin.


confer :-           repeat,
                    retractall(_,requestbb),
                    consult("req.dba",requestbb),
                    decomp,
                    findall(Mod,request("CM",Mod,_,_,"U"),Qlist),
                    splitqueue(Qlist),
                    endofcycle.


decomp :-           request(_,"CM",Fact1,Act1,Ref1,"U"),
                    locate(Fact1,Xlist,Mod1).

locate(_,[],_).
locate(Prob,Xlist,Mod1):- mf(Prob,_,[H2|T2],Mod1),
                     Prob = H2,
                     T2   = [],
                     asserta(request("CM",Mod1,Fact1,Act1,Ref1,"U").

locate(Prob,Xlist,Mod1):- mf(Prob,_,[H2|T2],Mod1),
                     locate(Prob1,H2,Mod2),
                     locate(Prob2,T2,Mod3).


splitqueue ([]) :-        asserta(stop("Y")).
splitqueue ([H1|T1]) :-   system(X).

endofcycle :-             stop("Y").
```

```
evaluate_strategy :-     consistencyok,
                         appropriateok,
                         growthok,
                         riskok.

consistencyok :-         findall(Fact2,plan(Fact2,_),Flist),
                         check(Flist).


check([]).
check([H3|T3]) :-        findall(Act2,plan(H3,Act2),Actlist),
                         Actlist = [H4|T4],
                         H4 = T4,
                         check(T3).

growthok.
riskok.
appropriateok.

present_strategy :-      system ("report").

conclude :-              save("req.dba",requestbb),
                         save("plan.dba",functionalbb),
                         save("fact.dba",factbb),
                         save("genstrat.dba",genericbb).

CLAUSES

introscreen :- makewindow(1,32,0,"",0,0,25,80),
               makewindow(1,32,71,"",7,21,10,42),
        write("  DISTRIBUTED KNOWLEDGE BASED STRATEGIC"),nl,
        write("  MANAGEMENT SUPPORT"),nl,nl,
        write("  DIAGNOSTIC PROTOTYPE"),nl,nl,
        write("  VERSION 1"),nl,
        write("  1990"),readchar(_),
        removewindow,
        makewindow(1,32,71,"",3,10,15,60),
        write("  In this DIAGNOSTIC version of the system, you will be"),nl,
        write("  asked a series of questions in each of the following"),nl,
        write("  four categories"),nl,nl,
        write("  ENVIRONMENTAL STABILITY"),nl,
        write("  FINANCIAL STRENGTH"),nl,
        write("  INDUSTRY STRENGTH"),nl,
        write("  COMPETITIVE ADVANTAGE"),nl,nl,
        write("  Please try to be as objective and as accurate as "),nl,
        write("  possible when responding"),nl,readchar(_),removewindow,
        retractall(_).



cat1:-  makewindow(1,32,0,"",0,0,25,80),removewindow,
        ask([1,2,3,4,5,6,7,8,9,10,11,12,13],Total),
        nl,write(Total," For ES"),
        assertz(envscore(Total)).

cat2:-  makewindow(1,32,0,"",0,0,25,80),removewindow,
```

```
        ask([14,15,16,17,18,19,20,21,22,23,24],Total),
        nl,write(Total," For IS"),
        assertz(indscore(Total)).

cat3:-  makewindow(1,32,0,"",0,0,25,80),removewindow,
        ask([25,26,27,28,29,30,31,32,33,34],Total),
        nl,write(Total," For CA"),
        assertz(cadscore(Total)).

cat4:-  makewindow(1,32,0,"",0,0,25,80),removewindow,
        ask([35,36,37,38,39,40,41,42,43],Total),
        nl,write(Total," For FS"),
      assertz(finscore(Total)).

fin :-  assertz(factval("VECTOR SLOPE",Deg)),
      assertz(factval("STRATEGIC POSTURE",Pos)).



  q(43,"FINANCIAL STRENGTH","AVERAGE COLLECTION PERIOD ",
     " This factor is the ratio of accounts receivable to",
     " average daily sales and measures the the number of ",
     " days sales that are held as receivables. ",
     " A very high ratio implies that",
     " some receivables may be uncollectible.",
     " ",
     ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

  q(42,"FINANCIAL STRENGTH","RETURN ON INVESTMENT",
     " This is also known as the return on assets.",
     " It is the ratio of Earnings before interest and",
     " Taxes, to Total Assets.",
     " The value indicated here must be relative to",
     " the industry",
     " ",
     ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

  q(41,"FINANCIAL STRENGTH","LEVERAGE",
     "This is the extent to which borrowed funds",
     "are used to finance the company's normal",
     "operations.   ",
     "If there is no outside funding, rate this as ",
     "VERY LOW",
     " ",
     ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

  q(40,"FINANCIAL STRENGTH","LIQUIDITY",
     "This is the extent to which the claims of ",
     "short term creditors are covered by short term ",
     "assets and the extent to which working capital",
     "is tied up in inventory ",
     " ",
     " ",
     ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

  q(39,"FINANCIAL STRENGTH","CAPITAL REQUIRED/CAPITAL AVAILABLE",
     "This is a ratio of the capital required to run ",
     "the business to the capital available.",
```

```
   "It is also known as the Capitalization ",
   "An Undercapitalized situation should be  ",
   "indicated as LOW",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(38,"FINANCIAL STRENGTH","CASH FLOW ",
   "This is the amount of funds that are generated and used ",
   "in the company's normal operations",
   "In normal circumstances, if the liquidity value",
   "is high, then this value should also be high ",
   "  ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(37,"FINANCIAL STRENGTH","EASE OF EXIT FROM MARKET",
   "This is a measure of the potential difficulties  ",
   "that could be experienced in the case of Exit. ",
   "If there is a considerable investment in specialised ",
   "Plant etc, then this factor should be VERY LOW ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(36,"FINANCIAL STRENGTH","LEVEL OF RISK ",
   "This is the level of Risk associated with ",
   "the nature of the company's business.",
   " ",
   " ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(35,"FINANCIAL STRENGTH","INVENTORY TURNOVER",
   "The rate at which the company's inventory ",
   "is used/sold and replenished",
   "If this happens often, the inventory turnover ",
   "is high. ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

/*************************************************************/

q(34,"COMPETITIVE ADVANTAGE","MARKET SHARE",
   "This is the size of the company's share" ,
   "of the market, relative to the other",
   "competitors",
   " ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(33,"COMPETITIVE ADVANTAGE","PRODUCT QUALITY ",
   " This is the standard of quality in the",
   " product/s relative to rival products",
   " ",
   " ",
```

```
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(32,"COMPETITIVE ADVANTAGE","PRODUCT LIFE CYCLE ",
    "This is the stage of the product life cycle ",
    "at which the product is currently placed. ",
    "The valid stages are Introduction, Growth, ",
    "Stable, Maturity and Decline. ",
    "Introduction is VERY HIGH",
    "Decline is VERY LOW ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(31,"COMPETITIVE ADVANTAGE","PRODUCT REPLACEMENT CYCLE",
    "This is the rate at which the product is  ",
    "replaced by the consumer. ",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(30,"COMPETITIVE ADVANTAGE","CUSTOMER LOYALTY",
    "This is an indication of the extent to which  ",
    "customers repurchase the company's product, ",
    "on a continuous basis rather than purchase a ",
    "rival product ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(29,"COMPETITIVE ADVANTAGE","CAPACITY UTILIZATION OF COMPETITORS",
    " This is the degree to which competitors can ",
    " produce more output.  If the competitor's  utilization",
    " is high, and it is unlikely that they can increase ",
    " production dramatically in the short term,",
    " rate this as HIGH",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(28,"COMPETITIVE ADVANTAGE","LEVEL OF TECHNICAL EXPERTISE",
    "This is an indication of the level of technical ",
    "skill that the company exhibits. It is generally ",
    "made up of design, production and quality control ",
    "expertise ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(27,"COMPETITIVE ADVANTAGE","DEGREE OF VERTICAL INTEGRATION",
    "This represents the extent to which the company owns",
    "or is able to control either the sources of supply ",
    "or the channels of distribution. ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).
```

```
q(26,"COMPETITIVE ADVANTAGE","OPERATIONAL EFFICIENCY",
   " This measures the ratio of output produced to the ",
   " resource input consumed, ",
   " ",
   " ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(25,"COMPETITIVE ADVANTAGE","MANAGEMENT SKILLS",
   " This is an indication of the Planning,",
   " and controlling skills of the company's",
   " management",
   " ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

/***********************************************************/

q(24,"INDUSTRY STRENGTH","PRESSURE FROM SUBSTITUTE PRODUCTS ",
   " This is the pressure exerted on the company's products",
   " by products which are similar or perform the same",
   " function, ",
   " ",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(23,"INDUSTRY STRENGTH","BARGAINING POWER OF BUYERS ",
   " This is the power that buyers can assert on the  ",
   " company, either because of their size, or because",
   " there are no switching costs, or also because",
   " buyers have the potential to integrate backward.",
   " ",
   " ",
   ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(22,"INDUSTRY STRENGTH","BARGAINING POWER OF SUPPLIERS ",
   " This is the power that suppliers can assert on the ",
   " company because there are no substitutes for their",
   " products, or because the industry supplied is not an",
   " important customer,or because the suppliers have the ",
   " potential to integrate forward",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).


q(21,"INDUSTRY STRENGTH","GROWTH POTENTIAL ",
   " This is the potential for growth in the ",
   " industry as a whole.  This potential is ",
   " generally high when the product is still in the",
   " early stages of its life cycle.",
   " ",
   " ",
   ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(20,"INDUSTRY STRENGTH","PROFIT POTENTIAL ",
```

```
    " This is the potential of the companies in the ",
    " industry to generate profits",
    " ",
    " ",
    " ",
    " ",
    ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(19,"INDUSTRY STRENGTH","FINANCIAL STABILITY ",
    " This is an indication of the financial",
    " stability of the industry",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(18,"INDUSTRY STRENGTH","LEVEL OF TECHNOLOGICAL EXPERTISE ",
    " This is an indication of the level of technological",
    " expertise in the industry.",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(17,"INDUSTRY STRENGTH","RESOURCE UTILIZATION ",
    " This is the level at which resources is the industry",
    " are being used.",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(16,"INDUSTRY STRENGTH","CAPITAL INTENSITY",
    " This the ratio of capital employed ralative ",
    " to the employement of labour or land in the industry.",
    " Capital intensity may also indicate the degree ",
    " of automation in the industry.",
    " ",
    " ",
    ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(15,"INDUSTRY STRENGTH","EASE OF ENTRY INTO MARKET ",
    " This is a measure of the relative ease with",
    " which a new competitor may enter the market.",
    " Entry into the market may be difficult due to ",
    " large capital requirements or sophisticated ",
    " technology",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(14,"INDUSTRY STRENGTH","PRODUCTIVITY  ",
    " This is the ratio of production output",
    " per unit of input for the industry",
    " ",
    " ",
```

```
" ",
" ",
["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

/*********************************************************************/

q(13,"ENVIRONMENTAL STABILITY","PRICE RANGE OF COMPETING PRODUCTS",
    " This is an indication of the price choice a ",
    " consumer has in purchasing the company's product ",
    " or a similar product",
    " ",
    " ",
    " ",
    ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).


q(12,"ENVIRONMENTAL STABILITY","TECHNOLOGICAL CHANGE",
    " This factor involves both the rate as well as the",
    " degree of technological changes in your immediate",
    " environment.",
    " If sudden rapid changes are common in your  ",
    " environment, rate this as VERY HIGH ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(11,"ENVIRONMENTAL STABILITY","BARRIERS TO ENTRY INTO MARKET ",
    " This is an indiction of the difficulty with ",
    " which a new competitor may enter the market.",
    " Large startup costs, Customer loyalty and",
    " sophisticated technology are examples of entry",
    " barriers",
    " ",
    ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(10,"ENVIRONMENTAL STABILITY","RATE OF INFLATION",
    " ",
    " ",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(9,"ENVIRONMENTAL STABILITY","DEMAND VARIABILITY",
    " This is the stability of the demand for ",
    " the product.  If there are no seasonal or ",
    " other fluctuations in the demand for the",
    " product, rate this as LOW",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(8,"ENVIRONMENTAL STABILITY","COMPETITIVE PRESSURE ",
    " This is the degree to which competitors are able ",
    " to apply pressure which can dictate changes to the  ",
    " price, packaging, targeting etc", of the company's,
    " products",
```

```
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(7,"ENVIRONMENTAL STABILITY","PRICE ELASTICITY OF DEMAND ",
    " This is the relationship between the product price and",
    " the market demand.  If an increase in the price results",
    " in a decrease in demand, the price elasticity is elastic and",
    " this factor should be rated high",
    " ",
    " ",
    ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(6,"ENVIRONMENTAL STABILITY","COST OF RAW MATERIAL ",
    " This is the cost of material used in the company's",
    " production process.  ",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(5,"ENVIRONMENTAL STABILITY","COST OF ENERGY ",
    " This is the cost of the energy input to",
    " the production process.  It must reflect the cost",
    " of all forms of energy used",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(4,"ENVIRONMENTAL STABILITY","AVAILABILITY OF RAW MATERIAL ",
    " This is an indication of the relative ease with",
    " which raw material can be obtained",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(3,"ENVIRONMENTAL STABILITY","LEVEL OF GOVERNMENT SUBSIDY ",
    " This is an indication of the extent to which the",
    " government is assisting the industry through",
    " measures such as labour, capital and transport ",
    " subsidies",
    " ",
    " ",
    ["IMPOSSIBLE TO VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(2,"ENVIRONMENTAL STABILITY","GOVERNMENT PROTECTION FROM FOREIGN
COMPETITION",
    " This is an indication of the measures taken by
    " the government to protect the local industry.",
    " It is normally achieved through enforcing high importation",
    " costs for foreign substitute products in the form",
    " duties and surcharges",
    " ",
    " ",
```

```
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).

q(1,"ENVIRONMENTAL STABILITY","POLITICAL STABILITY ",
    " This is an indication of the long term stability ",
    " of the government and the economy",
    " ",
    " ",
    " ",
    " ",
    ["VERY LOW","LOW","AVERAGE","HIGH","VERY HIGH"]).


ask([],0).
ask([X | Y],S):-
        ask(Y,T),q(X,CatTitle,FactTitle,ES1,ES2,ES3,ES4,ES5,ES6,Choicelist),
        makewindow(1,23,71,"",5,2,7,77),nl,quesnum(CatTitle,Q),W=Q-X,
        write("     CATEGORY : ",CatTitle),nl,
        write("     QUESTION : ",W),nl,
        write("     FACTOR   : ",FactTitle),
        makewindow(1,23,71,"",12,2,12,77),nl,nl,
        write(ES1),nl,
        write(ES2),nl,
        write(ES3),nl,
        write(ES4),nl,
        write(ES5),nl,
        write(ES6),nl,
        menu(16,55,7,7,Choicelist,"",3,ChoiceNo),
        S=T+ChoiceNo,removewindow,removewindow,
        assertz(factval(FactTitle,ChoiceNo)).

posture(Vcomp,Hcomp,1,Deg) :- Vcomp>0,Hcomp>0,
Deg=trunc(arctan(Vcomp/Hcomp)*180/3.141592653).
posture(Vcomp,Hcomp,2,Deg) :- Vcomp>0,Hcomp<0,
Deg=trunc(arctan(Vcomp/Hcomp)*180/3.141592653).
posture(Vcomp,Hcomp,3,Deg) :- Vcomp<0,Hcomp<0,
Deg=trunc(arctan(Vcomp/Hcomp)*180/3.141592653).
posture(Vcomp,Hcomp,4,Deg) :- Vcomp<0,Hcomp>0,
Deg=trunc(arctan(Vcomp/Hcomp)*180/3.141592653).
posture(Vcomp,Hcomp,0,0):- Vcomp=0;Hcomp=0.


quesnum("ENVIRONMENTAL STABILITY",14).
quesnum("INDUSTRY STRENGTH",25).
quesnum("COMPETITIVE ADVANTAGE",35).
quesnum("FINANCIAL STRENGTH",44).
```

APPENDIX C

Prolog Source Code
The Marketing Module

```
/**********************************************************
                DISTRIBUTED KNOWLEDGE BASED SUPPORT
                MARKETING MODULE
                VEVEK RAM
                JULY 1990
**********************************************************/
include "tdoms.pro"
include "tpreds.pro"
include "menu2.pro"
DOMAINS
  numberlist=integer*
  qnum      =integer
  categ,fact,exp1,exp2,exp3,exp4,exp5,exp6 = string

DATABASE
  medval(string,integer)

DATABASE - factbb
  factval(string,integer)

DATABASE - requestbb

  request(string,string,string,integer,string)

DATABASE - functionalbb

  plan(string,string)

DATABASE - genericbb

  strategy(string)

PREDICATES
  ask(numberlist,integer)
  q(qnum,categ,fact,exp1,exp2,exp3,exp4,exp5,exp6,stringlist)
  cat1
  cat2
  cat3
  cat4
  fin
  ask2(numberlist)
  qq(integer,string,string,stringlist)
  network
  standalone
  showmenu
  priceok
  pricepresent
  pricerequest
  confer
  ask2(numberlist)
  qq(integer,string,string,stringlist)
  newprod
  newproduct(string,real)
  mediadv
  media(string)
  soption(string,string)
  process(integer)
```

```
GOAL

network :-      comline(X),
                X = "NET",
                confer.

standalone :-   comline(X),
                X = "ADVICE",
                showmenu.

CLAUSES

showmenu :-     makewindow(1,32,0,"MARKETING ADVICE SYSTEM",
                0,0,25,80),
                menu(6,15,7,7,
                [ "MEDIA ADVISOR",
                "NEW PRODUCT SCREENING",
                "END PROGRAM"],3,CHOICE),
                process(CHOICE),CHOICE=3,!.

        process(1) :- media.
        process(2) :- newprod.
        process(3).


Confer :-       consult("req.dba",requestbb),
                consult("genstrat.dba",genericbb),
                consult("fact.dba",factbb),
                consult("plan.dba",functionalbb),
                soption("MARKET",M), asserta((plan("MARKET",M),
                soption("DEVELOPMENT",D), asserta((plan("DEVELOPMENT",D),
                soption("ADVERT",A), asserta((plan("ADVERT",A),
                soption("PRICE",P), asserta((plan("PRICE",P).


soption("MARKET","new"):-   strategy("DIVERSIFICATION"),
                        factval("COMPETITIVE PRESSURE",CP),CP<3,
                        factval("PRODUCT LIFE CYCLE",PLC),PLC<3,
                        factval("AVAILABILITY OF RAW MATERIAL",AR),
                        AR<3.


soption("MARKET","old"):-           not(soption("MARKET","new").

soption("DEVELOPMENT,"selective"):-  strategy("GROWTH"),
                                factval("MARKET SHARE",MS),MS<2,
                                factval("GROWTH POTENTIAL",GP),GP<3,
                                factval("COMPETITIVE PRESSURE",CP),
                                CP<3.

soption("DEVELOPMENT","primary"):-   not(soption("DEVELOPMENT","selective"),
                                factval("MARKET SHARE",MS),MS>4.


soption("DEVELOPMENT","none"):-   strategy("DIVEST");
                              strategy("TURNAROUND").

soption("PRICE","undercut"):-     soption("DEVELOPMENT","selective"),
```

```
                              factval("PRODUCT LIFE CYCLE",PLC),PLC>1,
                              priceok.

soption("PRICE","match"):-      not(priceok).

soption("ADVERT","up"):-        strategy("GROWTH"),
                              soption("DEVELOPMENT","selective"),
                              advertexpenseok.

soption("ADVERT","down"):-      not(soption("ADVERT","up")).


priceok :-          pricepresent or pricerequest.

pricepresent :-  request(_,_,"price","decrease",_,"OK").

pricerequest :-  asserta(request("MARK","CM","price","decrease",1,"U"),
                 exit.


newprod :-       cat1,cat2,cat3,cat4,fin.

cat1:-   makewindow(1,32,0,"",0,0,25,80),removewindow,
         ask([1,2,3],Total),
         assertz(score1(Total)).

cat2:-   makewindow(1,32,0,"",0,0,25,80),removewindow,
         ask([4,5,6],Total),
         assertz(score2(Total)).

cat3:-   makewindow(1,32,0,"",0,0,25,80),removewindow,
         ask([7,8,9,10,11],Total),
         assertz(score3(Total)).

cat4:-   makewindow(1,32,0,"",0,0,25,80),removewindow,
         ask([12,13,14,15,16,17],Total),
         assertz(score4(Total)).

fin:-    score1(J),score2(K),score3(L),score4(M),
         SCORE = (J+K+L+M)/17,newproduct(Rating,SCORE),
         makewindow(1,23,71,"",5,2,7,77),
         write(" THE PRODUCT HAS BEEN  "),nl,
         write(" RATED AS : ",Rating),nl.


newproduct("HIGHLY DESIRABLE",SCORE):- SCORE >= 4.5.
newproduct("DESIRABLE",SCORE):- SCORE >= 3.5,SCORE < 4.5.
newproduct("RISKY",SCORE):- SCORE  >= 3,SCORE < 3.5.
newproduct("HIGHLY UNDESIRABLE",SCORE):- SCORE <3.


q(17,"MARKETABILITY","RELATION TO PRESENT DISTRIBUTION CHANNELS",
   " A: requires entirely new channels",
   " B: mostly through new channels ",
   " C: equally between new and existing channels",
   " D: mostly through present channels ",
   " E: entirely through present channels ",
```

```
     " ",
     ["A","B","C","D","E"]).

q(16,"MARKETABILITY","RELATION TO PRESENT PRODUCT LINES ",
     " A: does not fit in with present products ",
     " B: can be fitted but does not fit readily ",
     " C: can be fitted to present line ",
     " D: complements present line, but is not really needed ",
     " E: complements present line which requires more products ",
     " ",
     ["A","B","C","D","E"]).

q(15,"MARKETABILITY","QUALITY/PRICE RELATIONSHIP",
     " A: priced above all competing products ",
     " B: priced above many similar competing products ",
     " C: approximately the same price as competing products",
     " D: priced below most similar products ",
     " E: priced below all competing products ",
     " ",
     ["A","B","C","D","E"]).

q(14,"MARKETABILITY","NUMBER OF GRADES/SIZES ",
     " A: many sizes and grades requiring heavy inventory ",
     " B: several sizes and grades ",
     " C: several sizes and grades but smaller inventories ",
     " D: not very many sizes ",
     " E: few sizes and grades ",
     " ",
     ["A","B","C","D","E"]).

q(13,"MARKETABILITY","MERCHANDISABILITY ,
     " A: no promotional appeal ",
     " B: some promotional appeal but not up to competition ",
     " C: promotional appeal equal to competition ",
     " D: has promotional appeal that marginally beats cpmpetion ",
     " E: has promotional appeal far superior to competition ",
     " ",
     ["A","B","C","D","E"]).

q(12,"MARKETABILITY","EFFECTS ON SALES OF PRESENT PRODUCTS ",
     " A: will reduce sales of profitable products ",
     " B: may hinder sales of present products ",
     " C: should have no effect on present sales ",
     " D: may help present sales ",
     " E: will help sales of present products ",
     " ",
     ["A","B","C","D","E"]).

q(11,"DURABILITY","STABILITY ",
     " A: product will be obsolete in the near future ",
     " B: will remain long enough to recoup initial investment",
     " C: as in B plus 5 years of profit ",
     " D: as in B plus 10 years of profit ",
     " E: product will always have uses ",
     " ",
     ["A","B","C","D","E"]).

q(10,"DURABILITY","BREADTH OF MARKET ",
```

```
    " A: a specialized market in a small marketing area ",
    " B: a regional market with restricted variety of consumers ",
    " C: national market OR wide variety of consumers ",
    " D: national market AND a wide variety of consumers ",
    " E: as in D plus a potential foreign market ",
    " ",
    ["A","B","C","D","E"]).

q(9,"DURABILITY","RESISTANCE TO CYCLICAL FLUCTUATIONS ",
    " A: extreme fluctuations in demand ",
    " B: fluctuations in demand ",
    " C: sales will move with the economy ",
    " D: moderate fluctuations ",
    " E: no fluctuation in demand ",
    " ",
    ["A","B","C","D","E"]).

q(8,"DURABILITY","RESISTANCE TO SEASONAL FLUCTUATIONS ",
    " A: severe seasonal fluctuations ",
    " B: heavy seasonal fluctuations ",
    " C: seasonal fluctuations but can be accommodated ",
    " D: steady sales except under unusual circumstances ",
    " E: steady sales throughout the year ",
    " ",
    ["A","B","C","D","E"]).

q(7,"DURABILITY","EXCLUSIVENESS OF DESIGN ",
    " A: cannot be patented and is easily copied ",
    " B: cannot be patented but only copied by large companies",
    " C: cannot be patented but copied with difficulty ",
    " D: can be patented but patent may be circumvented ",
    " E: can be patented with no loopholes ",
    " ",
    ["A","B","C","D","E"]).

q(6,"PRODUCTIVE ABILITY", "EQUIPMENT REQUIRED ",
    " A: product will require new equipment altogether ",
    " B: largely new equipment but some present equipment ",
    " C: largely present equipment but some new equipment ",
    " D: present equipment but shared with existing products ",
    " E: equipment that is presently idle ",
    " ",
    ["A","B","C","D","E"]).

q(5,"PRODUCTIVE ABILITY", "PRODUCTION PERSONNEL/EXPERTISE ",
    " A: new personnel and new knowledge required ",
    " B: old and new personnel/knowledge equally required ",
    " C: present personnel and knowledge with some exceptions ",
    " D: as in C with minor exceptions ",
    " E: present personnel and knowledge ",
    " ",
    ["A","B","C","D","E"]).

q(4,"PRODUCTIVE ABILITY", "RAW MATERIAL AVAILABILITY ",
    " A: all raw material only available at selected few suppliers ",
    " B: many suppliers but no previous purchasing relationships ",
    " C: from existing suppliers and new suppliers equally ",
    " D: major portion form existing supplier ",
```

```
     " E: all raw material from existing supplier ",
     " ",
     ["A","B","C","D","E"]).

q(3,"GROWTH POTENTIAL ","PLACE IN MARKET ",
     " A: product contributes nothing new to market ",
     " B: product displays minor improvements ",
     " C: product has some appealing characteristics ",
     " D: product displays substantial improvements ",
     " E: new product that fills a need not presently filled ",
     " ",
     ["A","B","C","D","E"]).

q(2,"GROWTH POTENTIAL ","VALUE ADDED COMPETITIVE ADVANTAGE ",
     " A: very low value added, encourages competition ",
     " B: low value added, only larger companies can compete ",
     " C: high value added, only strong companies can compete ",
     " D: high value added, competition only with heavy investment",
     " E: high value added, substantially restricting competition ",
     " ",
     ["A","B","C","D","E"]).

q(1,"GROWTH POTENTIAL ","AVAILABILITY OF END USERS ",
     " A: number of end users will decrease substantially ",
     " B: number of end users will decrease moderately ",
     " C: number of end users will increase marginally ",
     " D: number of end users will increase moderately ",
     " E: number of end users will increase substantially ",
     " ",
     ["A","B","C","D","E"]).

  ask([],0).
  ask([X | Y],S):-
        ask(Y,T),q(X,CatTitle,FactTitle,ES1,ES2,ES3,ES4,ES5,ES6,Choicelist),
        makewindow(1,23,71,"",5,2,7,77),nl,quesnum(CatTitle,Q),W=Q-X,
        write("     CATEGORY : ",CatTitle),nl,
        write("     QUESTION : ",W),nl,
        write("     FACTOR   : ",FactTitle),
        makewindow(1,23,71,"",12,2,12,77),nl,nl,
        menu(16,55,7,7,Choicelist,"",3,ChoiceNo),
        S=T+ChoiceNo,removewindow,removewindow,
        assertz(factval(FactTitle,ChoiceNo)).


mediadv :- makewindow(1,32,0,"",0,0,25,80),
           ask2([1,2,3,4,5,6]),media(MEDIA),
          makewindow(1,23,71,"",5,2,7,77),
           write(" THE MEDIA TYPE IS "),nl,
           write(" GIVEN AS : ",MEDIA),nl.


  qq(6,"ENTER THE PRODUCT TYPE ","PRODTYPE",
        ["Convenience",
        "Impulsive",
        "Shopping",
        "Speciality"]).

  qq(5,"ENTER THE CUSTOMER TYPE ","CUSTTYPE",
```

```
        ["Teenager",
        "Young-Single",
        "Married-Nochildren",
        "Married-Children",
        "Elderly-Retired"]).

  qq(4,"ENTER THE TARGET MARKET ","TARGET",
        ["General",
        "Selective"]).

  qq(3,"ENTER THE GEOGRAPHIC REACH","REACH",
        ["Local",
        "Regional",
        "National"]).

  qq(2,"ENTER THE BUYING DECISION ","BUY",
        ["Rational",
        "Irrational"]).

  qq(1,"ENTER THE ADVERTISING REQUIREMENTS","ADREC",
        ["Audio-Visual",
        "Detail-Info",
        "Shopping Medium",
        "Awareness",
        "Repetition"]).

  ask2([]).
  ask2([X2 | Y2]):-
        ask2(Y2),qq(X2,Title2,Fact2,Choicelist2),
        menu(10,7,7,7,Choicelist2,Title2,1,ChoiceNo2),
        asserta(medval(Fact2,ChoiceNo2)).

media("RADIO") :- medval("PRODTYPE",PT),PT=<2,
                medval("CUSTTYPE",1),
                medval("TARGET",2),
                medval("REACH",R),R=<2,
                medval("BUY",2),
                medval("ADREC",5).

media("TELEVISION") :- medval("PRODTYPE",PT),PT=<2,
                medval("CUSTTYPE",CT),CT>1,
                medval("TARGET",1),
                medval("REACH",3),
                medval("BUY",2),
                medval("ADREC",1).

media("TELEVISION") :- medval("PRODTYPE",PT),PT=<2,
                medval("CUSTTYPE",CT),CT>1,
                medval("TARGET",1),
                medval("REACH",3),
                medval("BUY",2),
                medval("ADREC",4).

media("MAGAZINE") :- medval("PRODTYPE",3),
                medval("CUSTTYPE",CT),CT>1,CT<5,
                medval("TARGET",2),
                medval("REACH",R),R>1,
                medval("BUY",1),
```

```
                  medval("ADREC",3).

media("NEWSPAPER") :- medval("PRODTYPE",3),
                  medval("CUSTTYPE",CT),CT > 1,
                  medval("TARGET",1),
                  medval("REACH",1),
                  medval("ADREC",4).
```

APPENDIX D

Representative Cases Studies and System Responses

VALUE	STRATEGIC FACTOR
A	Price range of Competing Products
A	Technological Change
L	Barriers to Entry
H	Rate of Inflation
A	Demand Variability
H	Competitive Pressure
A	Price Elasticity of Demand
H	Cost of Raw Material
H	Cost of Energy
A	Availability of Raw Material
L	Level of Government Subsidy
L	Government Protection from Foreign Competition
L	Political Stability
L	Pressure from Substitute Products
A	Bargaining Power of Buyers
A	Bargaining Power of Suppliers
H	Growth Potential
H	Profit Potential
H	Financial Stability
A	Level of Technological Expertise
A	Resource Utilization
L	Capital Intensity
H	Ease of Entry into Market
A	Productivity
L	Market Share
A	Product Quality
A	Product Life Cycle
VL	Product Replacement Cycle
L	Customer Loyalty
A	Capacity Utilization of Competitors
L	Level of Technical Expertise
A	Degree of Vertical Integration
A	Operational Efficiency
L	Management Skills
A	Return on Investment
A	Leverage
H	Liquidity
A	Capital Required/Capital Available
H	Cash Flow
A	Ease of Exit from Market
L	Level of Risk
A	Inventory Turnover
VL	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High**

Generated Test Data for Case A1: Ajax Engineering

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION AUG 90

CASE *AJAX ENGINEERING*

SCORES	FS	3.55
	ES	2.45
	CA	2.40
	IS	3.61

VECTOR POSITION 2
VECTOR SLOPE 42

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*very low*
ENVIRONMENT TURBULENCE IS	*average*
COMPETITIVE ADVANTAGE IS	*low*
FINANCIAL STRENGTH IS	*high*

INDICATED STRATEGIC POSTURE IS *Focus/Diversification*

FUNCTIONAL RESULTS

MARKETING

Market	*Niche*
Development	*Selective*
quality	*Improve*

PRODUCTION

Product Cost decrease by	*buying up*
	efficiency up
	quality control up
Product Line	*prune*

FINANCE

Growth by	*protect profitability*
	maintain cash flow

ORGANIZATION

Training	*Improve*

System Response for Case A1: Ajax Engineering

VALUE	STRATEGIC FACTOR
VL	Price range of Competing Products
H	Technological Change
A	Barriers to Entry
L	Rate of Inflation
H	Demand Variability
L	Competitive Pressure
H	Price Elasticity of Demand
H	Cost of Raw Material
A	Cost of Energy
A	Availability of Raw Material
VL	Level of Government Subsidy
VL	Government Protection from Foreign Competition
VL	Political Stability
H	Pressure from Substitute Products
H	Bargaining Power of Buyers
H	Bargaining Power of Suppliers
A	Growth Potential
A	Profit Potential
L	Financial Stability
A	Level of Technological Expertise
H	Resource Utilization
H	Capital Intensity
H	Ease of Entry into Market
A	Productivity
L	Market Share
A	Product Quality
H	Product Life Cycle
L	Product Replacement Cycle
A	Customer Loyalty
A	Capacity Utilization of Competitors
A	Level of Technical Expertise
A	Degree of Vertical Integration
L	Operational Efficiency
L	Management Skills
L	Return on Investment
VL	Leverage
L	Liquidity
VL	Capital Required/Capital Available
L	Cash Flow
L	Ease of Exit from Market
A	Level of Risk
A	Inventory Turnover
H	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High**

Generated Test Data for Case A2: River Textiles

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION AUG 90

CASE *RIVER TEXTILES*

SCORES	FS	2.00
	ES	3.45
	CA	2.70
	IS	3.30

VECTOR POSITION 3
VECTOR SLOPE 67

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*low*
ENVIRONMENT TURBULENCE IS	very high
COMPETITIVE ADVANTAGE IS	*low*
FINANCIAL STRENGTH IS	*low*

INDICATED STRATEGIC POSTURE IS *Divestment/Liquidation*

FUNCTIONAL RESULTS

MARKETING

Market	*Harvest/Retain*
Development	*None*

PRODUCTION

Product Line	*Discontinue*
Capacity	*Cut*

FINANCE

Growth by	*Defer investment*
	liquidate

ORGANIZATION

Personnel	*Defer promotion*
	Retire/Retrench

System Response for Case A2: River Textiles

VALUE	STRATEGIC FACTOR
VL	Price range of Competing Products
H	Technological Change
A	Barriers to Entry
L	Rate of Inflation
A	Demand Variability
L	Competitive Pressure
L	Price Elasticity of Demand
A	Cost of Raw Material
A	Cost of Energy
H	Availability of Raw Material
H	Level of Government Subsidy
H	Government Protection from Foreign Competition
A	Political Stability
H	Pressure from Substitute Products
H	Bargaining Power of Buyers
A	Bargaining Power of Suppliers
A	Growth Potential
A	Profit Potential
A	Financial Stability
A	Level of Technological Expertise
A	Resource Utilization
H	Capital Intensity
H	Ease of Entry into Market
A	Productivity
H	Market Share
VH	Product Quality
A	Product Life Cycle
H	Product Replacement Cycle
H	Customer Loyalty
A	Capacity Utilization of Competitors
H	Level of Technical Expertise
A	Degree of Vertical Integration
H	Operational Efficiency
H	Management Skills
L	Return on Investment
L	Leverage
L	Liquidity
L	Capital Required/Capital Available
VL	Cash Flow
A	Ease of Exit from Market
H	Level of Risk
L	Inventory Turnover
A	Average Collection Period

LEGEND **VL-Very Low, L-Low, A-Average, H-High, VH-Very High**

Generated Test Data for Case A3: Rhino Maize Products

DISTRIBUTED SUPPORT SYSTEM
DIAGNOSTIC SESSION AUG 90

CASE *RHINO MAIZE PRODUCTS*

SCORES	FS	2.11
	ES	3.36
	CA	3.70
	IS	2.30

VECTOR POSITION 4
VECTOR SLOPE 41

GENERAL RESULTS

INDUSTRY ATTRACTIVENESS IS	*high*
ENVIRONMENT TURBULENCE IS	*very high*
COMPETITIVE ADVANTAGE IS	*high*
FINANCIAL STRENGTH IS	*low*

INDICATED STRATEGIC POSTURE IS *Differentiation/Merger*

FUNCTIONAL RESULTS

MARKETING

Market	*Same*
Development	*Selective*
Quality	*Improve*

PRODUCTION

Quality Control	*up*
Product Line	*unique*

FINANCE

Growth by	*Merger with cash provider*

ORGANIZATION

Training	*Improve*

System Response for Case A3: Rhino Maize Products

APPENDIX E

Documented cases studies

Case 1: **Apple Computers**

Sources: Rue, L.W. and Holland, P.G, (1989), Strategic management: Concepts and Experiences, McGraw-Hill,New York.

Hinkle, C.L. and Stineman, E.F., (1984), Cases in Marketing Management,Prentice-Hall, Englewoofd Cliffs, NJ.

Case 2: **Hershey Foods**

Source: Wheelen, T.L. and Hunger, J.D., (1989), Strategic Management and Business Policy, Addison-Wesley, Reading, Mass.

Case 3: **Delorean Motors**

Sources: Rue, L.W. and Holland, P.G, (1989), Strategic management: Concepts and Experiences, McGraw-Hill,New York.

Hinkle, C.L. and Stineman, E.F., (1984), Cases in Marketing Management,Prentice-Hall, Englewoofd Cliffs, NJ.

Case 4: **Delta Airlines**

Source: Hinkle, C.L. and Stineman, E.F., (1984), Cases in Marketing Management,Prentice-Hall, Englewoofd Cliffs, NJ.