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AN INVESTIGATION INTO THE FEASIBILITY OF USING MULTIPLE-CRITERIA DECISION METHODS FOR PLANNING THE STRATEGIC ALLOCATION OF CAPITAL RESOURCES TO EXPLORATION AND PRODUCING ACTIVITIES IN THE DOMESTIC PETROLEUM INDUSTRY.

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AN INVESTIGATION INTO THE FEASIBILITY OF USING
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DOMESTIC PETROLEUM INDUSTRY

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To

My Wife

Muriel Kathryn Myers

and Children

Stephanie and Philip

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CHAPTER I

INTRODUCTION

General

The purpose of this investigation is to examine the applicability of employing multiple criteria for managerial decisionmaking relative to the strategic allocation of capital resources in the exploration and producing phases of the domestic petroleum industry. Exploration and producing, commonly abbreviated E&P, represents one operating segment of the large integrated oil company. Other industrial functions usually include refining, manufacturing, petrochemicals, research and development, transportation and marketing. While these separate entities are carefully coordinated and operated as a single economic unit by the parent organization, each is nonetheless expected to remain competitive within its own physical and financial environment to insure continued existence as an integral part of the system.

Decisionmaking related to the allocation of investment capital signifies a management responsibility frequently associated with the formal planning process in most commercial organizations. Moreover, in view of the long-term implications of capital decisions, each investment strategy as it is adopted in the planning process must strive to accommodate both immediate profitability criteria and established long-range objectives of the firm. Thus a critical aspect of formalized planning, and one of particular interest to this study, is the treatment of future strategic objectives in the presence of more immediate and pressing operational and tactical demands for corporate resources. Before discussing planning characteristics and problems specifically connected to E&P activities in the domestic oil industry, however, it seems fitting to digress briefly and trace the development of formalized planning practices in American industry. Membership in the top 1000 U. S. corporations embraces dozens of oil companies, eighteen of which number among the one hundred largest industrial firms.[1]

Importance of the Planning Process in American Industry

Historically some elements of planning have always

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[1] "The Five Hundred Largest Industrial Corporations," Fortune, Vol. 82, July 1970.

existed in American businesses, as in most other organized activities, since planning is an essential part of the decision making process. In the words of Russell L. Ackoff, "Planning is something we do in advance of taking action; that is, it is anticipatory decisionmaking."[2] Until the post World War II period most business planning, even for very large industrial concerns, was primarily an informal function carried out at various managerial levels without a conscious attempt to coordinate efforts on a company-wide basis. Most emphasis was directed toward what is now regarded as operational planning, specifically that of making forward decisions about activities currently in progress, and planning changes in activities to achieve short-range goals or to meet anticipated fluctuations in the business environment. A formal, comprehensive planning procedure, while it may have been helpful to some companies in the prewar period, was not considered essential; and indeed, probably could not have been economically justified by management in most cases. The span of twenty-seven years from 1945 to 1972 has ushered in a new era of business activity both in the United States and abroad. Competition on every front is greater today than at any previous period in history. Entire new industries have grown to maturity almost over night to add to the complexity of a dynamic and ever-changing business environment.

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[2]Russell L. Ackoff, A Concept of Corporate Planning, (New York: John Wiley and Sons, 1970), p. 2.

Manufacturing was recently surpassed by the services industry as the largest employer of American labor, an event which would have been unthinkable three decades ago.[3] Meanwhile the U.S. population continues to undertake more complicated local, regional and national migration patterns, adding to the increasing uncertainty experienced by businessmen and industrial leaders.

The new business environment offers little encouragement to those who today would prefer to depend on the raw intuitive judgment of a few company officials for the long-term success of an industrial organization. This is particularly true of large corporations operating in diverse and highly competitive fields. However, as a new business climate has evolved over the last quarter century, most successful industrial giants have adapted to it by modifying their internal organizational structures to facilitate the gathering and processing of information for decisionmaking and to take advantage of the innovative skills of their personnel. This restructuring has created what Peter Drucker calls the "knowledge organization," a group of specialists who presently compose a significant portion of industry personnel, and whose primary job is to collect, analyze and disseminate throughout the organization relevant information from all possible

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[3]Judson Gooding, "The Fraying White Collar," Fortune, Vol. 82, December, 1970.

sources.[4] The constant abundance of new information not only aids in forward planning and decisionmaking, but is also credited with stimulating innovative talent leading to invention or the creation of additional new knowledge.

Within the framework of modern domestic and international commerce, the necessity for expanded and more comprehensive planning methods has become increasingly evident. This is supported by the volume of literature now devoted to the field of planning, an increase of several fold over that of ten years ago. Aside from the vast quantities of information and intricate detail which presently characterize industry planning studies, the most noticable change in the planning process has been extending the planning horizon further into the future. The old adage, "cross each bridge as you come to it," is viewed with misgiving by modern industry. Long before a major company reaches any anticipated "bridge" today, the crossing has been charted and simulated dozens of times on its corporate computers, each acknowledged contingency analyzed and re-analyzed, and the entire spectrum of alternative strategies spread before management awaiting their decision. The final decision, of course, is still the prerogative of a handful of men; and in the final analysis may still be intuitive. Nevertheless, it has evolved into a highly disciplined brand of intuition.

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[4] Peter F. Drucker, Preparing Tomorrow's Business Leaders Today, (Englewood Cliffs, N.J.: Prentice-Hall, 1969).

Long-Range Planning - A New Corporate Function

Twenty years ago the concept of a long-range plan was all but unknown. One estimate quoted for 1953 placed the proportion of businesses then practicing any form of long-range planning at approximately twenty percent.[5] Just over a decade has elapsed since IBM first moved to formalize a long-range planning department in 1959; at that time IBM was among the vanguard of American industry in looking toward the future for guidance in making current decisions.[6] During the 1960's the popularity of long-range planning mushroomed and today it is the professed foundation of planning groups throughout industry, in federal government agencies, and in the military.[7] The monumental achievement of landing two Americans on the moon in July, 1969, is in no small way attributable to a superbly executed process of long-range planning.

Knowing that long-range planning exists, however, is of little benefit unless the conceptual basis of what constitutes a long-range plan is known and understood. George A. Steiner has defined long-range planning as "a

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[5]Kjell-Arne Ringbakk, Organized Corporate Planning Systems an Empirical Study of Planning Practices and Experiences in American Big Business, (University of Wisconsin, Doctoral Dissertation, 1968), p. 28.

[6]Ernest Dale, Readings in Management; Landmarks in New Frontiers, (New York: McGraw-Hill, 1965).

[7]George A. Steiner, Top Management Planning, (London: Macmillan Company, 1969), p. 6, 7.

process for establishing long-range goals; working out strategies, programs, and policies to achieve these goals; and setting up the necessary machinery to insure that the company gets where it wants to go."[8] Peter Drucker notes that long-range planning does not deal with future decisions, but rather with the futurity of present decisions.[9] The distinct philosophy of long-range planning conveyed by these authors centers around the term, "long-range," which implies that strategic planning decisions made today are adopted primarily to honor the long-term objectives of the enterprise with short-run goals selected to complement these objectives. Decision requirements of this broader calibre are invariably more difficult to describe than the traditional single-criterion optimization processes often employed to obtain immediate but limited solutions.

Two aspects of long-range planning, not specifically brought forth in the above definitions, are the sequential character of the decisionmaking process and the qualification that most LRP decisions are at least partially reversible. A long-range plan rarely culminates, since a decision to commit resources today is not implemented to achieve a specific benefit twenty years hence; it is implemented to improve the potential for decisionmaking in subsequent time

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[8] Ibid.

[9] Peter F. Drucker, "Long-Range Planning," Management Science, April, 1959, p. 239.

periods.[10] The purpose and sequential character of LRP all but guarantee, therefore, that any long-range plan will remain intact only a fraction of the time period for which it was originally intended. At the end of one to five years it will be superceded by an up-dated LRP and the process begins anew. All this is not without some disadvantage. According to John F. Magee, "In a sequential decision process, such as long-range planning, today's decision depends upon the one which will be made tomorrow. But, because of uncertainty, tomorrow's decision will depend on what we learn between now and tomorrow."[11] All long-range planners to some degree must contend with this dilemma.

While corporate LRP has become immensely popular in recent years throughout American industry, it apparently still leaves much to be desired. Dr. Kjell-Arne Ringbakk, who authored a dissertation on corporate planning systems at the University of Wisconsin in 1968, wrote in a recent paper, "Organized corporate long-range planning is neither as well accepted, nor as well practiced, as suggested in the literature on the subject. Although much planning is done, the effort is often sporadic, it is lacking in coordination, and it is less formalized and sophisticated than much of the

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[10] George A. Steiner, Top Management Planning, p. 18.

[11] John Magee, "Decision Trees for Decision-Making," Harvard Business Review, July-August 1964, p. 127, quoting Pierre Massé.

literature suggests."[12]

Strategic Objectives and Comprehensive Planning

Profit has been the acknowledged motivating incentive of the business profession throughout history. In early societies, supported commercially by small trading companies and one-man shops, the profit motive was very possibly recognized and accepted as the only rational goal for businessmen. This singular objective approach is no longer viable in the technological world of the 1970's. Making a reasonable profit is still necessary for perpetuating the health of any business organization, but so are a host of other things such as growth in assets, market penetration, product dependability, personnel development and customer goodwill, to cite only a few. From time to time any one of these could become more critical to the ultimate survival of a firm than generating profit.

Modern corporations in adopting long-range planning techniques have in essence admitted that success over an extended period depends upon striving for and accomplishing multiple objectives within certain time intervals. The trend of planning is no longer directed toward a confined spectrum of activities, but attempts to consider all pertinent variables found in the system, both internal and external. In discussing this approach to planning George Steiner prefers

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[12]Kjell-Arne Ringbakk, "Organized Planning in Major U.S. Companies," Long Range Planning, Vol. 2, No. 2, December 1969, p. 46.

the use of the expression "comprehensive planning" in lieu of long-range planning because of the narrow connotation of the term, long-range. Steiner's concept of a comprehensive plan is one which combines all categories of plans -- long-range, intermediate-range, short-range, fiscal, budgetary, etc. -- not just as an aggregation of functional plans, but as a system of planning designed for "maneuvering the enterprise over time through the uncertain waters of its environment to achieve prescribed aims."[13] To assist in describing his concept of a comprehensive plan, Steiner has divided business planning into five key dimensions which include the (1) subject, (2) elements, (3) time, (4) characteristics, and (5) organization. The whole can be viewed presumably as the set of all possible combinations of properties of these five dimensions which, as Steiner presents them, are further subdivided for detail as indicated below:

Subject - production; research; financial; .....
Element - policy; program; budget; .....
Time -- long-range; short-range; fiscal; .....
Characteristic -- quantitative; qualitative; formal, informal; .....
Organization - corporate; divisional; departmental; .....

It should be emphasized that the comprehensive planning scheme advocated by Mr. Steiner is a conceptual model, a unified planning process to aspire for, rather than a realized fact of life. The complexity of an authentic

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[13] George A. Steiner, Top Management Planning, p. 12.

comprehensive plan is considered beyond the capability of both planning personnel and data processing equipment found in industry today.[14] Nevertheless, much significant and very valuable planning effort is being conducted.

Planning as a process must begin with agreement on a set of goals or objectives to be achieved. In the literature it is common for business objectives, along with associated planning processes, to be grouped into three levels -- strategic, tactical, and operational -- depending on latitude and generality. Strategic planning is the process of determining the major objectives of an organization and the policies and strategies that will govern the acquisition, use, and disposition of resources to achieve those objectives.[15] Obviously, it must be carried out at the highest levels of management. Tactical planning is setting forth the detailed deployment of resources toward accomplishing multiple intermediate goals necessary for satisfying strategic objectives. Operational planning involves the myriad of immediate measures that must be undertaken to complete the countless minute tasks making up tactical, and finally strategic objectives. In progressing from strategic to operational planning one procedes from the abstract and imaginal of the future to the

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[14]Melville C. Branch, Planning: Aspects and Applications, (New York: John Wiley & Sons, 1966).

[15]George A. Steiner, Top Management Planning, p. 19.

concrete of the present, from a time-span of years to one of days, hours, or even minutes.[16]

Planning Practices in American Oil Companies

The industrial establishment representing a typical integrated oil company is a highly decentralized business entity, both functionally and geographically. Some of the discrete industry functions as noted earlier are exploration and production of crude oil and natural gas, refining of fuels and petrochemicals, manufacturing of plastics and petroleum base products, and transportation, marketing, and research related to all phases of the industry. In addition to the few large well-known corporations, there are dozens of smaller firms in the industry which deal principally in only one or two of these functions. Aside from being involved in a number of diverse industrial activities, major American oil companies find their operations widely scattered throughout this country as well as throughout much of the free world. The combination of these two conditions, function and location, significantly amplifies the need for comprehensive planning; at the same time, however, it magnifies the complexity of achieving such a goal.

It is an accepted fact that long-range planning and economic forecasting techniques are widely employed by the larger oil companies. Corporate or long-range planning

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[16]For definition of time-span, see: Jaques, Elliott, Glacier Project Papers, Heinemann Educational Books, Ltd., London, 1965, Chapter 7, p. 102.

departments can be found at vice presidential levels in the managerial hierarchy of almost every organization chart.[17] From an organizational standpoint in such companies there can be no question as to whether LRP is practiced, only as to whether the planning process is being employed effectively. With the highly functionalized structure of large oil companies, and the inherent autonomy in many of the separate divisions, the likelihood of creating and fostering suboptimization in the planning process is a significant consideration. Suboptimization in planning is the development of procedures which permit each operating segment of the enterprise to come up with some optimal plan of its own, the total long-range plan then being the sum of the individual plans. This common approach is most often referenced under the terminology, "decentralized planning."[18] While it may appear reasonably sound at first glance, considerable evidence has been presented in mathematical investigations of this problem to substantiate that a non-optimal composite plan must always result.[19]

Although there are many indications that the oil

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[17] Harold Stieglitz, Organization Structures of International Companies, Studies in Personnel Policy, No. 198, National Industrial Conference Board, Inc., 1965, p. 103,131.

[18] Zenon S. Zannetos, "Some Aspects of Centralization and Decentralization of Control and Decisionmaking," Management Science, Vol. 12, Series B-C, 1965-66, p. B-49.

[19] Ibid.

industry endorses strategic planning with respect to its various functional areas, there is little in the literature to suggest that any degree of comprehensive planning across major divisions has been formally attempted. Indeed, the same comment can be advanced regarding LRP within any single operating division. For instance, in domestic E&P, the question can be asked whether capital budget allocations to the activities of exploration drilling, development drilling, secondary recovery, and gas processing are made in response to a composite long-range goal for E&P, or in response to various goals developed by each department for each geographic area. Chances favor most oil companies using a planning process whereby the preliminary budget begins as a set of departmental investment objectives; these are subsequently revised and modified by various joint committees as the collective group of budget proposals from all departments proceeds up the hierarchy of approval authority, until a final composite is synthesized for official adoption by the Executive Committee, or Board of Directors. In view of what has already been said, a couple of observations can be made regarding this kind of procedure. First, there is a good possibility that the finalized E&P budget, since it tends to resolve investment conflicts within the E&P division as a whole, will be somewhat superior to a composite set of the original budget requests, especially if the latter were to be arbitrarily trimmed to accommodate available capital funds.

On the other hand, any basis of decisionmaking that created a long-range investment profile for each department originally is destroyed in the compromise process, and the construct of the final adopted budget is unlikely to have a consistent internal rational to serve as the fundamental criterion for an overall long-range plan. This suggests that the comprehensive planning philosophy, advocated by Steiner and others, probably exists in the oil industry more in spirit than in practice at this time.

Even though the industry does not make full use of the concepts of comprehensive planning, there have been several works published which signify that some thought is being given to this area. James R. Collier, a vice-president of Mobil Chemical, in his book, Effective Long-Range Business Planning, discusses the prerequisites to initiating long-range planning procedures, the implications of setting goals and objectives, and the general administering of a strategic business plan.[20] M. D. Ensign and J. F. Wasmuth recently presented a paper to the Society of Petroleum Engineers of AIME wherein they describe the Husky Oil, Ltd. master plan and LRP financial model coordinating the company's production, supply, refining, and marketing functions.[21] A paper by

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[20] James R. Collier, Effective Long-Range Business Planning, (Englewood Cliffs, N. J.: Prentice Hall, Inc.), 1968.

[21] M. Dale Ensign and J. F. Wasmuth, Husky's Long-Range Planning Model, SPE Paper 2991, Society of Petroleum Engineers of AIME, 1970.

B. Wagle describes three models prepared by Esso Petroleum Company, Ltd. which handle limited long-range forecasting and planning tasks required by company management and, in addition, carry out risk analyses and sensitivity studies.[22]

The Planning Environment in Domestic E&P

In the one hundred thirteen years since Drake's oil discovery near Titusville, Pennsylvania, in 1859, more wells have been drilled in the United States than in all other nations combined, accounting for over forty percent of the world's cumulative hydrocarbon production. Oil field development moved westward from Pennsylvania to Ohio and Illinois, then on to the Southwest, Rocky Mountain area and the West Coast. During the last few years several large fields have been discovered in Alaska, marking the first really major American oil discovery in more than a quarter of a century.[23] With the single exception of Alaska, the oil industry in the continental United States must presently be considered in an advanced state of maturity. Development of existing onshore fields is nearly complete as indicated by the unrelenting annual decline in the operating rig count. Offshore exploration and production, already slowed from earlier years of

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[22] B. Wagle, "The Use of Models for Environmental Forecasting and Corporate Planning," <u>Operational Research Quarterly</u>, Vol. 20, No. 3, p. 327.

[23] <u>Petroleum Facts & Figures</u>, (1967 Ed.), American Petroleum Institute.

fierce activity, is now beset with rising costs and the threat of serious financial loss as a result of liability for environmental pollution. Foreign oil, not needed in this country scarcely a decade ago, now constitutes approximately one-fourth of our daily refinery runs.[24] The domestic picture is not totally bleak, but it does represent a drastic turnabout in what was a very dynamic and rapidly growing domestic industry in the years immediately following World War II.

In the growth period of the oil industry the emphasis was on action; getting the job done was all too often more important than how well it was done. As a consequence capital resources, men and equipment were poorly utilized in the race for expansion. As the rate of growth in the domestic industry has slowed in recent years, a more conservative attitude has been developing. Oil companies still laud aggressiveness on the part of their employees as before, but now it is for eliminating waste, cutting costs and making effective tactical decisions to outmaneuver the competition. In this new environment the role of the planner appears to be unlimited. More attention is devoted by upper and middle management to determining the best way the company's resources can be employed, and a greater awareness prevails concerning the future and how current decisions will affect the pattern of company

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[24] "Showdown with Oil Nations--The Stakes in Prices, Markets," U.S. News & World Report, February 1, 1971, p. 43.

operations ten to twenty years ahead.

The conservative attitude in domestic oil affairs is not primarily one of concern, but of increased responsibility. There is no fear that the oil business will decline and gradually fade away; demand for fossil fuels is expected to continue increasing at near geometric rates for decades to come. Besides the billions of barrels of fluid hydrocarbon reserves still available in this country, there are trillions of equivalent barrels of virtually untapped reserves secured in oil shales, tar sands, and coal deposits. Yet, to take advantage of the opportunities available to it, the domestic petroleum industry must be prepared to submit to the rapid change of tomorrow's world. Long-range planning will play a significant part in meeting this challenge.

CHAPTER II

INVESTMENT ALLOCATION IN DOMESTIC E&P

Current Decisionmaking In E&P Investment Planning

The development of a comprehensive process of long-range corporate planning by companies in the petroleum industry will depend on creation of adequate LRP procedures within the many separate activities sponsored by each parent organization. Although the larger international firms face a far more complex task of coordinating the operations of widespread, self-sufficient divisions in the framework of a unified strategic plan, the human resources and information processing capability at the disposal of these industrial giants should more than compensate for the additional difficulty. In general, structuring and adapting a long-range planning process to meet the needs of a multi-division oil company will require a decisionmaking capacity relative to each division for both independent operation and integrated activities. Thus the input information designated to generate a long-range planning strategy (set of sequential planning decisions) for each division autonomously could also be used to develop a composite company strategy at such time a unified corporate plan were contemplated. Understandably the individual and composite long-range plans for each division would seldom result in identical strategies; nevertheless, conflict can usually be avoided by adhering to the hierarchy of the planning process - the company LRP, if adopted by management, would take precedence over the division LRP.

Upon analyzing the procedures of capital resource allocation in E&P, one must acknowledge that the planning methods employed today are far less sophisticated than the comprehensive planning process as it is outlined by Steiner. While oil company procedures are usually formulated in a way to give all the operating functions of the organization equal and impartial consideration, they are not designed explicitly to evaluate the long-term implication of all feasible decisions before selecting the strategy to be adopted. Moreover, rarely is the uncertainty and complexity of the future business environment adequately accounted for by present methods, irrespective of the consequences that subsequent company decisions may create. Capital allocation in E&P is typically attuned to short-range benefits rather than a committal to improved capital allocation decisions over future planning periods. This can best be illustrated by the nature of the criteria which are characteristically employed as "decision rules" in the existing allocation process. A representative list of criteria applicable to domestic E&P decisions might include the following:

(a) Standards for Profitability
(b) Level of Risk by Project
(c) Magnitude of Expected Returns
(d) Size of the Immediate Investment
(e) Uniqueness in Investment Opportunity
(f) Functional Distribution of Investment
(g) Distribution of Investment by Activity
(h) Support for Existing Operations
(i) Honor of Previous Commitments
(j) Preference Arising from Special Considerations.

It may be helpful to expand briefly on each of the decision criteria tabulated above: (a) Comparison of profitability indicators has traditionally been the most popular method for choosing among alternatives in capital budgeting decisions. Selection is made relative to internal rate of return, present worth ratio, payout, or some other economic parameter computed for each candidate project. (b) Risk in past years has frequently been a subjective assessment of the relative probability of success in undertaking a particular project. As such its value was predominantly that of a weighting factor assigned to each available alternative. Modern computers and simulation techniques, however, have enormously enhanced the usefulness of risk analysis through multivariate statistical models and probabilistic information displays, to the extent that it now provides very dependable intelligence upon which to base important managerial decisions.[25] (c,d) The amount of capital required for an investment or the size of expected return on an investment can be very important considerations. They often override more popular decision

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[25] J. E. Walstrom, T. D. Mueller and R. C. McFarland, Evaluating Uncertainty in Engineering Calculations, SPE Paper 1928, Society of Petroleum Engineers of AIME, 1967.

criteria, such as profitability indices, by influencing the collective utility of management decision makers via threat of ruin, or anticipation of uncommon gain.[26] A chance to get in on the ground floor, that is to capitalize on some unusual opportunity, frequently carries with it a willingness by management to tolerate a higher risk than would be acceptable under more normal circumstances. (f,g) The distribution of activities within these functions can be a fundamental instrument in the apportionment of funds for a business organization. In this case appropriations may become more a capitulation to personal influence and fair play in allocating funds, than to a rational division of funds based on perceived company-wide benefits. (h) A certain portion of nearly every capital budget must be spent in support of existing operations. Often funds earmarked for this purpose are regarded as capital replacement rather than new capital investment; even so, the money must be allocated and accounted for out of each year's revenues. (i) It is not unusual for very large projects to have capital expenditures spread over several years prior to completion. In these cases failure to honor the original commitment, once it has been formally initiated, can result in an unsuccessful venture and substantial loss to the company, as well as reflect unfavorably on the competence of its

[26]Paul D. Newendorp, Paul J. Root, Risk Analysis in Drilling Investment Decisions, SPE Paper 1932, Society of Petroleum Engineers of AIME, 1967.

management. (j) In E&P, as in most industrial activities, unusual situations arise from time to time. (Control of pollution could be an example here.) These may require deviation from customary decision criteria when making capital allocations because of abnormal and unexpected constraints imposed on the decisionmaking process.

Some observations can be advanced from reviewing the above set of criteria in the context that it is employed in E&P. First, a systematic procedure for allocating funds throughout a large company, both within and between divisions, would not be easily attainable from the decision process under which the criteria are presently employed. Second, no way is available to investigate the long-range consequences of selected strategies other than on a subjective or intuitive basis. Finally, it appears that no formal method can be realistically synthesized from the existing procedures to composite the many functions into a unified long-range domestic E&P strategy.

The Need for a Long-Range Approach to E&P Investment Planning

Even though a true comprehensive planning process involving detailed integration of physical assets, financial resources, personnel administration, governmental policy, economic growth, market competition and so on, may not be available to business and industry for at least another decade, the first steps toward this planning objective have already been taken. Since the success of an industrial firm is closely associated with its profitability and the growth of its financial assets, which in turn are dependent primarily upon the strategic employment of its capital resources, most planning effort to date has been dedicated to defining strategies for budgeting investments. Very few of these, unfortunately, can be regarded as techniques oriented toward long-range planning. The two most popular decision methods currently found in E&P literature are probabilistic decision trees[27] and investment simulation programs.[28] Both are used to assist management in selecting among multiple investment alternatives, and both provide a methodology to deal with future cash flows as well as the evaluation of decision situations expected to develop in later time periods. The decision rule applied to arrive at such decisions is essentially a combination of risk and profitability, that is, simply a method of establishing a revenue versus chance rating for each proposal competing for funds. Barring interference from other of the E&P decision criteria mentioned earlier, allocation of funds can be made to various proposals relative to assigned risk and profitability levels until available funds are exhausted. Normally no attempt is made by matter

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[27] Harrison L. Townes, Using Economics in Exploration Decisions, SPE of AIME Refresher Course No. 3, Oklahoma City, Section, Session No. 12, December 5, 1967, p. 8.

[28] Arthur W. McCray, Evaluation of Exploratory Drilling Ventures by Statistical Decision Methods, SPE Paper 2220, Society of Petroleum Engineers of AIME, 1968.

of formal procedure to predict such long-term consequences as the final investment profile may impose on the overall E&P activity of the company, or to analyze the long-range inter-functional significance of the selected set of capital allocation decisions.

Within the domestic E&P activity a large number of functions are simultaneously carried out; while these are not always distinctive physically, they tend to be regarded independent of one another from the financial planning aspect. For the purpose of this research a selected group of ten E&P functions will be considered; many of these are further subdivided in order to magnify the scope of the allocation problem. The ten functions are subsequently represented as twenty-nine activities, all entirely accommodated within E&P. This list of functions can be considered typical for the E&P division of any large oil company, although it is not necessarily exhaustive for E&P activities in general.

I. Exploration for Oil and Gas
   1. Continental Geophysical Activity
   2. Offshore Geophysical Activity
   3. Hard Rock Geophysical Prospecting

II. Lease Acquisition
   4. Oil and Gas Leasing
   5. Aquisition of Mining Rights

III. Exploration Drilling
   6. Continental Exploratory Drilling
   7. Offshore Exploratory Drilling
   8. Deep Exploratory Tests

IV. Primary Development
   9. Continental Oil Development Drilling
   10. Continental Gas Development Drilling
   11. Offshore Oil Development Drilling
   12. Offshore Gas Development Drilling

V. Secondary Development
 13. Secondary Recovery Projects
 14. Pressure Maintenance Projects
 15. Improved and Tertiary Recovery
 16. Steam and Insita Combustion
 17. Natural Gas Facilities
 18. Gasoline Plant Construction

VI. Operating Equipment
 19. Equipment Replacement
 20. Modernization and Computerization
 21. Installation of Remote Control System

VII. Non-Oil and Gas Operations
 22. Oil Shales - Tar Sand
 23. Uranium Activities
 24. Coal and Coal Fluids
 25. Other Energy Sources

VIII. Research and Development
 26. R & D Related to Oil and Gas
 27. R & D Related to Mining and Extraction

IX. 28. Public Responsibility

X. 29. Personnel Development

The problem of developing a means for allocating capital resources solely within the domestic E&P segment of a large oil company is evident from the number of functions and activities involved. To further add to this complexity, each activity can be associated with more than one geographic area, which may cause its relative utility to management to vary significantly depending on location. The three-dimensional diagram in Figure 1 illustrates schematically the relationships that can exist between activities, geographic areas, and forecast indicators of E&P "states of nature." In a large oil company the domestic E&P division is itself a subsystem of the total corporate structure which is similarly shown in three-dimension by Figure 2.

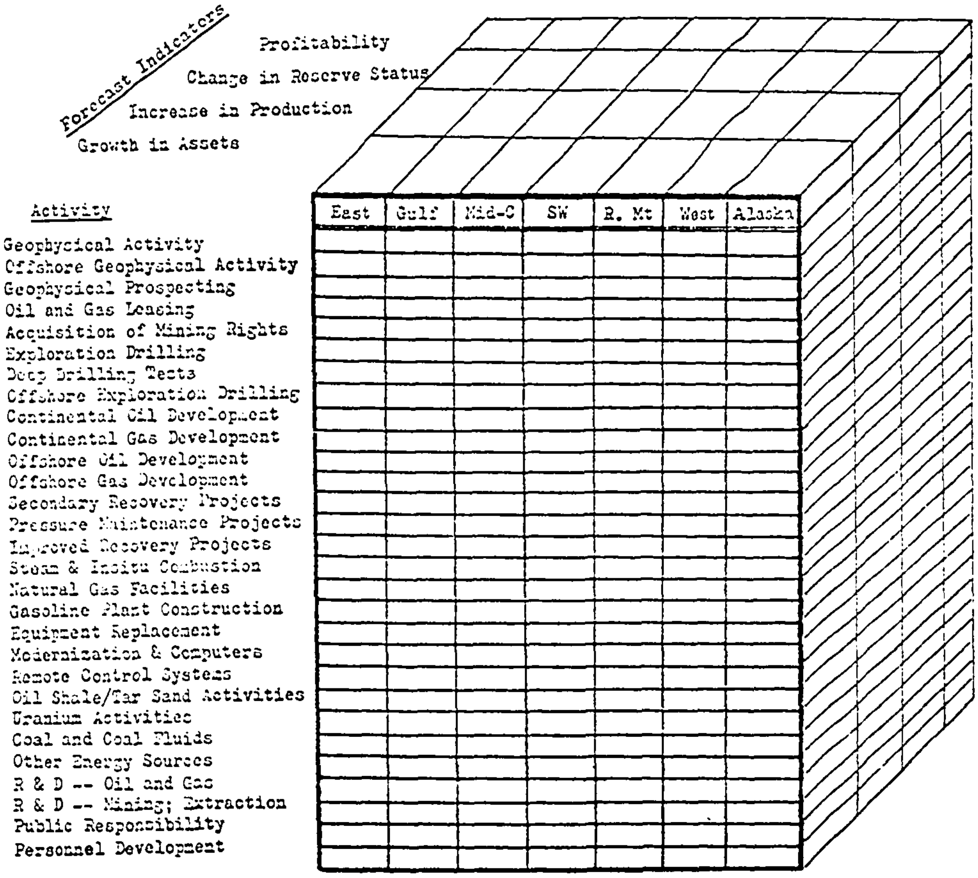

Figure 1. E&P Activity - Environment Matrix

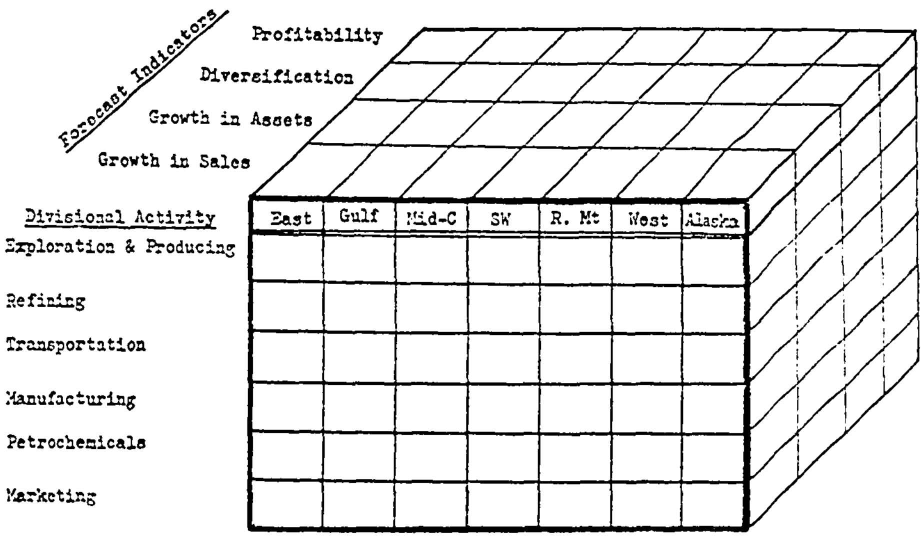

Figure 2. Division - Environment Matrix

As suggested by Figure 1 potential strategies for employing capital resources in E&P is virtually unlimited if each multivariate element is regarded a stochastic function of the assets committed. But finding a procedure to converge on a single strategy for a optimal, or even good-enough, allocation of capital resources relative to some complex decision rule will obviously present a problem. Nevertheless, if planning personnel are to be able to evaluate a company's potential for growth and its flexibility for change in future years, they must develop a capability for isolating and analyzing all available alternatives and mapping successive strategies to keep the company oriented toward the objectives set by its management.

Research Objective -- Selection of E&P Allocation Strategies

In previous sections an effort has been made to point out some of the shortcomings of the planning process for capital allocation in E&P as currently practiced by the domestic petroleum industry. The reader need not be reminded that the lack of a unified method to deal with long-term implications in the current planning process is not unique to the oil business. The general applicability and importance of this problem is indicated by C. W. Churchman:

> It is commonplace that the objectives one seeks to attain at a future moment of time may very well be the means for other objectives lying even farther ahead in the future. A man may seek a promotion as a step to in his more ultimate goal of the presidency; or, a firm may try to increase its share of a market in order to attain a larger profit over a five-year period.

> But the suggested general standard for value measurements makes no commitment concerning future objectives. Specifically, it does not include in the definition a knowledge about the probability of all possible outcomes over time, but only of the outcomes of a specific time. Quite clearly a person who knew the chances of success for outcomes at T_1, but not for outcomes at a later time T_2, might make different choices from a person who knew the chances relative to both times.[29]

It would be advantageous in E&P decisionmaking to be able to consider explicitly all facets of a company's organization, personnel, financial status, present operations and future opportunities before undertaking any tactical or strategic planning commitments. Such might be the objectives in a genuine comprehensive planning process. A more limited approach, and one that seems compatible with current planning efforts, is to relate the allocation of capital resources by top management to the growth and financial objectives of the E&P organization. This would represent a significant step in the direction of introducing the strategic aspect into E&P planning. Ostensibly, should a workable long-range procedure for arriving at investment planning decisions be developed for one area of a company's planning effort, the technique could eventually be expanded and modified to encompass the overall planning process.

Specifically, the approach of this research effort is the study of decisionmaking related to capital resource allocation in the domestic oil producing industry, subject

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[29] C. West Churchman, Prediction and Optimal Decisions, (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1961).

to the use of multiple-criteria decision rules, and structured analytically in the configuration of a strategic (long-range) planning process. Use of the LRP format can aid in the recognition and analysis of potential benefits in handling complex planning decisions beyond that of routine investment planning techniques which are too often limited to profit-maximization type solutions. Toward achieving this objective five basic steps were identified initially and used to guide the investigation. These steps were:

1) To interpret the general philosophy of long-range planning, and to probe the literature for analytical techniques appropriate for application to long-range planning in domestic E&P.

2) To explore the use of multiple-criteria in decision-making, isolating those applications which appear particularly adaptable to planning decisions in the oil industry.

3) To design a heuristic LRP model, and by way of computer simulation, to synthesize the findings in steps (1) and (2).

4) To employ the LRP model as a research tool for investigating simulated company growth, profitability, and competitive position, using various combinations of rational multiple-attribute decision criteria.

5) To compare and analyze the effect of the proffered LRP approach relative to more common planning methods under similar environmental conditions; and to judge, based upon obtained results, the relevancy of various decision criteria to the practical planning effort being carried out in domestic E&P.

When trying to communicate about long-range planning one must begin by defining what LRP actually represents. There are, of course, many differing opinions on this expressed in the literature, some of considerable variance with others, depending upon whether the author is visualizing a "concept" or describing a "process."

Conceptually, long-range planning is the act of making a current decision primarily on the basis of what is expected to develop in the future. The planning goal is oriented toward a desirable state or set of conditions in some environment other than the one at hand. In essence, it emphasizes the necessity to subjugate immediate benefits in lieu of long-term objectives. When looking at the budgeting of capital resources, for example, planning can be portrayed on a linear time scale as shown in Figure 3.

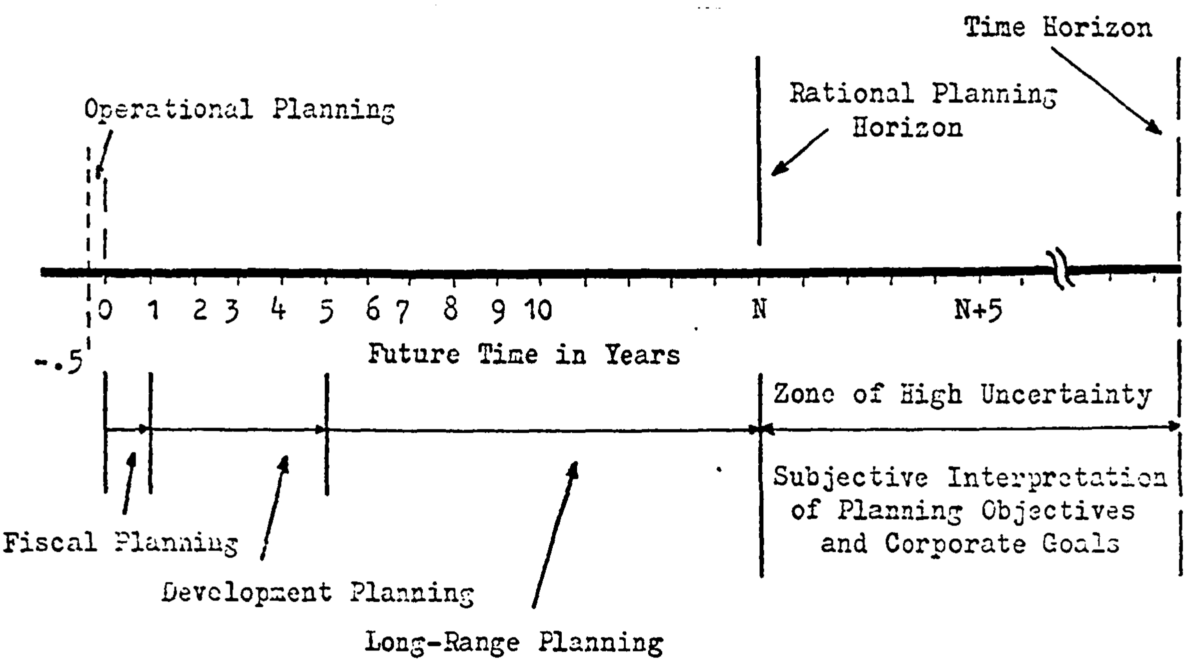

Figure 3. Forward Time Scale Capital Resource Planning

In this diagram the present is "-.5" (June 1, 1972) and management is faced with deciding what portion of capital funds, expected to be available at time "0" (January 1, 1972), should be allocated to activities A, B, C, ... for budgeting purposes. The planning periods identified are operational, fiscal, development, and strategic. Operational planning constitutes the day by day planning which takes place continuously; its horizon may range from a few days to several months. Generally, it only influences future capital planning with regard to the projected status of each activity at time "0," the point where the fiscal plan goes into effect. The fiscal plan, moreover, is the set of company projects and programs destined to be financed with the 1972 budget and to be carried out in the time interval between "0" and "1". Since this interval is normally the only one for which management will authorize commitment of capital funds at this time, it is the one of specific interest to this research effort.

However, in strategic planning, one cannot stop here. The time period from "1" to "5" is labelled the development planning period. Many emerging business opportunities, appearing in the industry today for the first time, will be capitalized on in the years from 1974 to 1978; management must therefore plan now to be in a position of taking advantage of such opportunities. The last interval, that from "5" to "N" on the time scale, is denoted as the strategic or long-range planning period. A company's status when the "planning horizon" is reached "N" years hence will largely depend on how effectively its capital resources were employed during previous years. The planning horizon represents a fixed point in the future at which time certain goals are entertained for accomplishment. Obviously, as one strives to predict further and further ahead in time, uncertainty continues to increase until it finally becomes a limiting factor. The "time horizon" shown on the diagram can be regarded as that point in the future beyond which complete uncertainty prevails.

On the other hand, when one finds strategic planning characterized in the context of a process, the physical sequence of activities required to execute adopted long-range strategies is usually described. A very general schematic for making capital allocation decisions under a LRP format is illustrated in Figure 4.[30]

This flow chart shows long-range (strategic) plans to be highest on the planning hierarchy followed by development, fiscal, and operational plans in that order. The planning process depicted in Figure 4 agrees in principle with the conceptual representation in Figure 3. In understanding both the "concept" and the "process" of long-range planning, one must keep in mind that LRP is sequential in nature,

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[30] M. F. Cantley, "A Long-range Planning Case Study," Operations Research Quarterly (Special Conference Issue, 1969), p. 7.

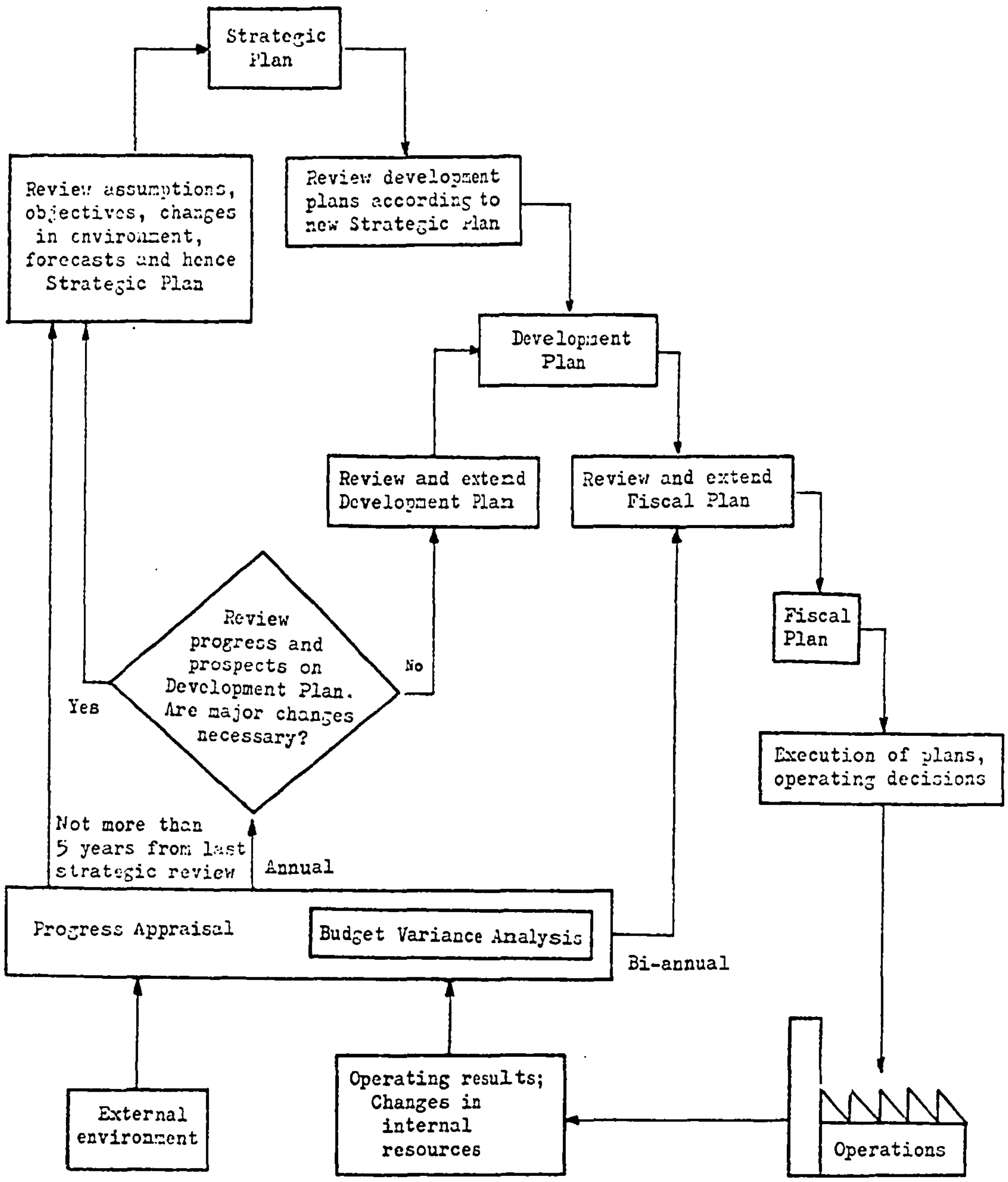

Figure 4. Planning As A Process

that in practice it will be superceded by a revised long-range plan before ever nearing completion.

One of the difficulties in developing a long-range planning model is the dependence on using forecast information for future changes in key factors of the environment. The increase in uncertainty with its corresponding decrease in validity is another important consideration in evaluating future strategies. Various methods have been proposed to overcome this difficulty, although none it seems has received universal acclaim. The problem can be illustrated as in Figure 5 for a forecast profit range of drilling shallow gas development wells in the Mid-Continent area projected over the next thirty years. Profitability runs from certainty, the estimated valuation of wells just completed or proposed for drilling in the very near future, to complete uncertainty, a period so far in the future that nothing in evidence can support a prediction.

Upon reviewing the list of ten decision criteria applicable to E&P given earlier, it appears unlikely that many capital allocation decisions in the industry are based on a single criterion; nearly all arise from multiple criteria. Such is true for most complex decisions required of industrial managers. Choosing among alternatives characterized by multiple properties is termed a multi-goal, multi-criteria, or multi-dimensional decision problem.[31] The more definitive nomenclature of "multiple-attribute" has been assigned to this type of decision problem by K. R. MacCrimmon because the existence of multiple attributes are to be expected when

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[31] K. R. MacCrimmon, "Decisionmaking Among Multiple-Attribute Alternatives: A Survey and Consolidated Approach," RAND Memorandum 4823, (Santa Monica, California: The RAND Corporation, December, 1968), p. 4.

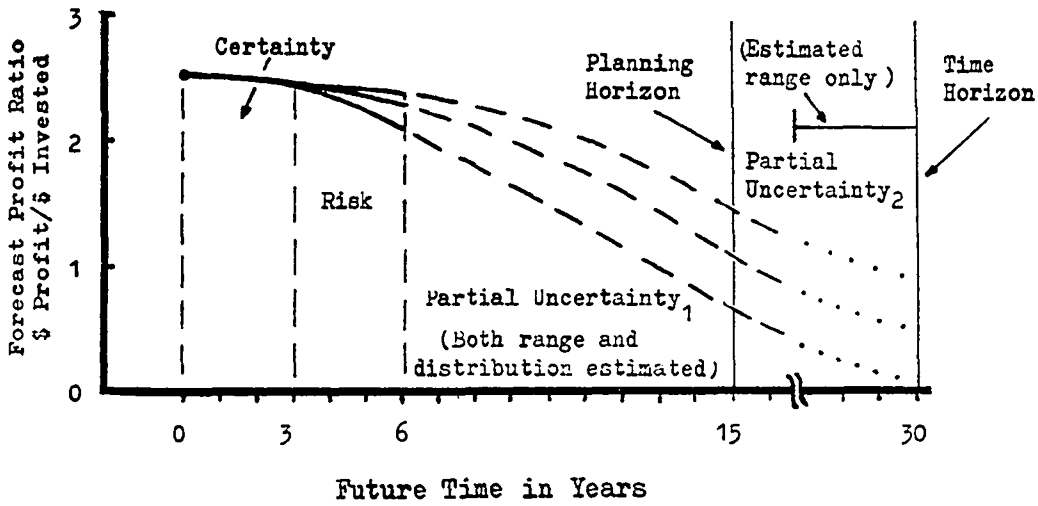

Figure 5. Forecast Profitability of Shallow Domestic Gas Wells

Certainty Zone -- deterministic; for all practical purposes the value is assumed to be precisely known.

Risk Zone -- The value is uncertain, but an exact probability distribution is known, or assummed to be known.

Partial Uncertainty$_1$ Zone -- the value is uncertain and the exact probability distribution is unavailable. However, the range of the variable, together with its probability distribution, is assumed estimateable within $\pm$ 20% accuracy based on the information at hand.

Partial Uncertainty$_2$ Zone -- the value is becoming very uncertain; sometimes a rough estimate of range and distribution can be made; at other times only a judgment on the range can realistically be made.

the decisionmaker has multiple goals, and is thus tempted to engage multiple criteria.[32] The term "multiple-attribute" makes direct reference to specific characteristics of the

[32] Ibid.

alternatives themselves, i. e. sets of performance parameters, components, factors, or properties within which the decisionmaker is offered a choice under the criterion. For instance, just being informed that the criterion for a particular selection process is to be "profitability" does not in itself ordain a definite preference among various alternatives. A performance standard of profit must first be established for the anticipated range of circumstances surrounding the decision to be made. Hence, in multiple-criteria decisions, the final selection is made by implementing a systematic process for comparing certain attributes representing each of the criteria being used.

From the above, then, it can be inferred that the existence of multiple goals will tend to require multiple decision criteria; and that these in turn give rise to multiple sets of attributes upon which the final choice or decision is predicated. Planning decisions, particularly those involving long-range planning in industry, are almost always committed to multiple goals or objectives. Decision rules for multi-goal planning, therefore, must embrace more than a single criterion such as maximization or minimization of one attribute. Although many widely applicable multi-attribute decision methods are available and acknowledged by decision theorists, few have been given more than limited use in formalized decisionmaking procedures. In many decision situations combinations of these can be applied concurrently to generate solutions or strategies that simultaneously satisfy multiple-attribute objectives. A select few criteria, discussed in the literature and quite useful when evaluating multiple-attribute decisions, are dominance, satisficing, utility theory, tradeoff, and non-metric scaling.[33] The merits of these and others are reviewed in this investigation with respect to their use in making long-range allocation decisions in the domestic petroleum industry.

Additional Considerations to Strategic Investment Planning Decisions

Any investigation of long-range planning decisions regarding the allocation of capital funds in an integrated oil company necessitates the design of a planning procedure by which future consequences of current decisions can be systematically examined and available strategies ranked for selection. With the benefit of insight into the probable effects of various feasible allocation programs, it appears reasonable that a set of strategic decisions can be obtained by the application of appropriate decision criteria. To accomplish this objective an approach was devised whereby the essential elements of several components requisite to the LRP process were combined into one procedure. The components included:

1) Integration of the "long-range" aspect into a planning format;

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[33] *Ibid.*, p. 17.

2) Acquisition and utilization of required information forecasts;

3) Design and operation of a dynamic company planning model; and

4) Formulation of multiple-attribute decision techniques within the planning system.

The first of these, that of objectively making provision for long-range considerations in the planning process, represents a major digression from the planning procedures in common use today. Inherent with this planning aspect is the dilemma mentioned earlier that today's planning decisions are subject to what one assumes one will be doing tomorrow, but tomorrow's actual decisions will be largely dependent on today's decisions coupled with what transpires in the interim.[34] Probing the future under normal circumstances is a nebulous task fraught with the menace of uncertainty and error. Using long-range projections as the basis for a capital allocation planning scheme might be regarded somewhat hazardous financially, especially if planned commitments were considered irreversible. While this is not the case, it does call attention to an important feature of every long-range planning analysis -- that of determining an appropriate planning horizon. By some this is considered as the point in future time beyond which forecast information may be disregarded without

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[34]Peter F. Drucker, "Long-Range Planning," Management Science, April 1959, p. 239.

adverse effect on the LRP process.[35] When one sets out to establish what length of time might provide a rational planning horizon for any significant endeavor, for example that of eliminating air pollution, the complexity of the problem is evident. The planning horizon problem has been frequently noted and even investigated in the literature;[36] yet it has never been solved to the complete satisfaction of those actually responsible for company planning functions.

Long-range planning decisions in industry are implemented to achieve proposed objectives, not in the present business environment, but in one more remote, conceived for some subsequent period in time. If this is to be successful, an intelligence concerning the expected future state of the business activity under consideration must be made available for use in the planning process. Normally forecast information from both public and sources internal to the organization yields much of the required data. Missing information frequently can be estimated or extrapolated by taking into account present levels and trends.

The planning process is a systematic procedure for arriving at planning decisions, in the theoretical sense a kind of programming model involving the human thought

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[35] Kode M. Iyengar, A Methodology to Determine Rational Planning Horizon in Corporate Long-Range Planning, Columbia University Doctoral Dissertation, 1967.

[36] Ibid.

process.[37] It is an abstract system, either descriptively or mathematically representing the interaction of certain physical, biological, and/or social components in the real world system. Thus, in order to investigate the long-range planning process, as in this case for investment capital allocation in domestic E&P, it is first necessary to conceptualize specifically what the process should entail and then construct an abstract model of it. Designing a planning model in this fashion generally falls under the classification of heuristic programming. According to Herbert A. Simon heuristic programming is

> . . . a point of view in the design of programs for for complex information processing tasks. This point of view is that the programs should not be limited to numerical processes, or even to orderly systematic nonnumerical algorithms of the kinds familiar from the more traditional uses of computers, but that the ideas should be borrowed also from the less systematic, more selective, processes that humans use in handling those many problems that have not been reduced to algorithm.[38]

A LRP model, as an abstract representation of an actual system, may be further classified relative to properties inherent in its design. For example, it may be static or dynamic, an open or a closed system, and exhibit

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[37]Robert C. Meier, William T. Newell, and Harold L. Pazer, Simulation in Business and Economics,(Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1969), p. 150.

[38]Herbert A. Simon, The New Science of Management Decisions, (New York: Harper-Row, Inc., 1965), p. 30.

either steady-state or transient behavior. The quality of modeling effort can often be measured using several features among which are the basis of the model construction, the similarity of the model and system being represented, and the validity of obtained results.[39] However, in the case of economic models, planning models, and others of similar nature, these features are less effective for judging potential merit than in the case of physical models.

Finally, the formulation of any process for making LRP decisions to be used in industry must include the capability of resolving multiple-objective management goals in generating recommended strategies. The handling of multiple objectives requires utilization of either a multi-criterion objective function or a combination of objective functions having some predetermined hierarchial arrangement. Converging on an optimal or at least acceptable solution is further complicated by the necessity of analysis over multiple time periods. For the investigation of decisions related to capital allocation strategies in domestic E&P, a determination was first required as to which of the various decision criteria proffered in the literature were most applicable to the specialized managerial decisions arising in E&P.

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[39] Robert C. Meier, William T. Newell, Simulation in Business and Economics, p. 294.

CHAPTER III

AN OVERVIEW OF PLANNING METHODOLOGY

Due to the nature of the proposed research effort, and the fact that it does not fit uniquely into a single academic discipline, the literature review to follow briefly explores relevant publications from more than one field. Important areas of inquiry were perceived to include long-range or strategic planning, multiple-criteria decisionmaking, and planning models including simulation. Selected contributions from these three subject areas are reviewed here in conjunction with allocation planning requirements in domestic E&P and serve as a foundation for this investigation.

Long-Range Planning: Theory and Applications

Since long-range planning, strategic planning, or corporate planning, as it is variously called in the literature has been recognized for only about fifteen years, nearly all source documents in the field are relatively new. Many writers such as Melville C. Branch, George A. Steiner, Peter Milton, Kirby Warren and Russell Ackoff treat long-range planning as an integral part of a very complex if not somewhat visionary process known as comprehensive planning. Comprehensive planning, as suggested in Chapter I, strives to combine all aspects of the organization and its environment into a single unified composite planning process. By contrast, the majority of authors deal with planning concepts and procedures related to specific practical applications, directing their work toward narrow but generally achievable objectives.

To serve as any kind of effective guide for establishing a workable planning system today, George A. Steiner proposes that planning may be described from four viewpoints.

1) The basic generic view of planning as dealing with the futurity of present decisions.

2) Planning as a process which establishes objectives; defines strategies, policies, and sequences of events; defines the organization to implement the process; etc.

3) Planning as a philosophy of projective thought . . . an attitude, a state of mind.

4) And, planning viewed in terms of a structure . . . a comprehensive and uniform program of plans reaching out over time.[40]

The process of "planning," as an organizational activity, tends to fall into three categories which include effort preliminary to planning, the actual planning step, and implementation and review of resulting operations.

A useful approach to long-range planning developed from practical experience is that of "gap analysis" and "gap

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[40]George A. Steiner, Top Management Planning, Chapter I.

filling." Michael J. Kami, who initiated long-range planning at IBM and later joined Xerox Corporation as Vice-President of Corporate Planning, is primarily responsible for popularizing the gap analysis concept. Kami's understanding of the LRP process is one whereby a systematic procedure is used to modify the present state of affairs more nearly to a blueprint of one's own choosing. To do this the planner must first determine where his organization stands at present and what future path it will likely follow if no forward planning is initiated. The difference between the desired position of the firm at the planning horizon, and where it will be under the latter set of conditions, is referred to as the "gap." Figure 6 below illustrates the idea of gap filling in the planning process.[41]

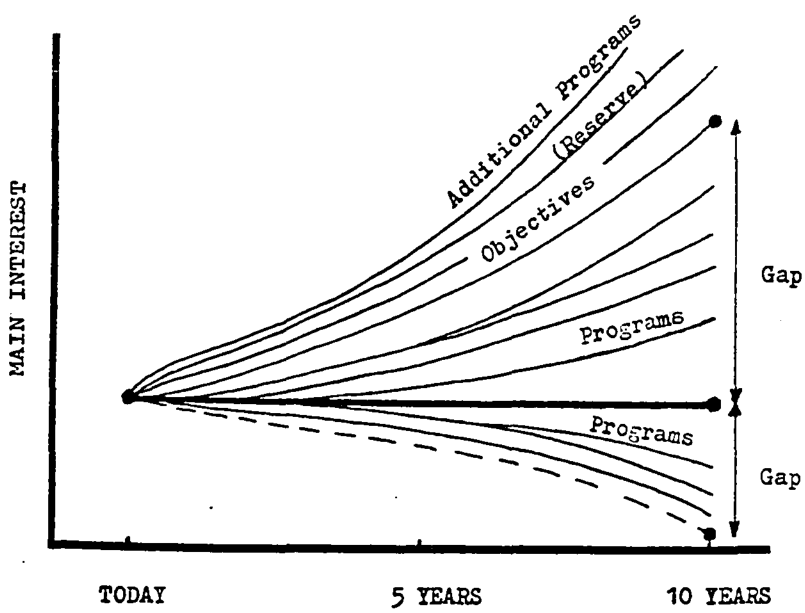

Fig. 6. Gap Analysis

[41]Michael J. Kami, "Gap Analysis: Key to Super Growth," Long Range Planning, Vol. 1, p. 44.

The challenge for long-range planning thus comes from finding and developing the necessary proposals to fill the projected gap. Moreover, based on experience with this process, Kami recommends that at least double the revenue-producing proposals required to fill the gap should be generated to hedge against possible error. Once the planning has been completed, company-wide commitment to the adopted programs is of primary importance in guaranteeing its success. While gap analysis on the surface appears wontonly heuristic and certainly less sophisticated than many other planning techniques, its application in industry has apparently produced results. IBM has been among the fastest growing of America's large corporations; similarly, Xerox is a leading growth company among the intermediates.

Before reviewing some of the quantitative methods in strategic planning, it may be worth noting the dialectic approach proposed by Richard O. Mason of the University of California. Mr. Mason contends that planning decisions are overly influenced by a "management-world-view" of the environment, representing for the most part a stereotype response based on the deeply rooted vestiges of cultural heritage found within most corporate decisionmakers. They are, nevertheless, the ones responsible for making the assumptions upon which planning procedures are formulated, and as such are instrumental to the outcome. This is true even in large planning groups where sophisticated techniques, as mathematical programming, and complicated technologies, as operating a complex computer system, tend to obscure the assumptions underlying their use. Hence the aura of "mystic" serves to give credibility to a plan beyond that which it rightfully deserves.

The dialectical approach is one that examines a situation completely and logically from two different points of view. In planning, the favored or optimal "plan" is pitted against a "counterplan," which also possesses the attributes of being feasible, politically viable, and generally credible in the organizational context. The view-of-the world for which the counterplan is "optimal" is then specified. The dialectical procedure has advocates from both points of view oppose each other, debating point by point the significance of available evidence. The purpose of the argument session is to bring out "hidden assumptions" that may be invalid, and to substitute, where possible, more relevant assumptions. The ultimate goal of the dialectical method is not to destroy the original plan, but to replace it with an improved plan when warranted.[42]

One of the more theoretical treatments of planning systems is given in a paper by Martin K. Starr, published in Management Science, December, 1966.[43] Professor Starr

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[42]R. O. Mason, "Dialectical Approach to Strategic Planning," Management Science, Vol. 15, April 1969, p. B-403.

[43]Martin K. Starr, "Planning Models," Management Science, Vol. 13, No. 4, December 1966, p. B-115.

acknowledges the fact that despite the volume of literature pertaining to planning and planning models, the associated terminology has very little substance, and taxonomy in the field is almost non-existent. He notes, while the function of planning is presumably related to managerial decision-making, what management needs in planning models has little counterpart to what has been delivered so far.

In view of the lack of conceptual definition of planning, which could be expressed in analytic terms, Professor Starr has attempted to formulate a workable definition of this function in terms of unit decisions, while carefully making a distinction between plans and policies. Briefly, his definition is as follows:

BASIC BUILDING BLOCKS-UNIT DECISIONS

Decisionmaking activities can be dichotomized:

A. The formulation of policies (a term we shall reserve for static situations) and

B. The development of plans (reserved for dynamic cases).

The base components of a plan or a policy are simple unit decisions. The unit decision includes the following elements and considerations:

1. At least two strategy alternatives: $X_i (i = 1,2,\ldots,m)$. Strategy variables are controlled by the decisionmaker.

2. One or more "effective" environments: $Z_j (j = 1,\ldots,n)$. Environmental variables are not under the decisionmaker's control

3. A set of results such that one or more relevent outcomes can be observed for each combination of a particular strategy and a particular environment: $Y_{ij} = f(X_i Zj)$.

4. The environments Z_j are distinct and mutually exclusive with respect to the index, j. Accordingly, for each environment we can attempt to estimate its probability of occurrence: Prob (Zj) and by defination, $\sum j$ Prob (Zj) = 1. Consciously or otherwise, a degree of belief is always associated with these estimates. It can be so low as to prohibit action on these estimates in which case other procedures must be found. (This typifies a major class of planning models.)

5. For each unit decision, only one of the members of the finite set of strategies $X_i (i = 1,2,...m)$ can be used at a time.

6. A particular decision criterion is invoked to select the one strategy from the total set of available alternatives which will maximize the decisionmaker's achievement of his objectives. (E.g., select X_i which produces MAX $\sum j(Y_{ij})$ Prob (Z_j); this assumes sufficient believability of the estimated probabilities for Z_j).

7. The plan or the policy is a set containing one or more unit decisions. Planning sets can be differentiated from policy sets by observing that the former are associated with evolving or dynamic environments and the latter with static ones.

PLANS VS. POLICIES

By identifying different temporal configurations of the decision elements, Z j, the total class of decision models can be divided into plans and policies. When the same type of unit decision problem occurs repeatedly it can be categorized as a policy situation. This phrase, 'the same type of unit decision' is intended to convey the idea that the initial decision elements are stable--remaining relevant and unchanged as the decision problem repeats itself. As a result, the same decision functions continue to be applicable over time. Under sufficiently repetitive circumstances (defined in terms of frequency and time span) it becomes economically reasonable to formulate a policy.[44]

After defining the concept of planning in terms of unit decisions, Professor Starr proceeds to characterize three specific quantitative approaches including fully-constrained, partially-constrained, and threshold-constrained planning systems. The relationships between these can best be illustrated by use of his descriptive chart:

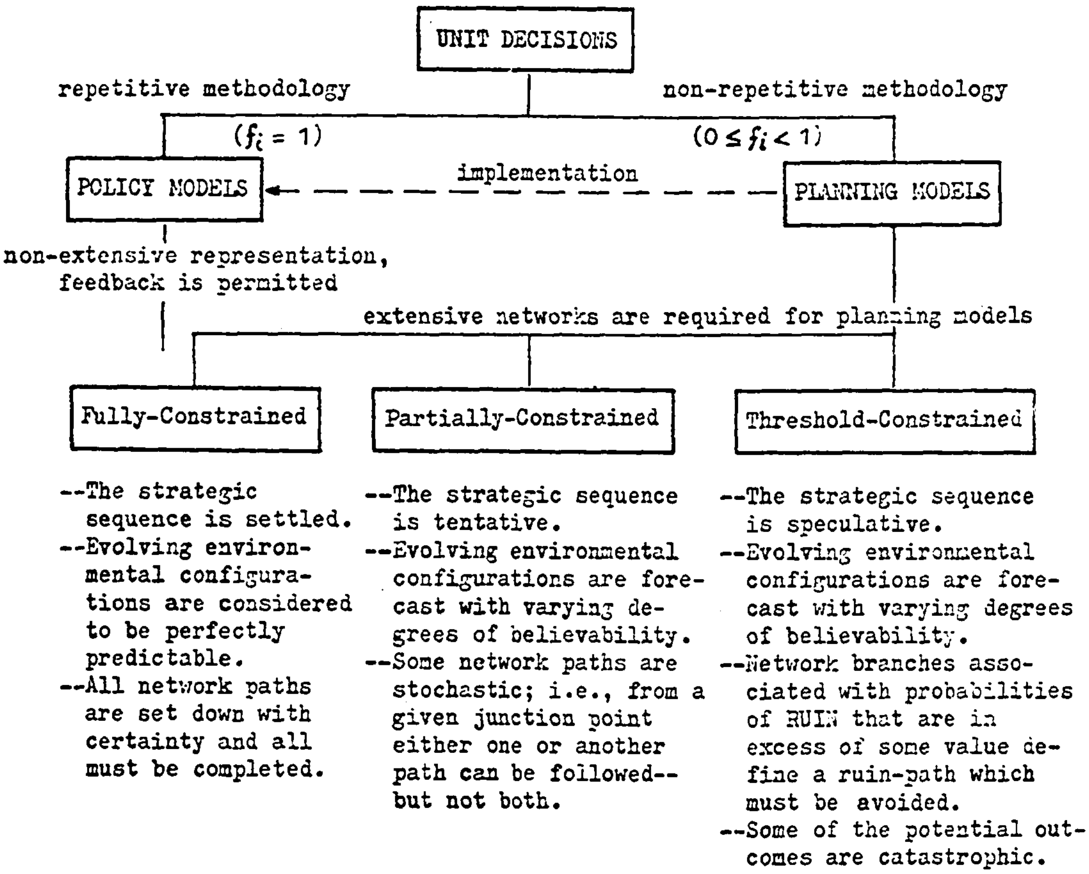

Figure 7. Unit Policy and Planning Models

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[44] Ibid., p. B-117.

Fully-constrained planning models are networks consisting of fixed, single path strategic sequences designed to cope with an evolution of environments that can be predicted with certainty. As a result, the one best plan or "optimum" solution may be selected from among the enumerated alternatives. Analytic techniques which have application in fully-constrained models include PERT, Gantt planning charts, dynamic programming, simulation, and game theory.

Partially-constrained planning models differ from their fully-constrained counterparts in the sense that they are vulnerable to a risk spectrum of environmental conditions, that is to say, there is no "best" way of achieving the objectives. For non-trivial cases there is no unambiguous optimal strategy; hence, every strategy (commitment) is to some degree susceptible to regret. Inclusion of the stochastic element introduces both realism and flexibility into the model, but greatly amplifies complexity due to the existence of multiple paths. Generally, one of two approaches can be taken for solving this type of problem. Either the planner accepts the coexistence of various strategy chains without knowing for certain which one will be followed, or he reduces the model to a fully-constrained system by means of the expected value criterion. In the former case, all the analytic techniques applicable to fully-constrained models can presumably be employed. Solution of the multiple outcome problem, however, is limited to probabilistic network techniques, such as stochastic versions of PERT or GERT, and simulation methods.

Threshold-constrained planning models are a special sub-class of partially-constrained planning models where severe ruin-type penalties can threaten the system. The primary feature of a threshold-constrained system is the requirement for a criterion that will not tolerate strategies containing ruin-prone nodes in excess of a certain prescribed probability cut-off. Objective functions of threshold-constrained type models therefore are intimately associated with extreme value analysis, a field where meaningful research is just beginning to evolve.

In summarizing Professor Starr indicates that planning models have a long way to go yet in gaining full acceptance in the field of management science, even though more attention is now being focused in this direction. Most success to date has been achieved with the fully-constrained class of models primarily due to their greater simplicity. The problems of search and scheduling, along with the underlying risk base, have made partially-constrained and threshold-constrained models far more difficult to handle analytically.

John F. Magee in his book, Industrial Logistics, has devoted a chapter to the discussion of long-range and logistic planning in which he approaches long-range planning through the decision-tree concept using conditional decision analysis. He justifies this approach with the comment:

> Today's decisionmaking sets the stage for tomorrow's decisionmaking. Decisions must not be made today just to maximize earnings or meet some such criterion in the light of a rigid specification of future conditions. Today's decisions must balance economy, capitalizing on profit opportunities that exist, with flexibility - the capacity to react to future circumstances and needs. Today's decisions concerning long-term commitments, therefore, must be based on an understanding of the "conditional" decisions that may be made in the future, conditional on the combined effects of today's decision and the outcome of intervening chance events or competitive moves.[45]

Magee patterns his LRP decision-tree in the traditional format, allowing for the usual decision nodes followed by chance nodes. However, an explicit time increment is assigned between specified successive decision nodes to indicate the future period in which the resulting strategy-decisions must be made. Each time increment thus amounts to a "stage" in the decision problem. The objective is to systematically work backwards through the decision-tree to evaluate the alternatives of the initial decision node, or "decision point." The decision-tree is reduced by following the three steps below:

Step 1: Evaluate each of the alternatives at the final-stage decision points. Select the alternative with the largest net present value. Assign this value to the position.

Step 2: Evaluate each decision alternative at the next preceding stage.

Step 3: By the repeated application of this process --the process of rolling-back--to each stage of decisions, the value of each alternative at the first stage can be found.

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[45] John F. Magee, Industrial Logistics (New York: McGraw-Hill Book Co., 1968), Chapter 12.

An example of a partial LRP decision-tree is shown by Figure 8.

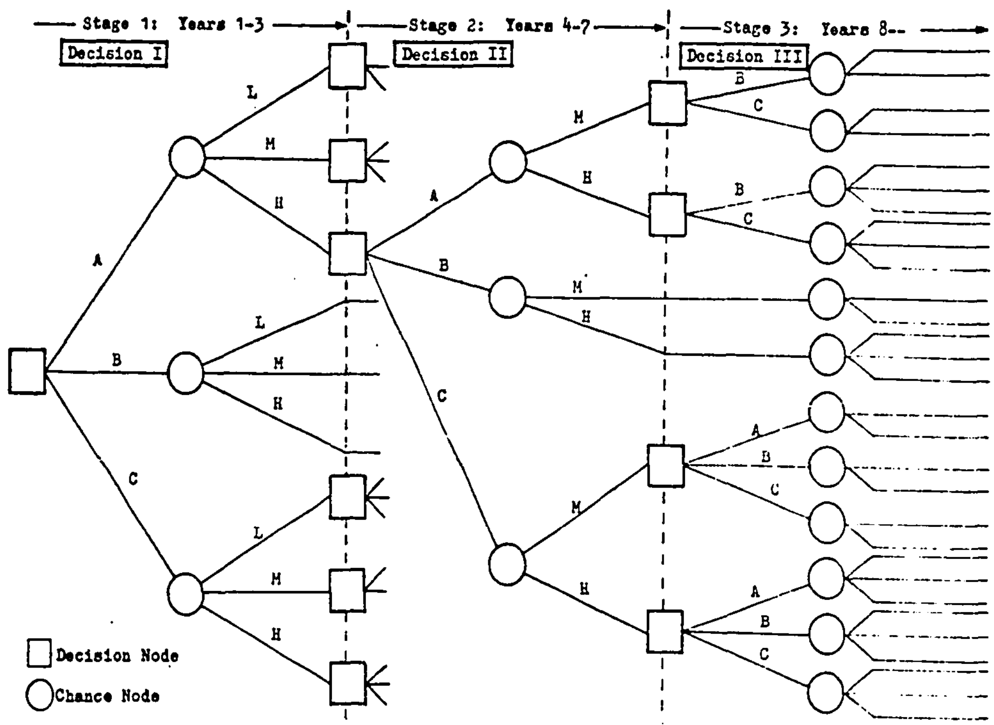

Figure 8. Long-Range Planning Decision Tree

Due to the time value of capital, net present value is used at succeeding decision nodes from initial decision point. While most decision-tree examples found in the literature are discrete representations, the author notes that continuous chance variables can be handled readily using decision-tree methods. In situations where probability density functions become too complex to evaluate analytically, Monte Carlo methods can be applied. He points out that the limitations in drawing up a complex decision-tree analysis is not the task of computation, but the capacity of analysts to imagine alternatives and think out the implications of various possible choices.

A long-range planning application currently in use in the petroleum industry is the Husky Long-Range Planning Model reported by M. Dale Ensign and J. F. Wasmuth. Husky Oil, Incorporated, is a small but fully integrated domestic oil company which produces 37,000 barrels per day of oil and gas equivalent, has four refineries in Canada and the U.S. with a throughput of 45,000 barrels per day, and operates 1,600 service stations. In addition Husky controls completely or in part a briquet and charcoal products firm, a steel fabricating and warehousing company, and investments in exploration drilling and petroleum pipelines. The Husky model is a simulation model consisting of a system of six separate computer programs which compile forecast data from multiple departments and subsidiaries into a finished long-range plan. The model itself does not optimize, however. The simulation is normally repeated 25 or 30 times with variations in input data before a plan is accepted. The sequence of the long-range planning process is given by flowchart in Figure 9.[46] Output from the Husky model includes a financial profile for production and marketing operations, a reading of the "gap" between the current company position and future goals, and an indication of what must be done to achieve these goals.

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[46]M. Dale Ensign and J. F. Wasmuth, Husky's Long-Range Planning Model, SPE Paper 2991, p. 3.

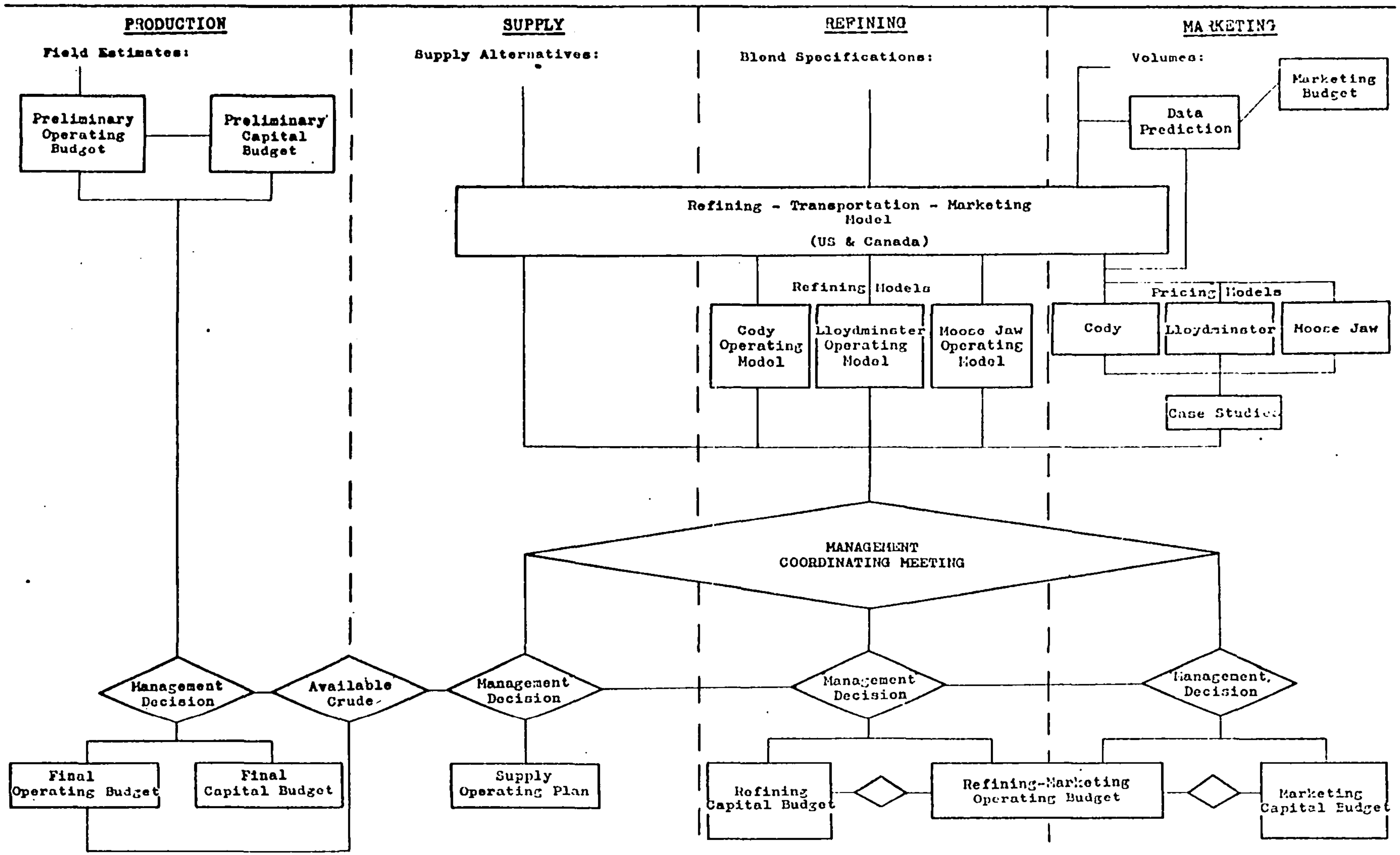

Figure 9. A Master Plan For Planning Husky Oil Operations

It also determines the most favorable method to finance and reduce tax consequences to obtain a desired earning per share.

Finally, a informative publication evaluating decision techniques with respect to long range planning is RAND Memorandum-6151-NASA prepared by S. H. Dole, G. H. Fisher, E. D. Harris, and J. Strong, Jr. The study was carried out to investigate problems involved in performing an effective long-range planning function within NASA. The authors define long-range planning as, "The conscious determination of courses of action to achieve prescribed goals," and identify the following salient aspects:

1) The process begins with an examination of long-range objectives and develops from them concrete goals for achievement.

2) It establishes policies and strategies.

3) It examines the future consequences of present decisions and provides an overall frame of reference for making decisions.

4) Above all, it considers a complete spectrum of figure alternative strategies and courses of action.

5) It does this for extended time periods.

In making this survey Dole et al. analyzed the major approaches and techniques of modern systematic analysis to ascertain their potential usefulness in the long-range planning function. A summary of those approaches, techniques, and methodologies having a definite or possible application in NASA are set out in a summary reproduced from RAND Memorandum-6151:63.[47]

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[47]S. H. Dole, G. H. Fisher, E. D. Harris and J. String, Jr., "Establishment of a Long-Range Planning Capability," RAND Memorandum 6151, September 1969, p. viii.

(Technique will be useful (✓), may be useful (x))

Planning Process Phase	Models	Simulation	Worth Assessment	Delphi	Resource Analysis	Uncertainty	Suboptimization	Tradeoffs	Relevance Trees	Forecasting	Decision Analysis	Operational Gaming	Systems Synthesis	Scenarios	Cohort Analysis
Input				✓					✓						
Projection															
Budgetary	✓			✓	✓	✓									
Political-technological	✓			✓		✓			✓	✓		x	x	x	x
Creative															
Evaluation of objectives	✓		✓	✓				✓				x	x		x
Alternative strategies, programs	✓			✓	✓	✓			✓		x	x	x	x	
Analytical															
Selection of criteria			✓	✓											
Comparison of programs	✓	✓	✓	✓	✓	✓	✓	✓			x	x	x	x	

Figure 10. Summary of Analytical Techniques Useful In Long-Range Planning

The Rand publication emphasizes that in long-range planning analytical approaches and techniques should be selected such that areas of uncertainty can be identified and properly handled. The variance of uncertain parameters in a long-range planning problem can frequently produce both triviality and ruin in the same model system. If the probability of occurrence is more or less objective, and determinable analytically, uncertainty can be treated by Monte Carlo techniques. If not, some suggested alternative methods include "best estimate analysis," "worse case analysis," and "a fortiori analysis." Appropriately the model should employ all three of these in combination.

While many authors have contributed to the conceptualization and definition of the strategic planning process, the publications referenced above were found most helpful in the construction of a long-range planning model for domestic E & P. Initially the planning concepts of Steiner, Kami, and Mason provided the theoretical base upon which the model was conceived. Model descriptions by Starr, Magee, and others were invaluable to the analytic formulation of a computer simulation program to represent capital resources in E & P. There were no references located, however, where the concepts of long-range planning had been combined with the analytical techniques cited and applied to exploration and producing operations in the domestic oil industry.

Methods of Multiple-Criteria Decisionmaking

It appears unreasonable that in complex business undertakings a single objective can be made the sufficient basis for an intricate network of organizational activities, yet most of the decision methods one employs routinely today operate on that supposition. Analytic procedures help to maximize profit, minimize costs, maximize expected utility, minimize risk, find the shortest route, isolate the critical path, or find solutions to a dozen or so other one-criterion optima. Many of these techniques are ingenious in their formulation and prove extremely useful when applied in the context of limited decision problems. In the opinion of this writer, however, it is an over-simplication of the long-range planning task to suggest that strategic decisions can be realistically resolved through attempts to optimize on a single business objective.

In reviewing the literature for decision procedures where more than one criterion can be employed, the most pertinent reference located was a paper by K. R. MacCrimmon. Many of the multiple-criteria decision functions outlined in the memorandum were adapted for this investigation. MacCrimmon discusses in considerable depth decision situations where alternatives are characterized by multiple attributes, and procedes to identify the various methods proposed for handling this type of problem. Although the goals toward which the decisionmaking activity is directed are usually reserved for a particular level in an organization's planning effort, the process itself is always a response to a perceived decision problem.[48]

According to MacCrimmon, when a decision problem has multiple attributes, it becomes a multi-criteria or multidimensional decision problem wherein the decisionmaker is attempting to satisfy multiple objectives by selecting a specific strategy. An abstract representation of the

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[48] K. R. MacCrimmon, RAND Manual 4823, p. 2.

multiple-attribute problem can be given as the Cartesian product,

$$A_1 \times A_2 \times A_3 \times \ldots. \times A_n,$$

where each attribute is an element of the product. Thus the generic form of a particular alternative, $(a_1, a_2 \ldots, a_n)$ will be denoted as A^j. The set of all alternatives thus becomes a subset of the Cartesian product of attributes, for example,

$$\{A^j\} \subseteq \prod A_i$$

and the i^{th} attribute of the j^{th} alternative can be denoted as a_i^j, a_i being the values which A_i may assume.

In focusing on methods to handle multiple-attribute decisions MacCrimmon divides the methods into those which treat "full dimensionality," those which treat "single dimensionality," and those which lie between these two extremes. Full dimensionality refers to dealing with each dimension (attribute) separately and independently, each with respect to its own criterion. Conversely, single dimensionality is a result which comes from collapsing the original "n" attributes into a one-dimensional space, thus transforming the problem to single-criterion. All partial reductions of the original problem fall into the intermediate category. The most difficult problems, of course, are those of full dimensionality; they require a tremendous amount of calculation, and, by nature, rarely exhibit a unique solution.

Full dimensionality problems normally are treated by two methods, dominance and satisficing. In a comparison of all alternatives, if one alternative has superior attribute values for all attributes, it is said to "dominate" the others. In fact, if it is at least as good as n-1 attributes and superior only in the remaining one, it is considered the dominant alternative or strategy. This can be shown mathematically;

Let $(a_1, a \ldots, a_n)^1$ equal Strategy I

$(a_1, a_2, \ldots, a_n)^2$ equal Strategy II

Then Strategy II is said to dominate if,

$$a_i^1 \leq a_i^2 \text{ for all } i,$$

and $a_i^1 < a_i^2$ for some i.

In the case of satisficing, the decisionmaker supplies minimal attribute values that will be acceptable relative to each of the attributes. By applying these criteria, a set of acceptable strategies is obtained. The minimal requirements are then changed such that the set of acceptable strategies is further reduced. This procedure continues until the alternative strategies are narrowed to a single choice:

Let minimal attribute values $(g_1, g_2, \ldots, g_n)$ be defined on $\prod A_i$.
An alternative A^j is satisfactory only if $g_i \leq a_i^j$, for all i. From the remaining subset of $\prod A_i$, an alternative A^j is now satisfactory

only if $g_i \leq a_i^j$, for all i, and so on, until a single A^j is selected.

When looking at single dimensionality, several procedures are found in common usage. Among these are the maximun and maximax criteria, lexicography, additive weighting, effectiveness index, and utility.

The maximin criterion can be abstractly stated by the formula:

$$A^* = \underset{\{A^j\}}{\text{maximizer}} \quad \min \bar{a}_i^j$$

where $\bar{a}_i^j$ is the point value assigned to the i^{th} attribute of the j^{th} alternative

To illustrate this procedure MacCrimmon uses the example of choosing among chains, where as the saying goes, "a chain is only as strong as its weakest link." The Maximin criterion would examine the weakest link of each, and then choose the chain (alternative, or strategy) with the strongest weakest link.

The maximax criterion may be similarly stated as:

$$A^* = \underset{\{A^j\}}{\text{maximizer}} \quad \max \bar{a}_i^j$$

Here the decision would be to go with the strategy that has the strongest strongest attribute.

Another technique often found useful is that of Lexicography. By this method the decisionmaker specifies that the attribute which is to him most important. If the highest value of this attribute appears in only one strategy, the decision process is finished. If not, the strategies containing non-optimal values of this attribute are dropped, and the procedure passes to the second most important attribute. The process continues in this way until a decision is reached:

$$\{A^*\} = \underset{\{A^j\}}{\text{maximizer}} \quad a_i^j$$

If no decision, then

$$\{A^{**}\} = \underset{\{A^*\}}{\text{maximizer}} \; a_2^j$$

Barring a decision in the second set,

$$\{A^{***}\} = \underset{\{A^{**}\}}{\text{maximizer}} \; a_3^j$$

and so on, until

$$\{A^{***\cdots *}\} = \underset{\{A^{**\cdots *}\}}{\text{maximizer}} \quad a_\theta^j$$

In decision problems where the attributes have values which are both numerical and comparable, the method of additive weighting can often be used. In this case each attribute value is multiplied by a certain predetermined "weight" for that attribute and is summed with the weighted values of the n-1 other attributes for every possible strategy. That strategy containing the highest weighting average is then selected:

$$\{A^*\} = \text{maximizer} \sum_i W_i \cdot a_i^j$$

$$\{A^j\}$$

where W_i is the weighting factor for attribute i.

The biggest single difficulty with the weighted average technique, assuming all attributes are numerical and comparable, is finding an acceptable basis on which to assign weights. Except in rare circumstances this must be done in a subjective or intuitive manner.

The effectiveness index approach is analogous to that of additive weighting, except that the additive requirement is generalized to include multiplication, exponentiation, or other types of mathematical operations. In this model the form of the functional relationship is of paramount importance, although the same conditions which apply to the additive weighting model are also reservations in this procedure. The freedom of functional representation permits analysis where logical weighting or effectiveness index models is as follows:

$$A^* = \underset{\{A^j\}}{\text{maximizer}} \; f(A_1, A_2 \ldots, A_n)^j$$

Finally, for decision problems where a high degree of uncertainty is involved, the use of utility theory may offer the best approach. In this case it is the possible outcomes which are considered rather than the multiple attributes. A utility function is assigned to the outcomes of various uncertain events; subsequently, the effect of these events on each of the alternatives, as a whole, can be evaluated. The alternative, or strategy, with the largest expected utility function is thus selected. The difficulty with the utility theory approach stems from the presumed ability of the decision-maker to rationally assign a utility function to an uncertain event relative to alternatives that possess numerous attributes, in such a way that a decision will ensue.

A third categoty of multiple-attribute decision procedures includes those of intermediate dimensionality methods which make use of more than a single attribute, but less than the full complement of "n" attributes. Two intermediate procedures are considered by MacCrimmon, tradeoffs and non-metric scaling. The conconcept of a trade-off can be visualized if one will assume the criterion on a specified attribute is relaxed, that is its minimum acceptable value arbitrarily reduced by a certain amount, then the resulting increase in value of some other attribute becomes a basis for decision. These are several ways by which trading-off can be approached. For instance, trade-offs within a group of several attributes can be specified such that a subset of equivalent alternatives or strategies is generated; selection within this subset is then carried out on the basis of the remaining attributes, usually by one of the procedures mentioned earlier. Another way is to form $\binom{n}{2}$ trade-offs between pairs of attributes. Assuming a management policy to consider eight categories of business planning, there would be $\binom{8}{2}$ combinations of pairs, or 28 possible trade-offs. It should be noted, in this case, that the dimensionality of the problem has not been reduced. Moreover, if anything, it is rendered more complicated for the decisionmaker, not to mention the fact that some of these trade-offs may not be feasible or even relevant. One other complicating factor is that one trade-off ratio will usually not be valid over the entire ranges of any pair of attributes; if not, then considering multiple ratios becomes an additional drawback. For the most part, trade-off information has been used with greatest success in attributes represented by cost or other monetary functions. Trade-offs can be formally defined as ratios of partial derivatives of two attributes, being obtained either directly as individual ratios or from a function relating the attributes.

Assume $f(A_1, A_2, \ldots, A_n)$ where f is a general weighting function. The trade-off ratio between attributes A_i and A_j is given by

$$\left.\frac{\partial A_i}{\partial A_j}\right|_{A_1 = a_1, \ldots, A_n = a_n} = \frac{(\partial f/\partial A_j)_{A_1 = a_1, \ldots, A_n = a_n}}{(\partial f/\partial A_i)_{A_1 = a_1, \ldots, A_n = a_n}}$$

The second intermediate dimensionality method reported by MacCrimmon is that of non-metric scaling. In this procedure the decisionmaker, using judgments about the relative importance of various attributes, first reduces the number of attributes from n to k where $1 < k < n$. His second step is then to choose the best alternative considering only the k attributes in the reduced problem. Obviously there are numerous ways this approach can be carried out. One way proposed is to rank attribute values and compare alternatives by pairs in such a way that the "k" most favorable alternatives may be isolated. Next by specifying an "ideal" strategy, one with the most preferred values of each attribute, the best alternative can be selected by picking the one closest to the ideal. This can be stated as follows:

Assume there be q alternative strategies. Rank the $q(q-1)/2$ pairs in the manner below,

$A^1A^2 < A^1A^3 < A^2A^3 < \ldots\ldots,$

where $<$ means "is more similar than."

Let $X_A j$ be the point in t dimensional space representing alternative A^j; thus $X_A j$ has coordinates $(X_A 1, X_A 2, \ldots X_A t)$.

The distance between any two points $X_A j'$ and $X_A j''$ is defined to be

$$d_A j'_A j'' = \sqrt[r]{\sum_1^t (X_A j' - X_A j'')r}$$

where $r \geq 1$ For $r = 2$, $d_A j'_A j''$ becomes the Euclidean metric. The idea here is to construct the smallest space of dimension k so the distance rankings are congruent with the similarity rankings:

$$d_{A^1A^2} < d_{A^1A^3} < d_{A^2A^3} < \quad \ldots\ldots$$

Therefore, in this k dimensional space we specify an ideal

$A\# = (X_A\#1,\ X_A\#2, \ldots, X_A\#k)$ and identify A^* such that:

$$A^* = \underset{\{A^j\}}{\text{minimizer}}\ D_{A\#A^j}$$

MacCrimmon's presentation of the above multiple-criterion decision methods applies primarily for the deterministic case where attribute values are assumed fixed. An extension of most of these procedures, however, is possible under conditions of uncertainty.[49] As mentioned earlier, many of the multiple-criterion decision methods discussed in this section were adapted to the E & P LRP model used in the current investigation. A summary of the specific methods employed is presented in Chapter V with attribute descriptions provided in Appendix C.

Planning Models and Simulation

Since the task of examining the relevancy of various decision criteria to the strategic allocation of resources in the domestic oil industry was the principal objective of this investigation, a LRP model design was needed upon which logical comparisons could be made and the results somehow corroborated with respect to reality. Upon analyzing the dynamic behavior of complex interacting systems, it is often found that no formal mathematical procedures are available through which the problem can be given adequate analytical treatment.

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[49]*Ibid.*, Chapter III.

This is especially true for decisionmaking in long-range planning when such realistic considerations as a stochastic environment owing to future uncertainties, and the propensity of managers to simultaneously strive for multiple objectives, are not arbitrarily eliminated from the decision problem to make it manageable with existing analytic tools. A less rigorous and frequently heuristic approach for solving complex problems, which has received most attention since electronic computers have been in general use, is that of systems simulation. Although precise mathematical solutions are rarely possible through use simulation techniques, the information thus gained is sufficiently accurate for many purposes.

In contemplating the construction of a strategic planning model, one is ultimately drawn into the realm of heuristic programming, since few available analytical procedures appear to embrace the conceptual framework of long-term decisionmaking. Moreover, the structural approach in any one planning model may be more a function of characteristics of the individual decision situation than it is of the decisionmaking process itself. Robert C. Meier, William T. Newell, and Harold L. Pazer in their book, Simulation in Business and Economics, categorize heuristic methods into three subsets depending on whether they are problem-oriented, human-oriented or computer-oriented, as shown in Figure 11.[50]

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[50]Robert C. Meier, William T. Newell, and Harold L. Pazer, Simulation in Business and Economics, p. 149.

The heuristic methods associated with each category include (1) heuristic problem solving, (2) simulation of human thought, and (3) artificial intelligence. Obviously not all decision problems will fit into a single classification. In fact, most business planning applications, where complex systems are involved, might be expected to incorporate all three subsets in any non-trivial solution technique.

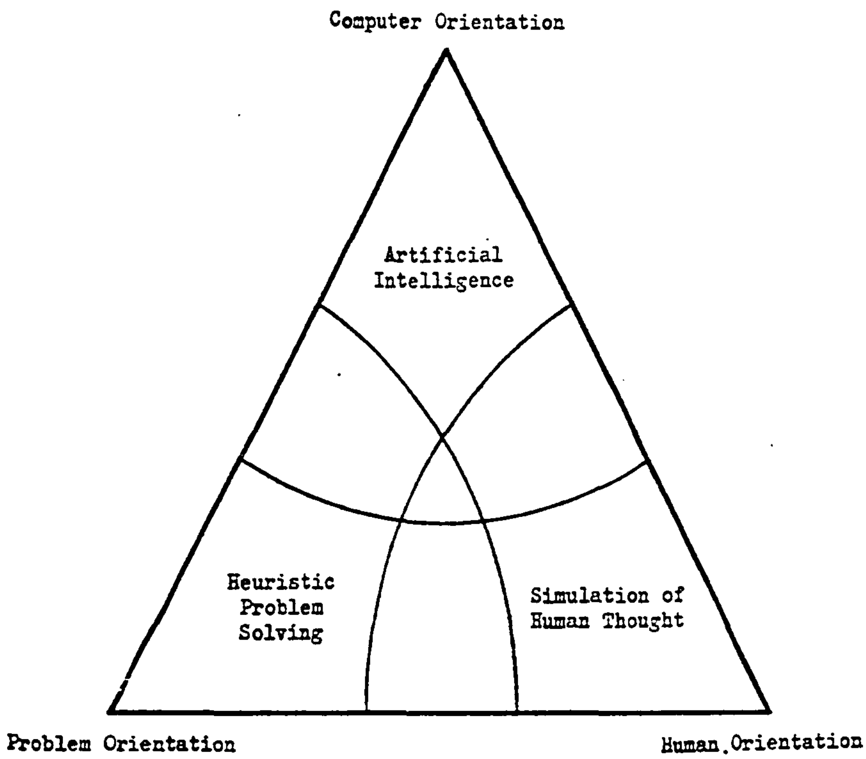

Figure 11. The Subsets of Heuristic Methods

These subsets are further defined by the authors in the following way:

> Heuristic problem solving: Problem-oriented use of heuristics to achieve a reduction of search in the attainment of a satisfactory solution.

Artificial intelligence: The use of computer-oriented heuristics in programs that may accomplish one or more of the following:

1. Search--the systematic investigation of the solution space.
2. Pattern recognition--the acceptance of certain groupings of elementary units as identifiable entities.
3. Organization planning--the breaking down of a complex problem into subproblems, the sequencing of analysis according to priorities and recombination into a solution of the higher level problem.

More sophisticated programs of this class may also include:

4. Learning--program modification resulting from experience.
5. Inductive inference--generalization for the purpose of prediction and decisionmaking.

Orientation is toward efficient use of the computer to obtain apparently intelligent behavior rather than to attempt to reproduce the step-by-step thought process of a human decisionmaker.

Simulation of human thought: The use of a heuristic computer program to replicate thought process of a human decisionmaker. The major criterion is exactness of subject simulation rather than efficiency of problem solution.[51]

The concept of a long-range planning decision model appears to overlap two of these subsets, simulation of human thought and heuristic problem solving. The LRP process alone constitutes a simulation of human thought directed toward attacking strategic decisionmaking problems; the actual solution procedure, on the other hand, may indeed represent a technique in heuristic problem solving designed to generate certain required information. Generally speaking, heuristic

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[51] Ibid., p. 150.

programming is a group of "ad hoc" methods created to fit specific problems. Emphasis tends to be placed on achieving results that are "good enough" rather than optimal; in effect, it symbolizes a philosophy of approaching problems much as the human decisionmaker does, rather than comprising an organized and definable set of techniques to solve these problems.

Regardless of the type of model developed, one of the most critical elements of model building is that of making sure the model is providing the information required.....that it is really a representation of the system under study. Donald E. Sexton, Jr. lists several "dimensions of validity" which should be carefully checked before a model is considered acceptable. These include face validity, internal validity, prediction validicy, hypothesis validity, and completeness.

Face validity is merely whether or not the output from the model seems "right." One who is familiar with a certain system can frequently detect anomolies in output information that are obviously inconsistent with reality. If a simulation is run several times beginning with the same initial values for variables and parameters, and there is a large unexplained difference in output, the model is said to have a low internal validity. Prediction validity involves confirmation that specific changes in key variables and parameters will result in changes in output in the direction and about to the degree expected. Likewise, it requires that events taking place within the simulated system have average values, ranges, and so on, which can be regarded typical for the actual system. Hypothesis validity is satisfied when model reaction to a given input is what we know it should be from real-world experience. Completeness is just being confident to say 'NO' to the question, "have any additional or alternate variables or relationships been overlooked."[52]

Assuming that a valid model can be constructed, when one talks of company planning models, it is not generally in the context of comprehensive organizational planning, at least not for the present. The majority of industry models are designed to simulate and analyze a specific facet of the company's operations. Among the most popular of these, mainly due to its forecast of profitability indicators associated with future possible strategies, is the long-range financial model. Dohrn and Salkin have noted that LRP financial models are divided into three groups based on analytical procedure used; these include (a) simulation models, (b) decision-tree models, and (c) mathematical programming models. They further note that the successful use of financial models depends on the model being:

1) practical, and only as complex as required by the program and as allowed by the quality of data and available facilities;

2) built with close cooperation of the managers and accountants who are to use it;

3) readily convertible into working budgets;

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[52] Donald E. Sexton, "Before the Industive Leap: Eight Steps to System Simulation," Decision Sciences, Vol. 1, No. 1 & 2, (Concinnati: American Institute for Decision Sciences, 1970), p. 193.

4) updated regularly and subject to continual development.[53]

The financial condition of any company is of particular importance to its stockholders who use this information to guage the soundness of their investment. Financial models thus provide a way for managers to avoid planning errors by experimenting with the future, exploring in depth some of the more promising business opportunities, and investigating the impact of principal assumptions affecting their planning program.

The strategic allocation program for domestic E & P to be discussed in the following chapter is a heuristic LRP prototype representating the functional and financial activities of domestic exploration and producing. The organizational model utilizes many of the planning concepts introduced by Steiner, Kami, Magee, and others in conjunction with the basic model-building philosophy of Starr to trace the development of an E & P entity over a specified planning interval. Multiple-attribute decision functions, as outlined by MacCrimmon, are subsequently employed to aid in identifying preferred investment allocation strategies. An extensive search of the literature failed to yield any reference to a long-range planning procedure or model which integrates multiple-criteria decisionmaking with the strategic objectives of an organization.

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[53]P. J. Dohrn, and G. R. Salkin, "The Use of Financial Models in Long-Range Planning," Long Range Planning, Vol. 2, No. 2, p. 27.

CHAPTER IV

FORMULATION OF A STRATEGIC PLANNING MODEL FOR DOMESTIC E & P

Relating Capital Resource Allocation to Strategic Budgeting

The allocation of capital funds for investment purposes, and the actual budgeting of money among alternative projects, reflect two different levels of management decision-making. The budgeting process, which produces a detailed breakdown of authorized expenditures within each E & P activity, is not regarded as part of the "strategic" allocation problem for this investigation. Strategic allocation of capital is limited to the systematic analysis of strategies for commitment of annual investments over an extended planning period. The basis of long-range planning for domestic E & P as developed herein is based on the following postulates:

1) Future development of a company is primarily dependent upon the recurrent budgeting process which seeks to employ effectively its capital resources.

2) Upper management regulates a company's long-term orientation and rate of development, either consciously or unconsciously, by establishing allocations for investment capital within and between company divisions.

3) Capital resource allocation, if approached

> systematically from a forward planning viewpoint, can be used to improve the quality of management decisions relative to future company objectives.

An effort has been made to model domestic E & P as a separate entity in an attempt to circumvent the arguments suggested by suboptimization. E & P is treated in the abstract as a self-sufficient exploring and producing organization which is completely dependent on its own capital structure, resource development, and planning initiative. A company engaged in more than one related industrial function becomes difficult to analyze since the possibility of frequent interaction among divisions arises from high-level planning decisions. An excessive capital outlay to one function, for example, could significantly effect available funds and investment strategies relative to other areas of operation. Therefore, to simplify environmental considerations, the E & P planning model operates under an assumption of independence wherein resource capital neither flows into nor out of the E & P system.

The simulated E & P organization, developed as an iterative financial model, consists of the ten E & P functions and twenty-nine activities as presented and discussed in Chapter II. Each of the various functions, together with associated activities, are in competition for investment funds allocated annually by top management for implementing the capital budgeting program. The philosophy behind employing capital resource allocation as an approach to long-range planning is reflected in the importance of investment spending as a mechanism for orienting organizational growth in the direction of anticipated future objectives. Descriptive details relative to each E & P function and its associated activities, as interpreted for the model program, are provided in Appendix A.

The E & P Long-Range Planning Model

The model employed in this study is a heuristic programming model designed as a functional and financial representation of the overall E & P activity. It updates itself one year at a time moving forward to the planning horizon, activated by capital allocation inputs, and sensitive to forecast conditions within the industry. Model characteristics such as capital structure, tangible assets, rate of production and reserves are specified initially, but become subject to model enumeration in subsequent time periods. Forecasts of future industry conditions associated with various E & P activities are deterministic inputs to the model using published industry information sources where possible. In the absence of recorded data, educated judgment was exercised to provide additional breakdown of forecast information as to activity or geographic region. Forecast industry statistics, relative to the planner's decisionmaking task, are assumed to portray the most likely future domestic E & P developments as perceived from the present. The model itself does not alter current forecasts in any way; consequently, conclusions generated by the model are conditional to the accuracy of the data provided.

The fundamental purpose of this model is to define the range of feasible development patterns of the representative E & P organization under forecast industry conditions. These development patterns are subsequently reduced on the basis of various multi-criteria decision methods to reflect the preferred investment strategy for selected decision functions characterizing specific long-range management objectives. The operational sequencing of the E & P model permits the allocation of capital investment funds to be budgeted for each succeeding fiscal year such that management objectives can be analyzed under the conditions expected to prevail throughout the projected planning period. Internally the model program applies policy constraints to define practical limits on the allocation range of capital funds toward any activity, thus controlling the flow of funds contributing to capital available for investment, and insuring the continued financial stability of the enterprise. As illustrated by Figure 12 below, the model begins each time increment with an E & P status summary which includes both an operational and a financial summary. Funds available for investment may come from reinvestment of earnings, changes in the level of liquid assets, and borrowing, when necessary. Allocation among functions is then determined by a random procedure representative of the range of free choice open to management decision. The investment capital allocated to a certain functions and associated activities, in conjunction with the industry forecast of development in this area, establishes the basis for updating the E & P model for the year to follow. Status summaries are then recomputed, available investment capital redetermined, and the allocation scheme repeated as the model moves ahead in time to the planning horizon.

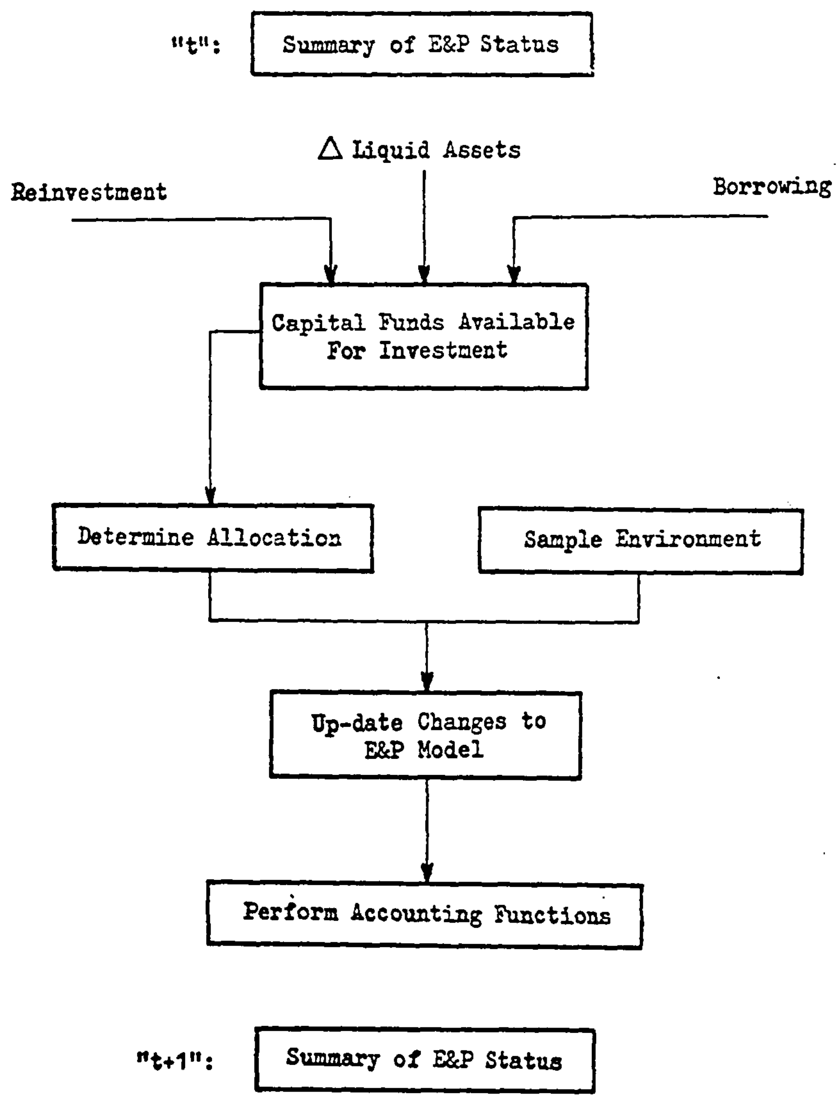

Figure 12. E & P Model Programming Sequence

The model organization always starts from a set of initial properties which represent producing rates, cumulative reserves, acreage under lease, investment commitments, assets, and financial parameters for the year immediately preceding the planning interval. From the capital available for investment the program allocates the first year's capital investment among the ten E & P functions subject to the policy limits imposed; if funds available are not adequate to meet minimum capital requirements, short or long-term borrowing is permitted up to specified cumulative levels. After funds have been allocated to the ten functions, it is further suballocated among the twenty-nine activities according to prescribed policy rules. In updating the model to the next year, the anticipated effect of the allocation scheme relative to the properties of each activity must be assessed. This is accomplished through use of forecast industry statistics over the planning period as regards success ratios, profitability, discovery potential, commitment of investment, reserve potential, cost of acquisition and others. It is assumed that the model E & P organization, which comprises only a small fraction of the total domestic E & P industry, will have a negligible influence on future industry development regardless of its long-range investment strategies. Therefore, the model status at the end of the first year is a function of its original status and the updating changes produced by the initial investment allocation scheme. The model iterates forward from each year to the next in a similar manner. Upon every designated 1st-year allocation strategy, model development can be replicated as needed over the planning interval to yield sets of feasible investment strategies. Multiple-criteria decision techniques are subsequently employed to analyze these strategies in relation to indicated management objectives.

Functionally the planning model serves to simulate the development possibilities of the E & P organization from the initial fiscal year forward to the planning horizon, selected for this investigation as the end of the fifteenth year. At each stage, representing each year-end, model updating is conducted as a function of its cumulative status carried forward, along with revisions resulting from new capital expenditures as of the preceeding year. Final model status at the end of the planning period is summarized on the basis of thirty decision attributes. The development cycle of the model is replicated on each initial allocation scheme as required to firmly establish the feasible growth patterns permitted within future years of chance allocation, restricted only by the policy constraints. Initial allocation schemes can be specified by the planner, or generated randomly, depending on the purpose of each planning investigation.

As noted the E & P model consists of ten "functions" and twenty-nine "activities" making up these functions. Obviously within any E & P structure relationships and dependencies will exist among the various activities to which the organization is committed. In the context of long-range planning these inter-activity effects in the E & P model have been classified as direct and feedback effects based on the sequence in which the activities normally occur. For instance, leasing of acreage follows geophysical activity since the latter locates areas for prospective exploratory drilling. Leasing, therefore, is directly influenced by the amount of recent geophysical work. On the other hand, little is to be gained by leasing more acreage than can be reasonably explored through drilling in say the next ten years. Hence, the cumulative acreage under lease has a feedback effect by restraining future commitments to geophysical activity. The various relationships between activities in the E & P model are indicated by Figure 12 with additional detail provided in Appendix B.

The E & P long-range planning simulation program is composed of the E & P model linked with a series of multi-criteria decision subprograms. The total computer program consists of a main program which generates forecast information from input data and provides control, an E & P model subroutine, and two multi-criteria decision subroutines. Three subprograms make up the E&P model subroutine; these include the iteration subprogram, annual summary subprogram, and strategy termination subprogram. The iteration subprogram is the sequence of computational instructions which moves the model E & P organization forward one year at a time to the planning horizon. The first step is to establish upper and lower

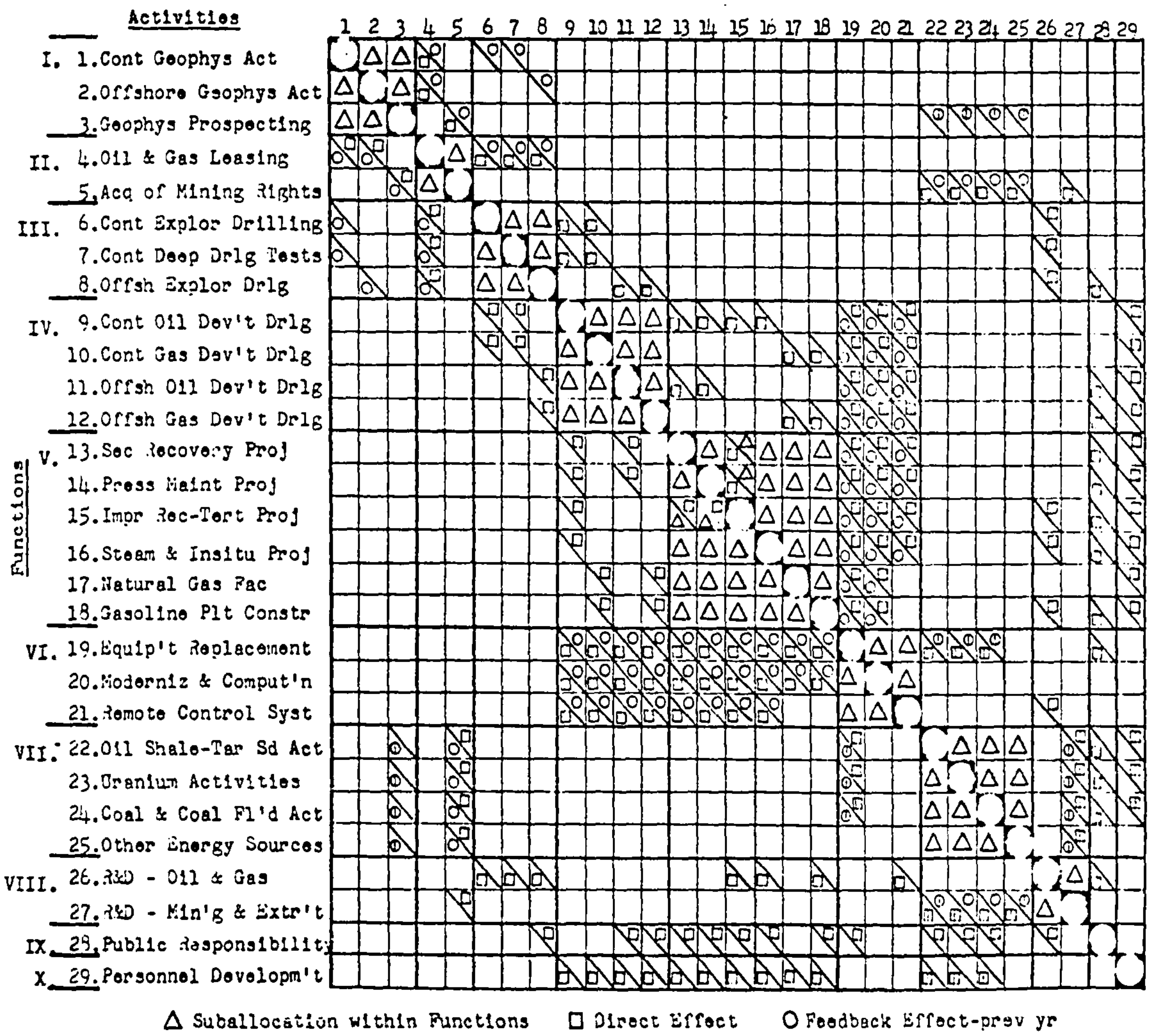

Figure 13. E & P Activity Relationships

investment capital limits for each function based on the existing status of the organization. Once this is accomplished, principal allocations are determined for each function, followed by suballocation to activities and regions again based on model status. Finally the effect of the allocation strategy is calculated for each successive year as the model proceeds to the planning horizon. The summary subprogram takes the updated model information and generates both an operating and a financial summary which determine available capital for investment in the coming year. The last subprogram, strategy termination, halts the iteration sequence in any year where insufficient capital can be found to meet minimum investment requirements for that year. At this point the model organization is regarded in financial jeopardy and the allocation strategy dropped from further consideration. The program can move out to the planning horizon from a given initial allocation scheme hundreds or even thousands of times generating the multi-dimensional facimile of a decision tree, each feasible allocation path from the trunk representing an allocation strategy. A flow diagram of the LRP simulation model for the E & P organization is given in Figure 13.

Allocation Strategy Analysis Using Multi-Criteria Decision Methods

The last two subroutines of the LRP program are multi-attribute decision procedures which are used to select specific allocation strategies relative to a given set of attributes under prescribed criteria. The first of these subroutines is made up of an attribute tabulation subprogram, a multiple-attribute decision subprogram, 15th-year financial and operating subprograms, and an allocation strategy subprogram. The latter subroutine includes a statistical summary subprogram

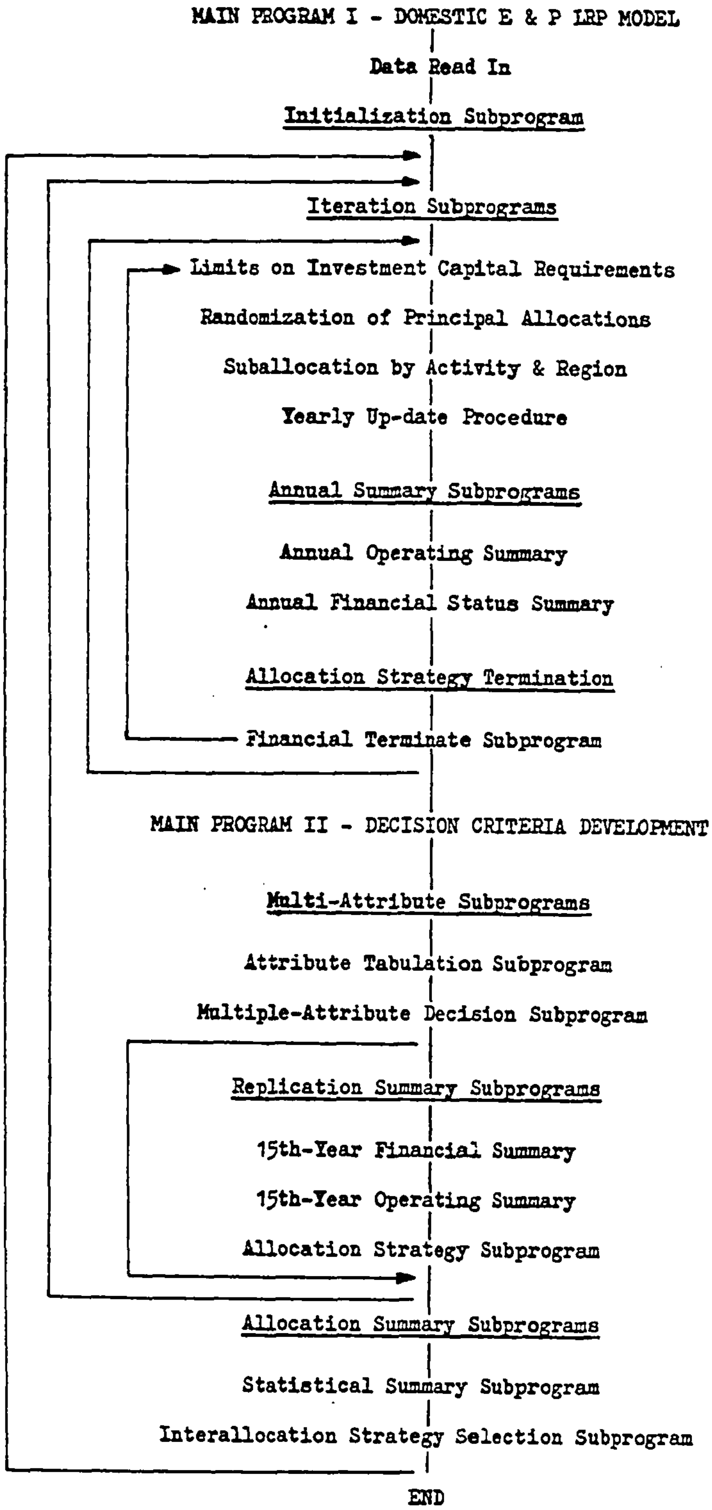

Figure 14. Flow Diagram for Long-Range Planning Simulation Model

and an interallocation strategy selection subprogram. The flow diagram above illustrates schematically the relationship of the decision subprograms to the overall LRP system.

The multi-criteria decision subprograms represent phase two of the LRP program, the first phase being the E & P model itself. All variables in the system are held in common. Information generated in the E & P model under phase one is picked up, processed, and analyzed under phase two. The attribute tabulation subprogram calculates values for each of thirty attributes of the E & P model system which later serve as bases for management criteria in the strategic planning process. Although thirty attributes were selected and programmed for possible use, it should be noted that many more could have been identified. The attributes selected are generally indicative of the areas of profitability, financial status, growth rate, production rate, fractional capital commitment, public responsibility, and personnel development. The multiple-attribute decision subprogram consists of a series of thirteen analytical procedures, each designed to process a seven-attribute item of information according to one or a combination of multi-criteria techniques. Maximum 1st-year profit and maximum 15th-year assets growth strategies are also computed for comparison. The 15th-year financial summary, 15th-year operating summary, and allocation strategy subprogram are executed and printed in any iteration of an initial allocation scheme where improvement occurs in one of the decision programs as a result of finding a better allocation strategy. Upon completing the iteration sequence for each allocation scheme, the program transfers to the final subroutine operation. A statistical summary subprogram computes the range, mean, variance, and standard deviation of each attribute considered in the multi-criteria decision procedures. In the interallocation strategy subprogram the allocation strategies selected for each multi-criteria decision technique under the current allocation scheme are compared with the best from previous allocations to determine which is to be retained.

Dissimilarities in decision criteria, such as the preference for increased production over growth in assets, can be expected to result in different choices for starting allocation and long-term allocation strategies. However, in cases where the same decision criteria can be applied without distortion in two multi-attribute decision procedures, the resulting variance in outcome between the two is usually insignificant. The thirty attributes programmed and generated in the LRP program are discussed briefly in Appendix C.

Validation of the E & P Planning Model

One of the more important aspects of constructing a model, and perhaps the most difficult in many cases, is showing that the model is a valid representation of the system under investigation. The term "validation" should not be interpreted as proof that the model system is an exact duplication of the actual system; rather it should be acknowledged as confirmation that the model output under a specified range of conditions can be taken as analogous to that of the true system. In models of physical systems, where experimental data is readily obtained, validation can be approached directly by way of statistical tests such as analysis of variance, regression analysis, chi-square, and others. Validation of management decision models is less explicit than for physical models, due mostly to the vague structural nature of the systems under examination. Frequently validation administered through a series of empirical tests or checks is the only method available. In such circumstances, as long as no "negative" results appear from the tests, the investigator is usually presumed free to treat the model as a valid simulator of the system being studied.

In a book titled, The Design of Computer Simulation Experiments,[83] compiled by Thomas H. Naylor, one suggested validating process proposes subdividing the task into three separate activities which include (1) verification, (2) validation, and (3) problem analysis. Verification is insuring that the computer program is actually executing the steps indicated by the flow chart, while validation is the procedure through which, by mathematical or empirical means, the model system is shown analogous to the actual system. Problem

[83] Thomas H. Naylor, The Design of Computer Simulation Experiments (Durham, N. C.: Duke University Press, 1969), p. 232.

analysis represents a final check to confirm that formulation of the model is sound, that no loss of essential information is occurring, and that statistical properties such as independence are not assumed one way and treated in another.

Validation of the E & P model was approached essentially as outlined above. Verification was carried out by compiling and running the program in small segments with selected input data; model output could then be checked against known information computed for each program segment. Problem analysis was performed throughout the debugging stage of program development by continually reviewing the logic and internal consistancy of each subprogram as it related to other components of the model system. Demonstrating the critical relationship between allocation of capital investment and organizational growth in the model, compared to that found in industry, represented considerable effort by reason of the documentation required. The first step was to verify "face validity" in the model transformations. For example, increases and decreases in the average allocation to various functions were observed to produce corresponding changes in the growth of these functions in the direction and approximate amount anticipated. The magnitude of generated growth patterns was then compared with industry statistics, in so far as availability would permit, to confirm the relative proportionality of model output with real world data. As a last check, simple empirical tests were made using the means, variances, and distributions of key variables for each year to insure that no abnormal conditions were developing within the LRP time series.

Comparison of the E & P Model to Existing Long-Range Planning Methods

References quoted in the discussion on long-range planning in Chapter III cover a very wide range of approaches to this subject. Some are general in nature, having virtually universal application in strategic problem solving, but lack the detail in many instances for direct application to real-world situations. At the other end of the spectrum are a number of practical techniques that can be initiated with a minimum of difficulty, but are relevant to only selected types of planning decisions. Based on content most planning literature, in the opinion of this writer, can be placed into one of three categories:

1) Theoretical or conceptual planning models
2) Mathematical planning models, and systems simulation adapted to planning circumstances
3) Planning applications in industry

A possible fourth category of literature dedicated to research in the area of planning is that typically found in published research works, theses, and dissertations, where investigation usually concentrates on the planning process as related to a specific physical system under a predetermined set of conditions. The system studied may be a hospital, a library, the traffic pattern of a city, market distribution for a group of products, or one of a thousand other possibilities. With the exception of several "conceptual models" on the subject of strategic planning, few references of relevant value to this study were located by use of the dissertation abstracts.

Even though this research into LRP decisionmaking is oriented toward a single area of the petroleum industry, and indeed possesses specialized planning requirements not applicable elsewhere, the general approach to developing an LRP methodology for E & P, and the interpretation of results so obtained, should offer possibilities for parallel treatment in other areas where the need for strategic allocation planning becomes evident. While the literature review cited herein, provided no unified guidelines along which a long-range allocation planning procedure could be synthesized, it did offer a wealth of information concerning the concepts of strategic planning, together with some of the more successful attempts toward implementing these concepts. The ideas proposed by Steiner in regard to the philosophy of comprehensive planning and the efforts of Kami to design a functionable strategic planning model both contribute to one's understanding of the limitless horizons associated with complex planning systems. Branch emphasized the need for completeness and internal consistency when setting up planning models, whereas Mason's concern in plying the dialectic approach underscored elimination of invalid and irrelevant assumptions to improve planning decisions.

MacCrimmon examined planning decisions in the context of multiple-attribute problems, visualizing the decisionmaking process in terms of pre-choice and post-choice functions. None of these conceptual planning constructs, however, furnished sufficient working information to construct a workable LRP prototype.

The abyss between conceptualization of strategic planning models and explicit model building is being bridged by such authors as Starr, Magee, Ansoff, and Forrester. The classification of planning models into fully-constrained, partially-constrained, and threshold-constrained, along with the mathematical formulations of unit planning and unit policy decisions, proposed by Starr, represents an important contribution to both the understanding and the designing of systems for optimal planning. Magee's decision-tree approach offers an interesting alternative to the Starr models, but would appear to be less adaptable to extensive development as the complexity of planning processes expands to include entire organizations composed of multiple subsystems. In other cases "planning" is observed to be a by-product derived from simulation studies where the primary objective originates from an attempt to gain an understanding of how some real-world system operates. Nevertheless, industrial applications suggest that much of the future research in planning systems, especially long-term planning, will utilize computer simulation models because of their inherent flexibility and the vast quantity of information that must be processed.

Conceptually true long-range planning appears far in advance of the models and analytical techniques now available for implementing the planning process. By the same token, much of what is termed "long-range planning" in industry bears little resemblance to the few noteworthy applications reported in the literature. This investigation into strategic capital resource allocation in the domestic oil producing industry, as well as the decisionmaking procedure employed, is thought to be unique. The E & P program model was specifically designed to be compatible with the philosophy of long-term decisionmaking as reported in the literature. In effect, it represents an analytic adaptation of the conceptual long-range planning process, and applies multiple-criteria decision functions to the selection of preferred allocation strategies. Although the conceptual and analytical tools have been drawn from various parts of the literature, no similar approach to long-range planning was found.

CHAPTER V

MODEL APPLICATION AND ANALYSIS OF RESULTS

The E & P Model and Related Industry Forecasts

The E & P organization employed for testing and analysis of the proposed multi-criteria strategic allocation computer program is hypothetical; nonetheless, it does offer in dimension and functional development a reasonable facsimile of the domestic E & P entity of a large oil firm or independent energy-producing company. As a fraction of total assets the model E & P organization is initially assumed to account for 4/100 of the industry total. Since this share appears very small, it should be pointed out that 1972 industry assets in domestic E & P total some fifty-six billion dollars. Four percent of this amount, or two and one-fourth billion dollars, suggests an organization of significant proportions, even though smaller than several of the industry's giants.

Initial information provided for the model E & P organization includes both operational data in terms of acreage, production, reserves, and such financial data as might be found in any consolidated financial report. Operating information is divided into two basic types, initial data which depicts statistical information applicable to the year immediately preceding the planning period, and cumulative data summarized as of the same year. Annual information includes acreage surveyed, acreage leased, proved, prospective and speculative reserves added, and recovery rates for both continental hard rock mineral activities. Cumulative data, moreover, represents the organization's accumulated status relative to these items, composited and carried forward from the operations of previous years. The subdivision of initial financial data is similarly treated according to annual and cumulative information. The former relates to commitments and expenditures of capital funds made during the year prior to initiating the plan, while the latter conveys the beginning financial status. Specific cumulative financial data comprises assets levels of the various activities, notes payable, long and short-term debt, unpaid taxes, retained earnings, and stockholders equity. The investment policy constraints programmed into the LRP model take into consideration forecast industry commitments, fraction of industry assets, and current levels of activity in the simulated organization. These constraints are intended to be indicative of the kind of limitations on investment decisions that management itself would presume to observe, and therefore be likely to accept as rational barriers to unrestricted future commitments. The effect of the constraints is to permit reasonable latitude in the allocation of capital for investment, while eliminating those allocation strategies considered in contradiction to management's investment philosophy. The result should be a series of investment decisions over the 15-year planning interval that offer managerial feasibility, yet provide a range of alternative possibilities which can be analyzed on the basis of selected multiple-attribute decision criteria. Random variability in the allocation of capital budget funds is confined to investment by function. In any iteration of the model, once the allocation to each function has been established, the subsequent suballocation to activities is computed deterministically subject to model status and forecast industry conditions.

In deciding the primary allocation for each of the ten functions, upper and lower limits are first calculated based on the current cumulative status of the model organization together with forecast information. The capital available for investment is determined from the financial summary of the previous year. If available capital is less than the sum of the lower lower limits, funds are borrowed to bring the level above this minimum requirement. Should available capital be greater than the sum of the upper limits, the difference is treated as excess and retained in capital surplus. The allocation to each function then becomes its lower limit plus a randomly designated fraction of the increment between available capital and the summation of the lower limits. The amount thus obtained is the principal allocation of investment funds relative to the major E & P functions. Suballocation of capital among the respective activities comprising these functions is performed next. This apportionment is administered deterministically, dependent primarily on current model status, forecast industry conditions, and indicated future potential pertinent to the various activities. Following the allocation of funds according to function and activity, an updating procedure is executed to document the impact of the new investment on the model organization. Net changes are recorded relative to both the operational and financial elements of the model from which revised summaries are prepared for the indicated budget year.

The above sequence, that of (1) establishing upper and lower limits, (2) computing principal allocations by function, (3) sub-allocating by activity, and (4) updating the model are carried out each successive year until the planning horizon is reached. A horizon of fifteen years was chosen for the E & P model for two reasons. First, most recently published forecasts of industry developments seem hesitant to venture beyond 1985 or 1990. Secondly, putting a long-range plan into effect requires an immediate orientation of capital expenditures in response to committing toward distant objectives. Because of the mounting uncertainty, it is difficult to visualize planning decisions by E & P management involving lag times much above fifteen years between commitment and realization. Of course, this is not to preclude the industry being aware of and studying potential developments twenty or even thirty years in the future. Fifteen years can thus be viewed as a judgment of the interval of management confidence in the forecast future industry environment.

Industry data forecasts relative to the various E & P activities is provided to the LRP model as input to the main program. This information includes predicted future commitments of investment capital, production, and proved plus prospective reserves by geographic area. Also forecast where applicable are estimates of future reserve potential, leasing and geophysical costs per acre, and production and reserves added per unit of committed investment. This input data should represent the best information available at the time the program is implemented. In any sequential annual development of long-range plans, forecast information can be expected to change each year to reflect the current outlook of the industry. Nevertheless, the annual budgeting of investment capital based on strategic objectives should prove superior over the long term to budgeting on short-range profitability criteria.

Multiple-Attribute Decision Functions for E & P

From the list of thirty attributes identified for the E & P model, seven were selected for use in investigating the application of multiple-attribute techniques in making long-range planning decisions. Four of these attributes measure long-term characteristics of the organization over the 15-year planning interval. They include average annual rate of return, the ratio of model to industry assets, increase in total production rate, and the average change in non-oil and gas commitment. Two attributes measure intermediate-range characteristics occurring within the initial five years of the planning period. These are average quick ratio and the model fraction of industry commitment to geophysical activities. The final attribute, total profit, is measured only during the first year. Choice of these seven attributes from among the thirty programmed was arbitrary, as was the number seven itself, except that an attempt was made to include as much diversity in the selection as possible. Any one of the seven, if considered independently of the others by E & P management, could provide the substance for developing a realistic organizational goal. The unique benefit derived from using multiple-attribute decision functions is to provide a means for weighing several attributes concurrently in arriving at an allocation planning decision.

Altogether thirteen multiple-attribute decision functions were employed to analyze the strategic planning strategies generated by the E & P model. Eight of the decision processes represented utilize a single multiple-attribute function; the remaining five consist of combination functions. The eight basic multiple-attribute decision functions are identified and briefly discussed below:

1) Dominance

Each of the seven attributes are considered of equal importance. When any two strategies are compared, the preferred alternative must prove superior in at least four of the seven paired attributes.

If $(a_1, a_2 \ldots, a_7)^1$ equals Strategy I

and, $(a_1, a_2, \ldots, a_7)^2$ equals Strategy II

Strategy II is considered dominant provided:

$a_i^1 < a_i^2$ in at least four i.

2) Satisficing

A minimum value is initially prescribed for each of the seven attributes. The preferred alternative becomes that strategy which exceeds the prescribed minimums, and subsequently proves superior in a comparison of all seven attributes.

Assuming $(a_1, a_2, \ldots, a_7)^0$ represents the minimum

acceptable attribute levels

$(a_1, a_2, \ldots, a_7)^1$ equals Strategy I

and $(a_1, a_2, \ldots a_7)^2$ equals Strategy II.

Strategy II is preferred when:

$a_i^o < a_i^1$ and $a_i^1 < a_i^2$ for all i

3) Lexicography

The seven attributes are ordered in a priority sequence. Each pair of strategies being compared are evaluated attribute by attribute until one of the two is proven superior.

Given that $(a_1, a_2, \ldots, a_7)^1$ equals Strategy I

and, $(a_1, a_2, \ldots, a_7)^2$ equals Strategy II

Strategy II is preferred if:

$$a_1^1 < a_1^2,$$

or $a_1^1 = a_1^2$ and $a_2^1 < a_2^2$,

or $a_i^1 = a_i^2$ for all i except one set of

paired attributes wherein $a^1 < a^2$.

4) Additive Weighting

A weighting factor is assigned to each attribute, the sum of which constitutes a preference index for the total set. The sum of the weighted attributes from each succeeding strategy are compared to establish which is preferred.

Letting $(a_1, a_2, \ldots, a_7)^1$ be Strategy I

and, $(a_1, a_2, \ldots, a_7)^2$ be Strategy II

Strategy II is preferred when:

$$\sum_i W_i \cdot a_i^1 < \sum_i W_i \cdot a_i^2$$

5) Effectiveness Index

An index was developed using the seven attributes in a multiplicative, exponential type function. As in the case of additive weighting, the resulting index value will dictate the preferred alternative.

If $(a_1, a_2, \ldots, a_7)^1$ equals Strategy I

and, $(a_1, a_2 \ldots, a_7)^2$ equals Strategy II

Strategy II is preferred in the case where:

$$f(a_1, a_2, \ldots, a_7)^1 < f(a_1, a_2, \ldots, a_7)^2$$

6) Utility

Three attributes, assets ratio, commitment to non-oil and gas activities, and commitment to offshore operations, were selected as high priority attributes. A utility function combining these attributes is used to ascertain the preferred strategy.

Given that $(a_1, a_2, \ldots, a_7)^1$ represents Strategy I

and $(a_1, a_2 \ldots, a_7)^2$ represents Strategy II

Strategy II is preferred if:

$$\mu(a3,a4,a6)^1 < \mu(a3,a4,a6)^2$$

7) Trade-off

Two attributes, average quick ratio and 1st-year profit, were chosen as priority attributes. In this case preference is conditional to a trade-off relationship established between values of the two priority attributes. Selection is made contingent to both absolute value and fractional differences upon comparing any two sets of paired attributes.

Assuming $(a_1,a_2,\ldots,a_7)^1$ is Strategy I

and, $(a_1,a_2,\ldots,a_7)^2$ is Strategy II

Strategy II is preferable when:

$a_5^1 < a_5^2$ and $a_7^1 < a_7^2$, or when $A_5^2 > A_5^1$ and $A_7^1 > A_7^2$

$$\frac{a_7^1 - a_7^2}{a_7^1} < \frac{a_5^2 - a_5^1}{a_5^1}$$

8) Non-Metric Scaling

Preference using this method follows from a comparison of the sum of absolute fractional deviations from a given standard. An ideal set of attribute values is specified initially, and the strategy selected is the one which most nearly fits the proposed ideal.

Defining $(a_1,a_2,\ldots,a_7)^0$ as an ideal strategy,

$(a_1,a_2,\ldots,a_7)^1$ as Strategy I

and, $(a_1,a_2,\ldots,a_7)^2$ as Strategy II.

Strategy II is to be preferred when:

$$\sum\left|\frac{a_i^1 - a_i^o}{a_i^o}\right| > \sum\left|\frac{a_i^2 - a_i^o}{a_i^o}\right|$$

In addition to the eight multiple-attribute decision procedures outlined above, five combination methods were investigated which employ two of the basic decision methods in tandum. In combination cases the problem of compatability can be a significant factor in obtaining a function capable of effecting the desired reduction on a population of feasible strategies. Those selected for use with the E & P model include:

9) Dominance and Satisficing

10) Satisficing and Lexicography

11) Additive Weighting and Trade-off

12) Dominance and Effectiveness Index

13) Non-Metric Scaling and Utility.

The same seven attributes were applied throughout in order to provide some measure of unification among the various methods. It is obvious, however, that a manager visualizing specific criteria relative to a multiple set of attributes would encounter difficulty in trying to accommodate them on an equivalent basis.

The final two decision functions generated were actually single-attribute criteria:

14) First-year Profit

15) Fifteen-year Assets Growth

These were computed to provide a reference for reviewing the thirteen decision functions discussed previously. Profit and growth objectives are more nearly representative of management's traditional orientation for planning, and thus provide a sort of base upon which to analyze the effectiveness of the multiple-attribute functions in guiding investment strategies toward long-range goals.

Strategic Allocation Program Output Format

The E & P allocation planning model offers substantial flexibility for adjustment of input/output information without major program modification. Data card instructions permit variation in the type and quantity of output generated depending on the scope and specific requirements of each investigation. Check points are provided throughout the model subroutine where printouts can be initiated and the output reviewed, if necessary. The model itself furnishes no final output; all information generated is stored for later use by the decision subroutines. Upon instruction, however, the program will print eighty items of annual operational and financial data depicting model status at the end of each model iteration.

The first formal program output are 15th-year financial and operations summaries available after each iteration cycle to the planning horizon. Print out is initiated only if a preferred strategy is registered by one of the fifteen decision subprograms described above. Following the summary printouts is an allocation strategy tabulation for the preceeding iteration sequence indicating the percentage of total investment committed by activity for each of the fifteen years in the planning period.

The model subroutine can be instructed to replicate on a given initial allocation strategy as many times as desired by the user. At the end of any specified replication cycle, a statistical summary of the seven critical attributes is printed. The summary includes the mean, variance, standard deviation, highest and lowest values, and number of observations for each of the seven attributes. By use of the statistical summary along with the allocation strategy tabulation, trends of the seven attributes can be monitored relative to changes in average allocation by function or activity. The final output is generated from a multi-attribute comparison of the preferred strategies in successive initial allocation schemes. Identification of the preferred strategies is indicated by allocation and replication number for each of the decision subprograms. Based on this identification, the preferred overall strategy for each sub-program can be located from among the previous output sheets.

As the allocation pattern changes randomly after the first year, the seed to the random number generator is printed out. If when reviewing the output data an allocation scheme of particular merit is noted in any year, the full 15-year planning sequence may be run using this same allocation through data card instructions. A visual comparison can then be made to determine if this allocation scheme is superior to the best of previous schemes.

Review and Discussion of Model Output

A basic assumption of the E & P LRP program is that within the profit-generating activities of the industry, the model organization is competitive on the average; that is, given a specific allocation of investments over a period of years, the revenues produced will be typical of the projected industry mean. Modification of this assumption can be made, however, if one considers the organization to be either leading or lagging the industry as a whole in one or more individual activities. Similar assumptions govern such quantities as acreage surveyed, acreage leased, and equivalent barrels of increase in oil and gas production per unit of allocated investment capital. Average success is again anticipated for the model organization unless otherwise indicated. Finally, the condition must be accepted in using the program that any feasible investment strategy undertaken by the model organization will have an insignificant effect on the current forecast of future developments within domestic E & P. As noted earlier, this assumption is not unrealistic when comparing the relative size of any single entity to that of the total industry. Implicit with the latter assumption is an acknowledgement that the model organization may improve or loose in competitive standing over the planning period within any of the twenty-nine activities depending upon its investment allocation program.

Forecast information is furnished to the model for a period of fifteen years and includes industry projections, time-dependent changes in production, profit, reserves, and predicted levels of increased development potential. Depending upon type, forecast data is provided to the program in one-, two-, or three-dimensional arrays. In the one-dimensional array a single element of information is stored for each year of the planning period. A two-dimensional array consists of 105 elements of data, one element for each geographic area over the 15-year time interval. The three-dimensional array includes activities as well as geographic areas and is composed of 3045 data elements. The dimension of each array depends upon the kind of forecast information presented, and its application in the LRP model. Some of the forecasts employed by the program were directly available from published industry sources; other of the data had to be extrapolated or estimated as needed. In either case the predicted values represent the writer's best current appraisal of the E & P environment between the years 1973 and 1987. A summary of the various required items of forecast information is given in Table I of Appendix D.

In addition to the forecast information certain other preliminary data items were needed to represent the initial status of the organization being investigated. An essential characteristic of this data is consistancy as concerns realistic proportioning of the internal organizational structure and its inherent capability for sustaining profitable operations and a reasonable growth in assets value. The initial operational and financial status of the proposed E & P organization is summarized in Tables II and III of Appendix D.

Since the E & P LRP model is designed as a computer simulation program to identify preferred investment strategies under multiple-attribute decision criteria, the greater the number of initial feasible allocations and subsequent replications of these allocations, the potentially more definitive the information generated. However, the cost of computer time can soon become a limiting factor to any unorganized search for preferred strategies. The simulation trials conducted for this investigation were run primarily to demonstrate the utility and flexibility of the proposed LRP model as a management information tool. Three cases were selected to illustrate various avenues of inquiry available to the planner. In case I a single initial investment allocation is designated and the LRP program replicated to the 15-year planning horizon a total of seventy-five times. Case II examines four different starting allocations wherein each is run twenty-five replications. Final trial, Case III, utilizes twenty-five distinctive initial allocations and imposes an identical fractional assignment on available investment funds in successive years throughout the planning interval. In this sequence of runs each allocation was replicated but once, since the model output becomes unique when subject to a fixed allocation scheme.

The purpose of Case I is to suggest the range of variability to be encountered in the model relative to attributes of particular interest to the planner, while Case II provides an indication as to the significance of "initial allocations" of investment capital to the selection of long-term allocation strategies. The potential benefits of adopting a fixed allocation policy in strategic planning can be reviewed using Case III. A compendium of model output for each of the three cases is summarized and discussed below:

Case I

The E & P model was replicated to the 15-year planning horizon a total of seventy-five times from initial fixed assets of $2,240 million and available investment capital of $189 million. Fixed assets were observed to increase over the planning period to a terminal value ranging from $2,322 million to $2,667 million, representing an overall growth up to 19 percent. Net profits rose from $226 million during the first year to an average of $332 million in year fifteen. Variability relative to the seven critical attributes can be illustrated as follows:

Attribute	Upper Value	Lower Value	Mean	Variance	Standard Deviation
Average Annual Rate of Return	.1485	.1140	.1275	.0001	.0081
Average Annual Change in Total Production	-.0077	-.0551	-.0313	.0012	.0112

(continued)

Attribute	Upper Value	Lower Value	Mean	Variance	Standard Deviation
Ratio of Model to Industry Assets	.0245	.0212	.0228	.0000	.0007
Average Variation in Non-Oil & Gas Commitment	.5876	.1955	.4197	.0068	.0825
Average Quick Ratio	3.2547	2.4759	2.9405	.0409	.2023
Fractional Commitment To Offshore Geophysical	.0988	.0668	.0824	.0001	.0075
First-Year Profit, B$	.2265	.2265	.2265	.0000	.0000
Final Model Assets Level, B$	2.6696	2.3226	2.5072	.0056	.0750

A preferred strategy if identified from among allocation schemes within the seventy-five specified program replications, was designated by each of the multiple-attribute decision subprograms. Allocation strategy preference by subprogram for Case I is tabulated below:

Subprogram	Decision Method	Selected Replication
01	Dominance	#74
02	Satisficing	None
03	Lexicography	#75
04	Additive Weighting	#53
05	Effectiveness Index	#35
06	Utility	#75
07	Trade-off	None
08	Non-metric Scaling	#10
09	Dominance + Satisficing	None

(continued)

Subprogram	Decision Method	Selected Replication
10	Satisficing + Lexicography	None
11	Additive Weighting + Trade Off	None
12	Dominance + Effectiveness Index	None
13	Non-Metric Scaling + Utility	None
14	First-Year Profit	#75
15	Fifteenth-Year Assets	#68

In the decision subprograms where "None" is shown, the model organization failed to achieve minimum indicated management objectives specified in the LRP program. Under satisficing, for example, each attribute must exceed a certain minimum value for the allocation strategy to be considered. The goal in this case was to increase production with the minimal acceptable condition one of staying even. In the simulation runs the model was unable to maintain its initial production forward through the 15th year, and all resulting strategies were thus eliminated by the second subprogram.

Case II

In this trial the LRP model was replicated twenty-five times for each of four starting allocations having initial fixed assets of $2,240 million and available investment capital of $189 million as before. Based upon this combination of one hundred allocation schemes final model assets ranged from $2,165 million to $2,436 million and 1st-year net profits, $225 million to $244 million. The effect produced by changing the starting allocation of investment in the model can be observed by deviations in the mean values of critical attributes:

Attribute	Upper Value	Lower Value	Mean	Variance	Standard Deviation
Average Annual Rate of Return	.1363	.1160	.1239	.0000	.0048
	.1420	.1228	.1316	.0000	.0052
	.1917	.1345	.1546	.0002	.0128
	.1854	.1249	.1457	.0002	.0149
Average Annual Change in Total Production	-.0221	-.0549	-.0373	.0005	.0073
	-.0207	-.0565	-.0385	.0006	.0081
	-.0042	-.0524	-.0283	.0005	.0078
	-.0006	-.0535	-.0253	.0008	.0094
Ratio of Model to Industry Assets	.0240	.0210	.0221	.0000	.0007
	.0225	.0200	.0211	.0000	.0002
	.0214	.0192	.0203	.0000	.0006
	.0224	.0198	.0214	.0000	.0006
Average Variation in Non-Oil & Gas Commitment	.4955	.1886	.3441	.0059	.0769
	.4560	.1331	.3087	.0050	.0705
	.4373	.1050	.2492	.0061	.0780
	.4277	.0954	.2795	.0058	.0759
Average Quick Ratio	3.2867	2.7346	3.0641	.0162	.1271
	3.0858	2.4651	2.8812	.0268	.1637
	2.8866	1.9728	2.5280	.0698	.2642
	3.0604	1.8415	2.6613	.0995	.3155
Fractional Commitment to Offshore Geophysical	.0938	.0715	.0811	.0000	.0064
	.0918	.0667	.0796	.0000	.0065
	.0911	.0585	.0728	.0001	.0088
	.0825	.0634	.0739	.0000	.0047
First-Year Profit, B$	.2265	.2265	.2265	.0001	.0078
	.2436	.2436	.2436	.0000	.0051
	.2393	.2393	.2393	.0001	.0081
	.2251	.2251	.2251	.0000	.0059
Final Model Assets Level, B$	2.3391	2.1178	2.2329	.0040	.0631
	2.4639	2.1999	2.3266	.0054	.0733
	2.6221	2.2646	2.4319	.0063	.0794
	2.4537	2.1648	2.3500	.0052	.0722

Again preferred allocation strategies were selected for each of the decision subprograms from among the total one hundred allocation-replication schemes:

Subprogram	Decision Method	Selected Allocation	Selected Replication
01	Dominance	#4	#25
02	Satisficing	None	None
03	Lexicography	#1	#25
04	Additive Weighting	#1	#10
05	Effectiveness Index	#4	#1
06	Utility	#2	#25
07	Trade-off	None	None
08	Non-metric Scaling	#1	#9
09	Dominance + Satisficing	None	None
10	Satisficing + Lexicography	None	None
11	Additive Weighting + Trade-off	None	None
12	Dominance + Effectiveness Index	None	None
13	Non-metric Scaling + Utility	None	None
14	First-Year Profit	#2	#25
15	Fifteenth-year Assets	#3	#18

As in Case I, the marginal performance of the model organization under the given policy configuration made it incapable of locating strategies to override minimum objectives relative to some of the attributes. While changes the initial allocation sequence created minor variations in the model's terminal status, these were not significant to produce additional selections of preferred strategies. It is worth noting, however, that on Subprograms 3,4, and 8 the seventy-five replications of Case I found strategies superior to those of Case II wherein the first initial allocation scheme is identical to that of Case I, but replicated only twenty-five times. A check of the means and variances of critical attributes between the twenty-five and seventy-five replication trials suggests that little additional information is to be gained by excessive replication on any single initial allocation strategy.

Case III

The third set of trials assumes a fixed allocation sequence will be followed by the model organization. Under this condition only one replication of each allocation is required to obtain the essential information. The table of critical attributes below indicates the highest and lowest observed values and associated allocation strategies for the twenty-five allocation schemes attempted:

Attribute	Highest Value	Allocation	Lowest Value	Allocation
Average Annual Rate of Return	.2739	#6	.1296	#12
Average Annual Change in Total Production	+.0751	#6	-.0570	#13
Ratio of Model to Industry Assets	.0211	#22	.0177	#21
Average Variation in Non-Oil & Gas Commitment	.5887	#12	-.1564	#25
Average Quick Ratio	2.8149	#12	1.2484	#6
Fractional Commitment to Offshore Geophysical	.0853	#9	.0503	#12
First-Year Profit, B$	.2419	#6	.2002	#13
Final Model Assets Level B$	2.3018	#12	1.9766	#6

In this trial preferred strategies relative to each multiple-criteria decision function were selected from among the fifteen prospective allocation policies.

Subprogram	Decision Method	Selected Allocation
01	Dominance	#6
02	Satisficing	None
03	Lexicography	#22
04	Additive Weighting	#1
05	Effectiveness Index	#6
06	Utility	#12
07	Trade-off	None
08	Non-metric Scaling	#12
09	Dominance + Satisficing	None
10	Satisficing + Lexicography	None
11	Additive Weighting + Trade-off	#6
12	Dominance + Effectiveness Index	None
13	Non-metric Scaling + Utility	None
14	First-Year Profit	#6
15	Fifteenth-year Assets	#12

The fixed allocation approach to investment scheduling indicates a rather significant range of possibilities available to the planner. Allocation strategies 12 and 6 clearly point out that shifting emphasis from secondary operations to development drilling activities tends to increase profitability, but slow the rate of assets growth.

The E & P organization described in the cases above proves to be less than successful relative to the projected growth of the industry. While strategies can be selected to improve profitability, the growth of the organization in assets remains marginal. This is basically a problem imposed by the policy constraints limiting investment strategies in the model. In most of the allocation schemes less than half the investment capital was routed into direct revenue producing activities.

Typically, for the average investment profile, more than a third of all monies were spent on geophysical, acquisition and exploration drilling activities. As a consequence lease holdings and reserves in the model had been increased two and three fold at the planning horizon, while fixed organization assets showed mean gains of only about ten percent. Discrepancies of this type become obvious from model results and can be easily remedied by redefining the allocation policy constraints to insure a better balance among expenditures.

Use of multiple-attribute decision functions to analyze systems and select preferred alternatives, as in the case of the E & P LRP model, can be very helpful in studying the system. The application of some methods appears more obvious than others. Two of the simplest of these techniques, dominance and satisficing, represent excellent LRP reduction procedures. By the stipulation of minimum criteria, as in satisficing, it can be quickly determined whether an acceptable strategy is available. In the trials discussed above the model organization failed to attain the minimum goals hoped for. In lieu of the failure to achieve minimum criteria, nonmetric scaling offers a technique to isolate that strategy which seems to approach most nearly the "ideal" situation.

Decision functions, such as additive weighting, effectiveness index and utility, which are attempts to transform several attributes into one, provide good answers if the functional relationship set up between attributes is meaningful. Some attempt was made in the E & P model to achieve a kind of parity among these functions in an effort to select the same or similar strategies. This resulted in a partial success; the strategies selected, while usually not the same, were reasonably alike. Employing two multiple attribute functions in tandum was not useful in the simulation experiments, but only because the model was unable to generate acceptable outcomes. The dual decision function does not add to the complexity of the decision process; it can, however, substantially reduce the number of prospective strategies.

Tables IV through X in Appendix D show selected allocation strategies from the three cases cited above. The columnar data represents the ten E & P functions to which funds were allocated and the year the allocation was made. Tabulated are the fractional commitments of capital invested during each year of the planning period. From Tables IV and V (Case I) the variation in long-term strategy can be observed between a preference of assets growth along (Replication 68) and the multiple attribute criterion developed by additive weighting (Replication 53). The criterion of assets growth suggests a greater commitment should be made relative to secondary producing operations, particularly in later years where the level of investment is highest.
In this trial the average annual commitment to secondary operations under Replication 68 was thirty-two percent higher than under Replication 53. Tables VI and VII (Case II) illustrate the difference in preferred strategies between the criteria expressed by additive weighting (Allocation 01, Replication 10) and effectiveness index

(Allocation 04, Replication 01). The effectiveness index function places a greater emphasis on average rate of production, reflecting a significantly higher commitment to development drilling than the former strategy. It is also worthwhile to note that starting allocation played a role in strategy selection in Case II. A summary of the four sets of initial allocations are provided in Table X. Finally, in Case III twenty-five trials were run employing a fixed allocation format throughout the planning period. In this analysis allocation 06 was selected by four of the decision subprograms, dominance, effectiveness index, additive weighting and tradeoff, and first year profit. Allocation 06 is characterized by high production and revenue as indicated by the extensive commitments to development drilling shown in Table VIII. Utility and non-metric scaling criteria were influenced by investment in secondary operations (Table IX) signifying a stronger preference for assets growth.

The E & P organization used for the LPP trial runs was input as a conservatively-managed company oriented basically to continental oil and gas operations. Forecast declines in the success of onshore development drilling and the increasingly marginal profitability to be gained from secondary operations accounts largely for its loss of competitive position within the industry. However, even though growth in assets averaged less than one percent per year, and daily production nominally declined to some seventy percent of its original level, the profit-making potential of the model organization remained attractive. This was due in large part to projected increases in the price of hydrocarbon fuels. Development of the simulated E & P organization was dependent upon the limits on investment commitments programmed into the model as representing management policy. It should be pointed out that minor adjustments to these policy constraints, signifying a shift in management attitudes, would produce corresponding changes in the model output and thus effect the selection of preferred allocation strategies.

From the series of trials discussed above an inference can be drawn regarding the multiple-criteria approach to planning decisions versus the more commonly accepted criteria such as profit or growth. Indeed, from the results obtained it appears unlikely that a management objective formulated among several attributes of a system would be associated with the same planning strategy as one keyed to a single attribute. The multiple-attribute criteria used in this investigation, moreover, all employed the same seven attributes, several of which were measuring related properties of the E & P system. Differences in preferred allocation strategies among the various criteria could be expected to magnify if a group of divergent attributes were introduced in the decision subprograms. Hence a profit-oriented business organization, despite its short-term gains, could well be sacrificing the opportunity for even greater achievements in years ahead by not considering explicitly the forecast trends of the industry.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER RESEARCH

The purpose of this research has been to develop a model for evaluation of planning decisions to apply the concept of strategic planning quantitatively in the area of domestic exploration and production of energy resources. To this end a "type" organizational structure for E & P was defined and programmed as a heuristic computer simulation model. While the LRP model herein lacks the sophistication that could be built into a detailed representation of any real world E & P system, it does provide a viable framework to test the feasibility of the proposed multiple-attribute approach to strategic investment planning.

Summary

Strategic or long-range planning is destined in the years ahead to play a significant role in the activities of business and industrial organizations. Commerce in the United States, and throughout the world, is becoming increasingly complex. Competitive advantage in the future will most assuredly rest with those who can correctly anticipate changes in the business climate and adjust their plans accordingly. Although this investigation relates to only a small segment of American industry, the procedure employed for strategic decisionmaking should have application in many other areas.

The fundamental premise of the proposed LRP model provides that investment strategy over a period of years can materially contribute to the success of a business firm relative to its competition; and, as a consequence, management, through the use of environmental business forecasts and an inherent knowledge of the internal functioning of various organizations, can seek to improve its strategic decisionmaking capability. The E & P model utilizes the allocation of available investment capital to diverse organizational functions over a specified planning period to indicate the expected success of following certain strategies. The allocation of capital funds to each function, and subsequent reallocation by activity and geographic area, determines the annual budget level of every financial entity. Through the use of forecast information an incremental output from successive annual investments is repetitively generated until the planning horizon is reached. A measure of preferrence among alternative feasible strategies is then ascertained through multiple-attribute decision functions keyed on preselected attributes of the system.

Using the E & P LRP simulation program test cases were run for a typical domestic organization to examine the versatility of the model and the feasibility of employing multiple-attribute techniques in making strategic planning decisions.

Thirteen selected multiple-attribute functions were designated and compared with near-term profitability and long-range growth as two of the most common management objectives. Output from the trial runs reveals that both the selection of critical attributes and the type decision function can affect the choice of allocation strategies. Moreover, the profile of initial allocation tends to alter the mean values of critical attributes, which in turn may change the indicated preferred strategy for any given decision function.

Conclusions

Results from the E & P LRP program support the proposition that orientation of an organization toward long-range objectives is feasible through the application of multiple-attribute decisionmaking methods. Obvious variations in allocation strategy could be observed among the multiple-attribute functions on one hand, and between these and the growth and profitability attributes on the other. Since decision functions composed of several attributes afford a high degree of flexibility and provide the chance to monitor many properties of the organizational system concurrently, it is believed their implementation represents an analytic procedure complementary to both the needs of long-range planners and top management decisionmakers.

The utilization of computer simulation techniques in the construction of heuristic planning models, as in this investigation, provides a means of developing LRP systems which are both unique and flexible. Herein the combination of E & P model and multiple-attribute decision subprograms used in tandum offered a selective method of reviewing the effect of various planning criteria. For example, the LRP model indicated that primary reliance on continental oil and gas energy sources over the next fifteen years would result in a substantial loss of competitive position and production, although profits would suffer little during the same period. A shift in emphasis toward offshore development and new production from non-oil and gas sources tended to bring about long-term competitive advantages and higher production rates, but this only at the expense of low profitability and heavy debt. Thus, by use of models like the one described, and the prudent application of decision criteria, company managements would be in a position to develop planning strategies capable of meeting future objectives while minimizing the susceptability of their organizations to intermediate financial hazards.

Two notable difficulties are associated with undertaking an approach to strategic investment planning as outlined in this investigation. First is the effort required to develop an LRP simulation program which is unique to the organization of interest. Modeling a large system can present complications relative to assumptions, functional relationships, and quantity of detail, not to mention the work required for verification and validation of the program with respect to the real system. Additionally, the program, once developed, must be periodically modified as conditions both internal and external to the organization change. A further difficulty may arise from attempts by the planning staff to translate long-term management goals into relevant multiple-attribute decision functions. As indicated in the discussion of results in Chapter V, some of the methods reviewed in this investigation were hard to adapt in the context of realistic decision situations.

One requirement for using LRP simulation models which soon became apparent in this study was the need for very high-speed computers and ample core capacity. The program described herein was run on an IBM 360/50, using overlays, and proved to be too large for efficient execution. Planning simulation programs of this type which stipulate a high degree of detail relative to the model system may tax even the largest of computers. The random search procedure for preferred allocation schemes, as employed in the E & P model, is inefficient with respect to minimizing computer usage. Planning personnel using similar LRP models, in addition to developing specific multiple-attribute decision functions for each program, would be wise to work out appropriate search routines to govern machine run time.

Finally, some comment should be made concerning the acquisition and use of forecast information. Much of the general data needed, especially in the energy industry, is available from public sources. A considerable volume of forecast information in this area is released each year in industry and government publications. While all the various sources rarely agree, approximate levels of activity can often be reliably established. The most difficult problem in the case of domestic energy resources is attempting to subdivide data forecasts by geographic regions different from those in the original source material. Under any circumstances operation of a planning department which uses LRP simulation would require a substantial and continuous effort to develop and update information projections related to both the organization of interest and the industry as a whole.

Recommendations for Further Research

The E & P model used in this investigation has elements of both the fully-constrained and partially-constrained models described by Martin K. Starr. Environmental forecast information is regarded as known with certainty, rendering the model outcome perfectly predictable given any 15-year allocation sequence. However, relative to the apportioning of capital funds, the model is stochastic within prescribed allocation limits. Elimination of the fully-constrained characteristic from the model forecasts would represent a significant improvement in the value of the information generated by the LRP program. Projected forecasts could then be described in terms of probability distributions which more nearly reflect the uncertainties encountered in attempting to quantify future events. The major difficulty to this may be identifying dependencies in the system and defining functional relationships among the dependent variables.

Another meaningful area for research is associated with the formulation of multiple-attribute decision procedures from real world planning objectives. The decision methods discussed in this investigation relate only to a few of the more common techniques. Some of these were found easy to apply and others very nebulous, but all offered the prospect of future utility if a way can be found to realistically transform planning goals into an appropriate analytic configuration.

In partially-constrained planning models, given stochastic future environments, random search for preferred allocation strategies can become extremely wasteful of both time and money. It seems reasonable that heuristic procedures or algorithms can be developed to monitor and direct the search patterns of large LRP simulation programs, even as the simulation procedes toward completion. Where more than one multiple-attribute method is employed concurrently, the search routine will need to be sufficiently flexible to permit adequate investigation by all decision methods. Such simulation control algorithms would eventually become an integral part of each decision subprogram available to the LRP model.

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APPENDIX A

FUNCTION AND ACTIVITY DESCRIPTIONS

Function I - Geophysical

The geophysical function represents the search effort for new sources of prospective energy reserves. Geographically, these areas can be located on the continent or in offshore coastal waters. The energy source may be oil, gas, coal, uranium, oil shale, tar sand, or other.

Activity 1 - Continental Geophysical Activity

This activity involves the search for new oil and gas fields within the confines of the continental United States. Geophysical work includes magnetometer, gravimeter, and seismic surveys, etc., along with supporting staff analysis to pinpoint potential targets.

Activity 2 - Offshore Geophysical Activity

Geophysical Surveys along the coastal regions are conducted using many of the same sensing devices as the onshore work, but the effort of acquiring and analyzing data is more expensive. Offshore geophysical work, as considered herein, is limited to the search for oil and gas reserves.

Activity 3 - Geophysical Prospecting

Geophysical prospecting is the summation of geophysical activity directed toward locating non-oil and gas (fluid) reserves. Much of this effort is concentrated in hardrock prospecting for minerals such as uranium, or hydrocarbons in the form of coal, oil shale, and tar sand. Most energy sources of this type are recovered through mining techniques.

Function II - Lease Acquisition

The leasing function follows from the results of geophysical activity conducted by E & P. Areas indicating a high probability for discovery of energy are identified and an attempt is made to secure mineral leases offering the best possible acreage position. The cost of acquisition varies depending on the type of energy source and the geographic area in which it is sought.

Activity 4 - Oil and Gas Leasing

Leases for oil and gas exploration are normally committed on the basis of geologic or geophysical data, or the presence of a nearby discovery. Lease size may vary from a few acres in some continental areas to hundreds of square miles in offshore governmental tracts.

Activity 5 - Acquisition of Mining Rights

This activity covers acquisition of mineral leases other than for oil and gas exploration. In most instances recovery of the source material will require a mining operation, as in the case of uranium, coal, and oil shale.

Function III - Exploration Drilling

For oil and gas leases proof of the presence of hydrocarbons under the leased acreage is accomplished by drilling exploratory wells. Exploration drilling has been divided geographically into continental and offshore; relative to continental exploration, further distinction is made between routine drilling and deep exploratory tests.

Activity 6 - Continental Exploration Drilling

Continental exploration drilling is the means of finding prospective oil and gas fields for future development. Most exploratory wells are drilled in localities where few, if any, previous discoveries have been made. The cost of individual exploratory wells depends primarily on the depth of investigation and the geographic area being investigated.

Activity 7 - Deep Exploratory Tests

An increasing number of very deep exploration wells are drilled each year to test zones previously considered inaccessable. These deep continental tests are regarded here in a separate category from other exploratory wells because of their disproportionately high cost. While the actual number of such deep probes is relatively small, the chance for a major discovery is probably higher than for the shallower exploratory ventures.

Activity 8 - Offshore Exploratory Drilling

Offshore drilling must be conducted from a drilling ship or platform. Exploratory effort in coastal waters requires far greater sophistication in skill and equipment than comparable continental drilling; consequently, the average cost per offshore exploratory well is significantly greater than a similar one drilled onshore.

Function IV - Development Drilling

Once an oil or gas producing horizon is discovered, additional wells are needed to define the field limits and produce the reservoir at an economic rate. Wells drilled for this purpose are called development wells. Development drilling has been classed into oil wells and gas wells and subdivided by continental and offshore production.

Activity 9 - Continental Oil Development Drilling

Continental oil development drilling accounts for producing wells to oil reservoirs on the continent.

Activity 10 - Continental Gas Development Drilling

Continental gas development drilling accounts for producing wells to gas reservoirs on the continent.

Activity 11 - Offshore Oil Development Drilling

Offshore oil development drilling accounts for producing wells to oil reservoirs drilled from platforms in coastal waters.

Activity 12 - Offshore Gas Development Drilling

Offshore gas development drilling accounts for producing wells to gas reservoirs drilled from platforms in coastal waters.

Function V - Producing Activities

In the production of oil and gas there is usually need for certain facilities over the life of a field to insure efficient operations and maximize recoverable reserves. Installation of these facilities may represent a significant capital outlay at some point in the life of the field subsequent to full development. Identified in this function are six activities considered typical of the major categories of post-development investment requirements. These include secondary recovery, pressure maintenance, tertiary, and insitu combustion projects, together with natural gas facilities and gasoline plants.

Activity 13 - Secondary Recovery Projects

Secondary recovery is injection of a fluid, usually water, into a primary depleted or semi-depleted reservoir, to move residual oil to the producing wells and increase ultimate recovery. The cost of injection equipment, lines, central producing facilities, etc., can run into millions of dollars on a major project.

Activity 14 - Pressure Maintenance Projects

Pressure maintenance is injection of gas or water into a new or partially depleted reservoir to maintain reservoir pressure as it is being produced to improve recovery. Equipment and facilities are similar to those required of secondary recovery, although generally in lesser quantity.

Activity 15 - Improved Recovery and Tertiary Projects

In some efforts to obtain added recovery from a reservoir, chemical additives are put into the displacing fluid to improve sweep efficiency; increases in ultimate recovery are often possible in reservoirs previously waterflooded. Equipment and facilities are similar to those used in secondary recovery.

Activity 16 - Steam and Insitu Combustion

In large reservoirs of relatively viscous crude the only effective means of producing oil is through application of thermal recovery techniques. One method is to inject steam into the reservoir. Another is to inject air and ignite the hydrocarbons in the reservoir to create a moving front toward the producing wells. The cost of applying thermal processes is normally quite high; moreover, it has not been economically successful in all areas of the U. S.

Activity 17 - Natural Gas Facilities

Production of natural gas often requires the installation of field gathering systems for extraction of liquids and delivery of gas to the purchaser. The degree to which company-owned gas facilities are needed depends upon field location and the avilability of transmission lines in the area.

Activity 18 - Gasoline Plant Construction

Natural gas, as produced from the wellhead, is usually processed before sale for extraction of natural gas liquids. A gasoline plant functions much as a small refinery separating ethane, propane and butane together with the heavier ends, from the wellstream. The capital investment for a gasoline plant may run from one-half to several million dollars depending on inlet capacity.

Function VI - Production Equipment

Periodic replacement and modernization of producing equipment and facilities is critical to efficient field operations. In many areas remote control systems are being used to monitor operations and aid in analyzing equipment failures.

Activity 19 - Equipment Replacement

The life of oil and gas fields vary, although the average may well exceed 20 years; there are fields, of course, where producing operations have continued for 50 years or more. Over a period of two or three decades not only do operational expenses occur, but capital equipment must occasionally be replaced due to wear or obsolescence.

Activity 20 - Modernization and Computerization

Efficiency of field operations is many times a function of the equipment. Substantial savings can be realized from a complete overhaul of producing facilities in some cases. Computer-assisted control of equipment in gasoline plants and secondary recovery projects in recent years has provided much needed flexibility in manpower deployment.

Activity 21 - Remote Control Systems

Monitoring production operations in widely scattered oil and gas fields can pose a serious manpower problem, especially in remote geographic areas. In the last few years computer monitoring systems have been developed which can continuously check producing facilities and equipment, and insure a minimum of down time. These monitoring systems not only warn of the existance and location of a failure, but indicate the probable source of difficulty.

Function VII - Non-Oil and Gas Activities

Certain potential sources of future energy will be derived from other than subsurface reservoirs of oil and gas in a movable fluid form. In some cases the energy source may not even be hydrocarbon in composition. Included among prospective energy sources are oil shales, tar sands, uranium, and coal.

Activity 22 - Oil Shale and Tar Sand

Very substantial reserves, possibly in the order of two or three trillion equivalent barrels of oil, are tied up in oil shales and tar sands in the continental United States. However, because of the very high development cost and limited technology relative to these sources, the reserves are at present not "economic reserves." As domestic energy requirements increase in years to come, more attention will be given to oil shale and tar sand sources for hydrocarbon fuels.

Activity 23 - Uranium

Uranium is a nuclear fuel and has been recognized as a potentially major energy source for twenty years. Many of the larger oil companies are engaged in uranium mining and related research activities.

Activity 24 - Coal and Coal Fluids

In the continental United States more energy is credited to coal reserves than any other single source. Mining of low grade coal, supported by extraction and processing facilities, could account for a sizable percentage of domestic hydrocarbon fuels toward the end of this century. The technology of extracting gas and hydrocarbon liquids from coal is currently under development.

Activity 25 - Other Energy

This activity provides for search and development efforts relative to prospective energy sources which are as yet in the infant stage. For example, this might include energy from sea currents, or heat transfer in volcanically active regions.

Function VIII - Research and Development

The science of recovering oil, gas, and other sources of energy from the earth is supported through the research efforts of industry, universities, and the federal government. Most large oil companies maintain research facilities to provide technical assistance in their search for new energy sources and to optimize recovery from existing operations.

Activity 26 - Research and Development for Oil and Gas

Research and Development related to oil and gas operations is usually concentrated in areas of science such as geophysics, geology, reservoir engineering, drilling, and production methods. Part of the research effort is directed to new technology; the remainder provides technical service to field operations along with personnel training.

Activity 27 - Research and Development for Mining and Extraction

As interest grows in securing greater quantities of energy from non-oil and gas sources, the magnitude of research effort in this area by E & P organizations will increase. The biggest problems at present center around economics. Mining, extraction, refining, and ecology are all expensive activities in the processes envisioned for recovering fuels from low-yield ores. Much research is needed before these prospective sources can be developed on a major scale.

Function IX - Activity 28 - Public Responsibility

Environmental protection in oil production has always been a factor to consider. In the future with increasing governmental safeguards the cost of capital equipment for pollution control will no doubt increase. Nevertheless, there will always exist a range of commitment for each E & P organization between meeting only minimum requirements and exercising utmost care in protecting the public domain.

Function 10 - Activity 29 - Personnel Development

Personnel, like buildings, equipment and capital, are assets to an organization. In general management would like to believe that a commitment to employees in the form of education or training will eventually pay dividends in better performance. Well-trained personnel can presumably give one organization a competitive advantage over another where equipment and facilities are essentially equal.

APPENDIX B

GENERAL DESCRIPTION OF E & P

MODEL INTERACTIONS

I.	GEOPHYSICAL FUNCTION - receives principal allocation according to a specified minimum and maximum as a function of forecast composition industry commitment.
1,2,3 - 1,2,3	Principal geophysical allocation is suballocated among continental geophysical, offshore geophysical, and hard rock prospecting. Suballocation is defined by policy, but conditional to status. In other words the suballocation for each activity is exactly calculatable according to policy, but the outcome is subject to the endogenous status of the model organization at the time and exogenous conditions forecast for the industry relative to this function.
1 - 4	The amount of acreage made available for leasing is a function of geophysical activity in the recent past . . . a certain backlog might be assumed nominal by management.
4 - 1	Feedback on cumulative acreage under lease. High backlog would have the effect of forcing a temporary reduction in the suballocation to geophysical activity.
6 - 1	The forecast exploratory drilling rate would determine the estimated current backlog in exploratory drilling.
2 - 4	Same as 1 - 4.
4 - 2	Same as 4 - 1.
8 - 2	Feedback -- same relationship as 6 - 1; 7 - 1.
3 - 5	The amount of property available for leasing is a function of recent prospecting activity. Prior to actual production, excessive investment in nonproducing properties must be avoided. After production begins, a new policy becomes effective.

5-3 Feedback on cumulative prospective reserves under lease from non-oil and gas sources. This is used to adjust hard rock geophysical activity.

22,23,24,25 - 3 Feedback to geophysical on forecast discovery potential by energy source.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast industry commitment to geophysical function by activity.

2. Forecast cumulative reserves in equivalent barrels from non-oil and gas sources by region.

3. Forecast average annual acreage, continental and offshore, to be explored for oil and gas.

4. Forecast increases in new industry reserves of oil and gas by region.

5. Forecast acreage surveyable per $ unit geophysical outlay; fraction of this leasable.

II. ACQUISITION FUNCTION - receives principal allocation over and above a set minimum (percent of industry share) and a variable maximum subject to cumulative leased property.

4,5 - 4,5 Principal acquisition allocation is suballocated among oil and gas leasing and acquiring of solid mineral rights.

Suballocation will be fixed as to mining rights under three conditions:

(a) Model reserves $<$ industry share
(b) Model reserves $>$ industry share
(c) After start of commercial production.

Remainder of principal allocation will be divided between continental and offshore oil and gas leasing on the basis of composite forecast discovery potential.

4 - 1	Given above.
1 - 4	Given above.
4 - 2	Given above.
2 - 4	Given above.
4 - 6,7	Record of cumulative leased acreage available for exploration drilling.
6,7,8 - 4	Forecast future potential for discovery.
5 - 3	Given above.
5 - 3	Given above.
5 - 22,23,24,25	Accumulative of recoverable reserves from non-oil and gas sources now under lease.
22,23,24,25 - 5	Initiation of commercial production stimulates the need for increased prospecting and leasing.
5 - 27	Sustained acceration of leasing places additional on R & D related to mining and extraction.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast percentage of continental and offshore surveyed acreage expected for leasing industry-wide during future years.

2. Forecast rate of expiration of leased acreage by year and previous year's industry commitment to drilling.

3. Forecast industry investment commitment to each of three categories: mining rights, continental oil and gas leasing, and offshore oil and gas leasing.

4. Forecast of Speculative reserves added by geographic region as a function of acreage leased.

III.	EXPLORATION FUNCTION - receives principal allocation as a function of forecast composite industry commitment to exploratory drilling. Dollar minimum is based on assets ratio.
6,7,8 - 6,7,8	Principal exploration allocation is suballocated among continental exploratory drilling, deep exploratory tests, and offshore exploration drilling. Suballocation is defined by policy with deep exploratory tests checked first and assigned on a rotational basis and given success ratio. Suballocation to continental and offshore are on a proportional ratio to future discovery potential.
6 - 1	Given above.
6 - 4	Given above.
4 - 6	Given above.
6 - 9	Exploratory drilling yields proved plus prospective reserves. . . . cumulative discoveries to be developed.
6 - 10	Same as 6 - 9 for gas.
26 - 6	The greater the R & D commitment to oil and gas related activities, the greater and probable drilling success.
7 - 1	Given above.
7 - 4	Given above.
7 - 7	Given above.
7 - 9	Exploratory drilling yields proved plus prospective reserves. . . . cumulative discoveries to be developed.
26 - 7	The greater the R & D commitment to oil and gas related activities, the greater the probable drilling success.
8 - 2	Given above.
8 - 4	Given above.
4 - 8	Given above.

8 - 11	Exploratory drilling yields proved plus prospective reserves . . . cumulative discoveries to be developed.
26 - 8	Same as 26 - 7

SOME RELATED INDUSTRY FORECASTS:

1. Forecast industry commitment to exploration drilling by category and by region.

2. Forecast discovery potential by category and region; proved plus prospective reserves. . . . per dollar of capital funds committed.

3. Forecast by region the probable success ratio of deep exploratory wells; maintains a counter for each region.

   Forecast by region the proved plus prospective reserves for a deep well success by region.

IV.	DEVELOPMENT DRILLING FUNCTION - receives principal allocation as a function of forecast composite industry activity. Subject to a minimum and maximum based on exploratory success record.
9,10,11,12 -	Suballocation in development drilling based on past 3-year record in exploration (reserves added). Composite weighting. Principal allocation is suballocated among oil and gas drilling, continental and offshore.
6 - 9	Given above.
7 - 9	Given above.
29 - 9	The level of personnel development relative to education, training, etc., over a period of years will influence the profitability of routine operations.
19,20,21 - 9	The composite commitment to equipment replacement, modernization and computerization, and remote control systems over time will favorably effect profits, provided commitment is above industry average.

9 - 13,14,15,16	Level of on-going development drilling and primary production influences commitment to secondary recovery, pressure maintenance, improved recovery, steam, and insitu combustion.
6,7 - 10	Given above.
29 - 10	Same as 29 - 9.
19,20,21 - 10	Same as 19,20,21 - 9.
10 - 17	Amount of gas production developed during the previous year dictates allocation to natural gas facilities.
10 - 18	Cumulative build up of gas activity in any area both by model organization and industry in general determines likelihood of building a gasoline plant.
8 - 11	Given above.
29 - 11	Same as 29 - 9.
19,20,21 - 11	Same as 19,20,21 - 9
11 - 13,14	Same as 9 - 13,14.
11 - 28	The higher the level of offshore development drilling, the greater the need for commitment to public responsibility.
8 - 12	Given above.
29 - 12	Same as 29 - 9.
19,20,21 - 13	Same as 19,20,21 - 9.
13 - 28	The more secondary recovery projects that go into operation, the greater will be the need for public responsibility.
9 - 14	Same as 9 - 13.
11 - 14	Same as 11 - 13.
29 - 14	Same as 29 - 13.
19,20,21 - 14	Same as 19,20,21 - 9.
14 - 28	Same as 13 - 28.

9,13,14 - 15	The level of improved recovery and tertiary recovery will depend on the joint level of primary, secondary recovery, and pressure maintenance.
29 - 15	Same as 29 - 13.
19,20,21 - 15	Same as 19,20,21 - 9.
15 - 28	Same as 13 - 28.
15 - 26	The more improved recovery and insitu projects under way, the greater will be the need for R & D support.
9 - 16	Commitment to steam and insitu combustion activity are a function of regional potential for this activity and level of production the model organization has in the area.
29 - 16	Same as 29 - 13.
19,20,21 - 16	Same as 19,20,21 - 9.
16 - 28	Same as 13 - 28.
16 - 26	Same as 15 - 26.
10 - 17	The combined level of gas development drilling, offshore and continental, will affect the need for natural gas facilities.
29 - 17	Same as 29 - 13.
19,20,21 - 12	Same as 19,20,21 - 9.
12 - 17	Same as 11 - 17.
12 - 18	Same as 11 - 18.
12 - 28	Same as 11 - 28.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast level of industry oil and gas production under primary by region.
2. Forecast profitability by region of primary oil and gas operations.

3. Forecast average annual decline of existing primary oil and gas production.

4. Forecast estimated increase in proved and prospective reserves, and primary rate of production, as a function of investment committed.

V.	PRODUCING FUNCTIONS - receives principal allocation as a function of the forecast composite industry activity in all areas subject to a minimum constraint set by policy.
13,14,15,16,17 18 - 13,14,15, 16-17-18	Suballocation requires an initial check of possible gasoline plant construction. Remaining suballocation based on relative potential of activities in the various areas . . . normalized.
9 - 13	Given above.
11 - 13	Given above.
29 - 13	Level of personnel development in education, training, etc., will improve profitability when above industry norm.
19,20 - 17	Same as 19,20 - 9.
10 - 18 12 - 18	Same as 10 - 17,12 - 17.
29 - 18	Same as 20 - 13.
18 - 28	Same as 13 - 28.
18 - 26	Same as 16 - 26.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast and commitment to secondary recovery, pressure maintenance, insitu, and improved recovery activities by region.

2. Forecast profitability of each by region.

3. Forecast estimate of reserves added and increased production rate as a function of investment committed.

VI.	PRODUCTION EQUIPMENT FUNCTION -- receives principal allocation as a function of accumulated invested capital (tangible assets) and the make up of that investment. A basic minimum established by policy guarantees nominal maintenance of equipment.
19,20,21 - 19,20,21	Suballocation between equipment replacement, modernization & computerization, and remote control systems is made on a fixed allocation basis depending on which the production occurs.
19 - 9,10, 11,12,13, 14,15,16, 17,18,22, 23,24,28	The cumulative level of tangible assets in each of these categories helps establish the minimum level of commitment to equipment replacement.
9,10,11,12, 13,14,15, 16,17,18, 22,23,24, 28 - 19	Equipment replacement tends to improve incremental profitability and increase reserves by reducing the rate of production decline.
20 - 9,10, 11,12,13,14, 15,16,17,18	Same as 19 - . . . above.
9,10,11,12, 13,14,15, 16,17,18 - 20	Same as . . . - 19 above.
9,10,11,12, 13,14,15, 16,18 - 21	Same as . . . - 19 above.
21 - 26	A high propensity to automate production would require additional input into R & D.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast of commitment in dollars to production-related equipment by the industry on an annual basis.

VII.	NON-OIL & GAS OPERATIONS -- receives principal allocation as a function of forecast future commitment to alternate energy sources. Minimum based on a fraction of average commitment by policy, prior to actual commercial production. Lump sum capital investment to undertake commercial production is a function of forecast industry conditions and cumulative company investment in the specific energy source.
22,23,24,25,-22,23,24,25	Suballocation among alternative non-oil and gas energy sources is allocated on the basis of forecast future composite development potential.
5 - 22	The amount of property under lease influences the choice of commiting a large investment to go commercial. Acquired mineral rights establish level of prospective reserves.
27 - 22	The amount of previous commitment to R & D up to a given time influences the decision to commit a large sum of capital for commercial development.
22 - 27	Advent of commercial development creates an additional demand on R & D.
22 - 3	Production in commercial quantities stimulates requirements for geophysical prospecting.
5 - 23 27 - 23 23 - 27 23 - 3	Same reasons as for 22 above.
5 - 24 27 - 24 24 - 27 24 - 3	Same reasons as for 22 above.
5 - 25 27 - 25 25 - 27 25 - 3	Same reasons as for 22 above.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast of commitment to non-oil and gas energy sources individually and by region.

2. Forecast productivity rate of non-oil & gas energy sources after initiation of commercial production.

VIII:	APPLIED RESEARCH & DEVELOPMENT -- receives principal allocation as a function of total investment as well as a function of the distribution of assets in the model E & P organization. Minimum allocation is a fraction of total commitment based on assets. Maximum is related to running level of industry research activity.
26,27 - 26, 27	Suballocation between oil and gas sponsored research and research related to mining and extraction depend on the levels of functions supported by the two R & D activities in so far as production, future reserves, and the need for R & D.
26 - 6,7,8	R & D support to exploration drilling, via geophysical, should result in an improved success ratio.
15,16,18 - 26	Increased operations influence the minimum level of R & D activities.
21 - 26	Additional application of remote control systems will require increased support from R & D in future years.
28 - 26	Increasing the commitment to public responsibility requires an increase in R & D for support.
5 - 27	Given above.
22 - 27 27 - 22	Given above.
23 - 27 27 - 23	Given above.
24 - 27 27 - 24	Given above.
25 - 27 27 - 25	Given above.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast of demand potential for R & D in specific producing activities.

2. Forecast industry commitment to R & D broken down by oil & gas and other energy sources.

IX. PUBLIC RESPONSIBILITY -- receives principal allocation as a function of forecast public demands for environmental control. Minimum is fixed by policy modified by accumulative investment level in pollution prone activities.

8,11,12,13, 14,15,16,18, 19,22,23,24 - 28 The allocation to public responsibility above the minimum set my management is influenced by the assets level in each of the activities noted.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast of industry commitment toward pollution control related to E & P activities.

X. PERSONNEL DEVELOPMENT -- receives principal allocation in accordance with a maximum and minimum established by management on a "per employee" basis. Number of employees is taken as a function of total assets.

9,10,11,12, 13,14,15,16, 17,18,22,23, 24 - 29 The level of allocation to personnel development over several years affects the profitability of production operations where training and employee competence is essential.

SOME RELATED INDUSTRY FORECASTS:

1. Forecast industry commitment to personnel development per employee.

APPENDIX C

Programmed E & P Decision Attributes

Profitability Attributes

1. Average Annual Rate of Return -- Long Range.

   The long-range average annual rate of return is the average percent of annual profits divided by assets over the fifteen-year period.

2. Selected Annual Rate of Return.

   Annual Rate of Return can be specified for any year or range of years.

3. Average Annual Rate of Return -- Intermediate Range.

   The intermediate-range average annual rate of return is the average percent of annual profits divided by assets over years one through five.

4. Average Annual Rate of Return -- Short Range.

   The short-range average annual rate of return is the percent of first-year profits to first-year assets.

Liquidity Attributes

5. Average Current Ratio -- Long Range.

   The long-range average current ratio is the average sum of current ratios for the fifteen-year period.

6. Average Quick Ratio -- Intermediate Range.

   The intermediate-range quick ratio is the average sum of quick ratios for years one through five.

7. Selected Current Ratio.

Current ratio can be specified for any year or range of years.

8. Selected Quick Ratio.

Quick ratio can be specified for any year or range of years.

Solvency Attribute.

9. Average Equity-to-Debt Ratio -- Long Range.

The long-range average equity-to-debt ratio is the average sum of equity-to-debt ratios for the fifteen-year period.

Market Attractiveness Attribute

10. Average Dividend Yield -- Long Range.

The long-range average dividend yield is the average sum of dividend yields for the fifteen-year period.

Growth Rate and Industry Position Attributes

11. Cumulative Percent Increase in Total Production -- Long Range.

The cumulative percent increase in total production is the incremental increase in production from year one to year fifteen divided by the first-year production.

12. Average Percent Increase in Offshore Producing Rate -- Long Range.

The average percent increase in offshore producing rate is defined as the average annual increase divided by two-thirds the initial offshore producing rate.

13. Increase in Processing -- Intermediate Range.

The fractional increase in processing is the increase in processing through year five divided by the initial processing rate.

14. Average Assets Growth -- Long Range.

Average long-range assets growth is the average increase in assets from year one to fifteen divided by first-year assets.

15. Cumulative Assets Growth -- Intermediate Range.

The cumulative assets growth over the intermediate range is the percent incremental from year one to year five divided by first-year assets.

16. Fraction of Total Industry Assets -- Long Range.

    The ratio of model assets to total industry assets represents the relative size of the model organization at the end of the long-range planning period.

17. Fraction of Non-Oil and Gas Assets -- Long Range.

    The fraction of non-oil and gas assets indicates the relative proportion of industry non-oil and gas assets represented by the model organization.

18. Percent Yearly Total Production Increase -- Intermediate Range.

    The intermediate-range yearly production increase is the incremental percent increase in total production from year two through year five.

19. Average Position as a Fraction of Industry-Long Range.

    The long-range model average position is the fraction of total forecast acreage under lease at the end of the planning period.

Commitment Attributes

20. Annual Geophysical Commitment as a Fraction of Industry.

    Annual geophysical commitment is the average fractional geophysical commitment by the model over any selected planning period.

21. Average Change in Geophysical Commitment -- Long Range.

    The average long-range change in geophysical commitment is the average incremental fraction over the fifteen-year period.

22. Offshore Geophysical Commitment as a Fraction of Industry -- Intermediate Range.

    Offshore geophysical commitment is the total increment of model commitment over industry commitment from year one through year five.

23. Average Change in Non-Oil and Gas Commitment -- Long Range.

    The average long-range change in Non-oil and gas commitment is the average incremental commitment fraction over the fifteen-year period.

24. Average Change in R & D Commitment -- Intermediate Range.

    The average long-range change in R & D commitment is the average incremental commitment fraction over the initial five-year interval.

25. Average Annual Percent Increase in Non-Oil and Gas Assets -- Long Range.

    The average annual percent increase in non-oil and gas assets is the average annual change in non-oil and gas assets over the fifteen-year planning period.

26. Fractional Non-Oil and Gas Increase -- Intermediate Range.

    The fractional non-oil and gas increase is the incremental change in non-oil and gas assets during the first five years.

27. Profit Increase in Long-Range Planning Interval.

    Profit increase in the LRP interval is the ratio of profit in non-oil and gas operations during the long-range planning interval over the intermediate-range planning interval.

28. Average Percent Increase in Public Responsibility -- Intermediate Range.

    Average increase in public responsibility is the average annual increase in capital committed to public responsibility during the first five-year interval.

29. Average Percent Increase in Personnel Development -- Intermediate Range.

    Average increase in personnel development is the average annual increase in capital committed to personnel development during the first five-year interval.

30. Change in Profit Relative to Number of Employees -- Intermediate Range.

    The fractional change in profit based on employees in the average change in profit per employee over the first five years.

APPENDIX D

Summaries of Input and Output Information

E & P LRP Program

TABLE I

LISTING OF MODEL FORECAST DATA

Extrapolated Industry Information

1. Investments by Function
2. Assets by Function
3. Leased Acreage
4. Production Rates
5. Proved Oil & Gas Reserves
6. Prospective Oil & Gas Reserves
7. Speculative Oil & Gas Reserves
8. Non-Oil & Gas Reserves

Projected Cost Information

9. Areal Geophysical Costs
10. Lease Acquisition Costs
11. Cost of Developing Oil and Gas Reserves
12. Cost of Non-Oil and Gas Development

Forecast Performance Increments

13. Areal Discovery Potential
14. Areal Reserve Potential
15. Production Increases per Unit Investment
16. Transmission Increase per Unit Investment
17. Processing Increases per Unit Investment
18. Annual Depreciation of Assets

TABLE II

INITIAL MODEL OPERATIONAL STATUS

		Leased Acreage (M Ac)			
Continental	4,037	Offshore	3,615	Non-O&G	94
		Reserves (MM Eq Bbl.)			
Proved:					
Continental	917	Offshore	155	Non-O&G	17
Prospective:					
Continental	2,106	Offshore	863	Non-O&G	425
Speculative:					
Continental	5,700	Offshore	2,000	Non-O&G	3,000
		Current Production (M Eq BOPD)			
Continental	349	Offshore	23	Non-O&G	0

TABLE III

INITIAL MODEL FINANCIAL STATUS

Assets (M$)		Liabilities (M$)	
Cash	67	Accounts Payable	17
Market Securities	104	Notes Payable	57
Accounts Receivable	128	Taxes	43
Inventory	56	Sinking Fund Payments	32
		Expenses Payable	15
Total Current Assets	355	Total Current Liabilities	164
		Long-Term Debt	585
Mineral Leases	297		
Facilities	1,072	Total Liabilities	749
Equipment	516		
		Stockholders Equity	935
Fixed Assets	1,885	Retained Earnings and Capital Surplus	556
TOTAL ASSETS	2,240	TOTAL LIABILITIES & STOCKHOLDERS EQUITY	2,240

TABLE IV

ANNUAL INVESTMENT ALLOCATION FRACTIONS
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	Functions									
Years	I	II	III	IV	V	VI	VII	VIII	IX	X
1	.1321	.1332	.1488	.1727	.0968	.0520	.0700	.0683	.0528	.0733
2	.1540	.0985	.0906	.1203	.2281	.0110	.0756	.0812	.0522	.0885
3	.1154	.0914	.1852	.0732	.1635	.0256	.1212	.0958	.0633	.0654
4	.1949	.0854	.1360	.1452	.0272	.0266	.0912	.0714	.0477	.0717
5	.1391	.0798	.0870	.0895	.1689	.0572	.1284	.0966	.0729	.0806
6	.0914	.0747	.2508	.0300	.1601	.1046	.0768	.0691	.0841	.0584
7	.0944	.0724	.1076	.0410	.1989	.1200	.1256	.0891	.0902	.0608
8	.0938	.0744	.1042	.0174	.2262	.1150	.1012	.1036	.0897	.0745
9	.0877	.0756	.3090	.0206	.0949	.0260	.0640	.1117	.0922	.1183
10	.1109	.0627	.1468	.0229	.3256	.0150	.0944	.0918	.0718	.0581
11	.1016	.0580	.1356	.0278	.3638	.0184	.0892	.0897	.0626	.0533
12	.0965	.0556	.1298	.0346	.3741	.0230	.0872	.0878	.0607	.0507
13	.0917	.0533	.1244	.0428	.3716	.0280	.0852	.0854	.0693	.0483
14	.0851	.0498	.1164	.0517	.3644	.0236	.0812	.0916	.0907	.0455
15	.0766	.0452	.1054	.0602	.3497	.0748	.0748	.0752	.1329	.0414

TABLE V

ANNUAL INVESTMENT ALLOCATION FRACTIONS
Case I - Allocation 01 Replication 68

Years	I	II	III	IV	V	VI	VII	VIII	IX	X
					Functions					
1	.1321	.1332	.1488	.1727	.0968	.0520	.0700	.0683	.0528	.0733
2	.1391	.0985	.1384	.0775	.2168	.0568	.0500	.0865	.0482	.0882
3	.1496	.1472	.1472	.0680	.2178	.0380	.0800	.0908	.0407	.0748
4	.0872	.0662	.0792	.2309	.2309	.0198	.1180	.1052	.0279	.0965
5	.1305	.0810	.1524	.0777	.3039	.0016	.0640	.0916	.0317	.0656
6	.1243	.0734	.0628	.0699	.2738	.1664	.0388	.0817	.0314	.0775
7	.0957	.0770	.1778	.1251	.1168	.1878	.0772	.0640	.0188	.0598
8	.1026	.0793	.1374	.1193	.2792	.0356	.0776	.0845	.0143	.0702
9	.1054	.0786	.0822	.0897	.3572	.0408	.0824	.0900	.0130	.0547
10	.1075	.0607	.1420	.0899	.3008	.0542	.0916	.0878	.0093	.0562
11	.1293	.0767	.1086	.0746	.2011	.0970	.1344	.1079	.0090	.0606
12	.1086	.0625	.1462	.0761	.3068	.0470	.0984	.0911	.0062	.0571
13	.0960	.0559	.1304	.0871	.3444	.0534	.0892	.0864	.0066	.0506
14	.0887	.0520	.1213	.1039	.3591	.0844	.0837	.0085	.0085	.0474
15	.0829	.0489	.1140	.1252	.3625	.0476	.0808	.0804	.0129	.0448

TABLE VI

ANNUAL INVESTMENT ALLOCATION FRACTIONS
Case II - Allooation 01 Replication 10

	Functions									
Years	I	II	III	IV	V	VI	VII	VIII	IX	X
1	.1321	.1332	.1488	.1725	.0970	.0520	.0700	.0683	.0528	.0733
2	.1234	.1315	.0983	.1001	.2587	.0283	.0604	.0779	.0460	.0754
3	.1420	.1340	.0834	.0636	.2593	.0490	.0732	.0822	.0279	.0754
4	.1922	.0944	.0724	.0119	.2140	.0768	.1120	.1061	.0328	.0874
5	.0957	.1335	.1430	.0120	.2908	.0530	.0780	.0920	.0339	.0681
6	.0914	.1154	.1741	.0159	.1473	.1010	.1444	.0867	.0416	.0849
7	.0727	.0765	.1848	.0196	.1804	.0948	.0948	.1886	.0281	.0597
8	.1571	.0933	.0952	.0199	.3653	.0463	.0512	.1008	.0182	.0527
9	.1155	.1315	.1973	.0153	.2361	.0168	.1140	.0893	.0149	.0693
10	.1125	.1271	.1488	.0164	.3243	.0124	.0956	.0925	.0115	.0589
11	.1031	.1174	.1376	.0199	.3626	.0147	.0904	.0902	.0100	.0541
12	.0982	.1131	.1322	.0247	.3747	.0180	.0888	.0890	.0097	.0516
13	.0946	.1101	.1286	.0310	.3769	.0220	.0880	.0876	.0113	.0499
14	.0909	.1065	.1242	.0388	.3767	.0268	.0864	.0860	.0152	.0485
15	.0867	.1024	.1194	.0480	.3722	.0324	.0844	.0839	.0237	.0469

TABLE VII

ANNUAL INVESTMENT ALLOCATION FRACTIONS
Case II - Allocation 04 Replication 01

					Functions					
Years	I	II	III	IV	V	VI	VII	VIII	IX	X
1	.1014	.1124	.1428	.2758	.1150	.0608	.0316	.0612	.0477	.0513
2	.1054	.1563	.0808	.1624	.2557	.0080	.0352	.0803	.0484	.0675
3	.1131	.1037	.1300	.1144	.2710	.0064	.0648	.0837	.0371	.0758
4	.1309	.0931	.0676	.0609	.3290	.0784	.0744	.0785	.0235	.0637
5	.1357	.1481	.0870	.0740	.3033	.0496	.0508	.0690	.0238	.0587
6	.0789	.1608	.1364	.0976	.0758	.1186	.1328	.0937	.0430	.0624
7	.1360	.1168	.1516	.0983	.2290	.0140	.0832	.0815	.0242	.0654
8	.1174	.0923	.1166	.1230	.2563	.0460	.0992	.0756	.0166	.0570
9	.0955	.1598	.0817	.2314	.1322	.0850	.0888	.0676	.0116	.0464
10	.1157	.0886	.1528	.2053	.1955	.0056	.0864	.0841	.0104	.0556
11	.0869	.0993	.1160	.1809	.2651	.0496	.0764	.0736	.0066	.0456
12	.0909	.1058	.0466	.3119	.2312	.0396	.0524	.0655	.0072	.0489
13	.0778	.0904	.1056	.2521	.2432	.0446	.0724	.0675	.0054	.0410
14	.0861	.1027	.0880	.2656	.2250	.0100	.0844	.0789	.0081	.0512
15	.0769	.0906	.1058	.2288	.2591	.0442	.0748	.0695	.0088	.0415

TABLE VIII

ANNUAL INVESTMENT ALLOCATION FRACTIONS
Case III - Allocation 06

Years	I	II	III	IV	V	VI	VII	VIII	IX	X
					Functions					
1	.1477	.0752	.1560	.2737	.1015	.0178	.0572	.0588	.0431	.0690
2	.1400	.1391	.1333	.1968	.1366	.0150	.0596	.0638	.0376	.0782
3	.1429	.1466	.1488	.1912	.1134	.0180	.0704	.0624	.0304	.0759
4	.1389	.1459	.1518	.2088	.1065	.0188	.0756	.0611	.0211	.0715
5	.1314	.1407	.1472	.2381	.1005	.0180	.0772	.0598	.0206	.0665
6	.1225	.1330	.1370	.2670	.1040	.0164	.0756	.0584	.0233	.0628
7	.1179	.1296	.1322	.2925	.1018	.0154	.0764	.0585	.0147	.0610
8	.1142	.1271	.1290	.3115	.0996	.0148	.0772	.0579	.0092	.0595
9	.1119	.1259	.1273	.3284	.0905	.0144	.0788	.0579	.0063	.0586
10	.1100	.1252	.1262	.3430	.0814	.0140	.0800	.0581	.0043	.0578
11	.0726	.0829	.0970	.2867	.2516	.0414	.0640	.0631	.0026	.0381
12	.1020	.1176	.1146	.3835	.0786	.0120	.0772	.0568	.0028	.0549
13	.0691	.0803	.0938	.3114	.2428	.0396	.0644	.0601	.0021	.0364
14	.0562	.0659	.0768	.3170	.3080	.0322	.0536	.0580	.0023	.0300
15	.0880	.1032	.0962	.4263	.0997	.0092	.0696	.0530	.0049	.0499

TABLE IX

ANNUAL INVESTMENT ALLOCATION FRACTIONS
Case III - Allocation 12

Years	Functions I	II	III	IV	V	VI	VII	VIII	IX	X
1	.0839	.0752	.1970	.0236	.2193	.0776	.0952	.0949	.0471	.0862
2	.0904	.0995	.1878	.0276	.1993	.0656	.0968	.0925	.0440	.0965
3	.0844	.0966	.1942	.0248	.1980	.0686	.1080	.0967	.0379	.0925
4	.0789	.0937	.1990	.0230	.2030	.0708	.1180	.0967	.0281	.0888
5	.0741	.0906	.2000	.0212	.2065	.0712	.1248	.0978	.0291	.0847
6	.0702	.0876	.1964	.0196	.2149	.0696	.1284	.0973	.0345	.0815
7	.0698	.0883	.1964	.0181	.2212	.0686	.1336	.0995	.0236	.0809
8	.1055	.1165	.1382	.0195	.3224	.0600	.0832	.0831	.0167	.0549
9	.1020	.1140	.1334	.0241	.3710	.0166	.0836	.0873	.0148	.0532
10	.0974	.1101	.1288	.0303	.3788	.0208	.0828	.0866	.0134	.0510
11	.0940	.1074	.1256	.0381	.3795	.0258	.0828	.0852	.0122	.0494
12	.0909	.1047	.1223	.0477	.3766	.0318	.0824	.1839	.0119	.0478
13	.0874	.1015	.1186	.0590	.3716	.0386	.0812	.0824	.0136	.0461
14	.0829	.0971	.1132	.0721	.3675	.0462	.0788	.0799	.0180	.0443
15	.0786	.0927	.1082	.0872	.3641	.0452	.0764	.0777	.0274	.0425

TABLE X

ANNUAL INVESTMENT ALLOCATION FRACTIONS
Case II - Initial Starting Allocations

Year	Functions I	II	III	IV	V	VI	VII	VIII	IX	X
					Allocation 01					
1	.1321	.1332	.1488	.1725	.0970	.0520	.0700	.0683	.0528	.0733
					Allocation 02					
1	.1323	.1130	.1386	.1253	.2770	.0082	.0364	.0619	.0528	.0545
					Allocation 03					
1	.1177	.0889	.1228	.2325	.2134	.0334	.0272	.0699	.0439	.0503
					Allocation 04					
1	.1014	.1124	.1428	.2758	.1150	.0608	.0316	.0612	.0477	.0513