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THE UTILIZATION OF THE BEHAVIORAL SCIENCES IN LONG RANGE FORECASTING AND POLICY PLANNING

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The Technical Reports which comprise this volume provide detailed documentation of the technical work accomplished under this contract (ARPA Contract No. 3527-A1, DAHC 15 73 C 0197). These reports were written throughout the period of the contract and were originally submitted as appendices to the various Semi-Annual Technical Reports. Substantively these reports treat the range of topics dealt with under this contract including the role of forecasting in foreign policy planning, an evaluation →
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of various analytic methods used in forecasting and policy planning, an evaluation of the utility of some of the major empirical studies of international behavior for forecasting and policy planning, and extensive treatments of the various components of the Saudi Arabian planning simulation.

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Part I: Overview

The two chapters comprising Part I of this report serve as an overview of the project. Chapter 1 briefly places the methodology of this study in the context of other quantitative and mathematical studies in the field. Chapter two then provides a more substantive summary description of the simulation.

Chapter 1: Introduction

The major objective of this project has been to develop and assess the utility of a cmoputer simulatisn based policy planning methodology whereby the impact of various United States policies toward specific countries can be examined in terms of alternative U.S. objectives. As a substantive focus, Saudi Arabia was chosen. Within Saudi Arabia, oil production processes, agriculture processes, human resources, national accounts, and governmental decision-making are computer simulated. In addition, the user may supply various "international" events and/or scenarios. These scenarios are used to examine impacts of possible policies. The overall simulation was developed in interaction with policy planners in both the Defense and State Departments.* As much as possible, the strategy was to use both academic sources and planners assumptions in designing the simulation. This was especially important in the case of Saudi Arabia due to data availability problems.

Each of the simulation modules and the overall operation of the simulation is discussed in considerable detail in the following chapters. The purpose of this introductory chapter is to provide an overview of the methodology underlying the simulation and to suggest why this methodology might be a useful one in policy planning.

The last ten years has been significant funding for studies in international relations from a number of research supporting agencies such as National Science Foundation, Advanced Research Projects Agency, the Defense Department, and the National Institutes of Health. These funds have been primarily supporting macro-level analyses of the characteristics or types of countries and the patterns in the behavior of these nation types over time. Such approaches as those taken by R.J. Rummel, J. David Singer, Bruce Russett, Raymond Tanter and a number of others have certainly advanced the macro-level theorizing in international relations. At the same time as this development, others such as Charles McClelland, Charles Hermann, Ed Azar, and Bob Burrows have attempted to look more closely at what could be characterized as micro-level phenomenon of foreign policy decision making.

That research seems to indicate that there is a limit to what can be learned about the international system using traditional statistical methods. In general, there have been some notable successes in identifying

*This interaction was accomplished largely by Dr. Warren Phillips under subcontract to CACI and the University of Maryland.

trends across time and in developing and testing probabilistic models of the behaviors of nations. The former permits scholars and practitioners to observe or react to phenomenon of interest which for one reason or another seem to be a result of some kind of steady forcing function such as bureaucratic inertia or technological progress. The latter have generally taken the form of equation which purport to explain certain percentages of the variance of processes as a function of the knowledge of a set of other processes.

While these approaches have clearly had a significant impact on the state of knowledge of international politics, they have also pointed to a need to expand the field's repetoire of modeling capabilities. Specifically, the existing approaches have developed out of a macroeconomics background. Accordingly, while they do a commendable job of identiyfing patterns and trends, they are not particularly successful in dealing with dynamic systems whose decisions vary considerably due to the context within which a particular stimulus is received. Thus for example, one can frequently observe a wide variety of reactions to the same immediate stimulus. This gives international relations the appearance of a strongly stochastic process. While there is some good reason to believe that there are some stochastic elements in most societal processes, it is also likely that much of the apparently random fluctuation can be explained by improved models.

To begin with statistics alone will rarely identify the structure of foreign policy dynamics. Early attempts to deal theoretically and quantitatively with the problem of identifying the dynamics of foreign policy decision mkaing relied heavily on stimulus-response models of either the simple SR variety or of the more complex mediated stimulus response. Such models have generally proven inadequate for dealing with foreign policy decision making. There are numerous examples of quantitative attempts to replicate this sort of thinking. Unfortunately the difficulties become immediately obvious when one thinks about the implications of the model suggested by the underlying statistical work itself. For instance, how frequently have we thought about the likelihood that a given stimulus would result in a given response? Would the answer change even if we were to allow ourselves to reorganize the stimuli by some sort of internal interpretation ach as the mediated stimulus response models? Thus, it is not difficult for substantive experts to claim that those try such activity ignore the contextuality of international affairs. Indeed, few of those who have even tried the quantitative work suggested by such a format make claims for tremendous theoretical sophistication in their approach. The present study was based upon the assumption that explaining the dynamics of the foreign policy process requires an understanding of how decisions are made. New developments in computer simulations of human problem solving have significantly enhanced the feasibility of achieving such an understanding.

The basic approach is to attempt to simulate the process or "method" the Saudi decision units use to make decisions. Such a simulation must include explicit procedures describing how the decision units interpret their environment. This specification of interpretation rules permits the simulation of context-sensitive decision making. The end product of this approach is a tool which analysis can use to learn about the system by running the simulation under a wide variety of decision inputs and by varying the international context in which Saudi decisions are made. Thus this simulation differs radically from existing simulations of international behavior. Specifically, the construction of the simulation requires answers to the following questions:

What types of situations do particular Saudi foreign policy decision units recognize?

What interpretations do the decision units give to these situations?

What actions/productions would a particular decision unit take in this context?

The next chapters describe how this project attempted to provide preliminary answers to these questions.

Chapter 2 - The Simulation

This chapter provides an overview of the major design principles underlying this study and describes the basic structural properties of the simulation. The purpose of this chapter is to establish a context for the more technical and complete descriptions in Parts II and III.

The basic view of the Saudi government taken here is based upon Simon's (1969) conception of an artificial system as modified by Bailey and Holt (1971). Miller and Thorson (1975) provide a formalization of an artificial system. Simon conceives of the artificial as synthesized by man and characterized in terms of goals, functions, and adaptation. That is, they are designed to seek to achieve goals. Furthermore, the artificial system or inner environment (IE) exists in an environment, the outer environment (OE). The IE attempts to achieve some goals in an OE. Bailey and Holt take Simon's basic characterization and explicitly view the IE in a control perspective. The IE attempts to control the OE to achieve some goals. They also explicitly discuss the interfacing of the IE with the OE. There are two interfaces, one for receiving information from the OE, an observation interface (OI), and one for executing controls in the OE, an access interface (AI). Bailey and Holt also include in their description of an artificial system an image of the causal operation of the OE, the OE . The OE_m is used by the IE to project the consequences of behaviors by the AI and the OE (see Conant and Ashby, 1970, for a justification of this inclusion). Under this decomposition, the OE (outer environment) would have a causal description. But the IE (inner environment) would be described in terms of the goals and intentions of the decision units. While the image within the IE is causal in nature, its primary purpose is to support the intentional nature of the artificial system. The artificial system's structure is illustrated in Figure I. The OI receives information describing the OE and transmits it to the IE. The IE evaluates the current state of the OE with respect to the goals of the IE. Using the OE_m, the IE selects actions by the AI designed to increase goal achievement. Once an acceptable control action has been identified, the AI is instructed to emit the appropriate behaviors.

This structure is used to describe governments in the following manner: (1) the IE is the government of a particular nation; (2) the OE consists of everything external to the government; (3) the OI is that portion of the government (not necessarily distinct from the AI) responsible for observing the current state of the OE; (4) the AI consists of those elements of the government that execute actions designed to control the OE; and (5) the OE_m is the image of the causal operation of the environment, similar to the cognitive maps of Axelrod (1976).

Using this framework, governments can be viewed as attempting to achieve goals in the outer environment. The government observes the current state of the outer environment through the OI. The government must then produce an interpretation of that information. This interpretation must be sensitive to the goals the government is attempting to achieve - for it must monitor goal achievement - as well as the merits and assertions about the causal dynamics of the environment - for it must project the consequences of its behavior on goal achievement. When the government has identified a set of actioas that should, given its beliefs about the OE, increase goal achievement, the AI is instructed to emit them. The overtime process of the system is characterized as an observe, interpret, react cycle.

This basic artificial system's structure is not sufficient to limit very much the class of admissible models of governments. Therefore some additional structural properties or "organizing principles" were identified. These principles were developed as a result both of an examination of relevant literature and conversations with policy planners and analysts. Taken together, the seven principles described below greatly limit the sorts of theoretical assumptions which can be made. Indeed, we could find no other models which simultaneously satisfied all seven conditions.

First, and of considerable importance, governments must be modeled as structures operating in specific external environments. That is, governments attempt to manipulate specific external environments. No claim is made that governments are optimal control mechanisms. Further support for this claim can be found in Rosenau, 1970; Rosenau, 1974; and Thorson, 1974. A well-known example of an attempt to model international behaviors without viewing governments as control structures is found in Forrester, 1971.

Second, the internal structure of the government must be explicitly modeled. In systems terms, the output of the governmental control structure will be a function (in the mathematical sense) of the inputs and the current state of the government. There is considerable evidence to suggest that assessing the state of the governmental structure requires at least the mo-eling of bureaucratic structures within the government. Empirical support for this claim is found in Allison, 1971; Halperin and Kanter, 1973; and Halperin, 1974. Much of the arms race modeling effort (e.g., Brito, 1972), violates this principle and considers the government as a "unitary rational actor."

Third, internally governments are organized hierarchically. In other words, there is a large degree of specialization within a government. Different kinds of information and decisions are processed at differnet levels of the hierarchy. Support for this assertion is found in Phillips, 1974; Anderson, 1974; Mesarovic and Pestel, 1974; and Nurmi, 1974. Again, most arms race models and the Forrester WORLD2 model violate this principle.

Fourth, <u>governments pursue multiple (and sometimes conflicting) goals</u>. This principle is related to the previous principle, and support for it can be found in the same sources. While this claim seems most reasonable, there are some technical reasons (Miller and Thorson, 1975) why this rpinciple may need to be modified. Nonetheless, it has guided the modeling effort reported in this paper.

Fifth, <u>governments exhibit redundancy of potential control</u>. According to Arbib (1972, p. 17), the principal of redundancy of potential control "states, essentially, that command should pass to the region with the most important information." As an illustration Arbib (who attributes the example to Warren McCulloch) cites "a World War I naval fleet where the behavior of the whole fleet is controlled (at least temporarily) by the signals from whichever ship first sights the enemy, the point being that this ship need not be the flagship, in which command normally resides (p. 17)." The critical point here is that potential control need not reside in only one portion of a government. Indeed the way in which various governments resolve the redundancy is critical to understanding and explaining its behavior. Current attempts by the U.S. military to upgrade its command, control, and communications "systems" reflects an implicit recognition of the redundancy notion within one bureaucracy. Moreover, important decisions (e.g., whether to sell a sophisticated weapons system to some country) generally involve more than one bureaucracy at more than one level of the hierarchy. We could find no existing models which have the redundancy property.

Sixth, <u>governments are event-based</u> (that is, governments respond to events in the external environment). These events may have associated with them particular probability distributions. Thus long-range forecasting (though not policy planning) may be very difficult. Moreover the notion of time employed in the model should be "event time" that is, the "time flow" against which the system states are plotted should be event based. This suggests, for example, that differential equation models are either inappropriate or require considerable reiterpretation. The arms race models and the Forrester model are inconsistent with this principle. Crecine, 1969, provides evidence for the event-based nature of governmental structures. See Miller and Thorson, 1975 for a more detailed discussion of this and the next point.

Seventh, <u>models of governments must allow for disturbances</u>. The environment in which governments operate in noisy and random disturbances may be important in "defining" the events to which governments respond. The presence of disturbances is especially important to recognize if extremal experiments are to be designed.

The seven principles outlined above serve as framework conditions within which the simulation to be designed below was developed. The simulation was developed in interaction with policy planners in the State and Defense Departments (see Phillips and Thorson, 1974 for a description of the interaction). It is important to note that this view of governments is predicated upon some form of an interpretation process. At a minimum, this interpretative capability requires the possible inputs from the environment be well specified. It is insufficient to simply investigate decision making by presupposing the inputs and interpretation. Thus one capability of an acceptable theory of governmental decision making must be to specify the possible inputs of information from the outer environment, as well as the interpretation given to the information.

The simulation discussed below has these capabilities. It is a simulation of the government of Saudi Arabia. The simulation receives information from the environment and produces an interpretation of it. Moreover, the possible inputs to the government from the outer environment are given a formal- and exhaustive- specification. The simulation is unique in that where it is primarily a simulation of the government of Saudi Arabia, a significant portion of the outer environment has also been simulated. In particular, the domestic portions of the outer environment have been modeled using the language of difference equations.

Several aspects of this simulated outer environment raise important issues. First, because portions of the outer environment have been simulated (the remainder of the outer environment is provided through user interaction), the simulation is a self-contained dynamic system. The decision units within the simulation of the government of Saudi Arabia emit actions designed to control the outer environment. The decision units then observe the consequences of their actions. Based upon the interpretation of those consequences, the actions are reevaluated. Thus, not only does the simulation of the government pay careful attention to the structure of the environment, but portions of the environment are explicitly treated.

Second, the simulation illustrates the possibility of combining both causal and intentional explanations. The simulation of the government of Saudi Arabia is based upon an intentional view while the simulations of the outer environment are causal in nature. The result is an intentional based simulation of a government attempting to steer a causal based simulation of part of the environment so as to achieve the goals of the decision units. In this case, the questions posed about the environment are largely causal in nature: How will the environment respond under various general conditions? Notice that the entire outer environment has not been simulated under a causal view. In the realm of foreign policy and international reactions, the simulation user in an interactive mode, provides the responses to the simulation's behavior - presumably based upon an intentional view of action. Specifically, the simulation has the gross anatomy delineated in Figure 2. The oil, agricultural, and human resource modules are designed to reflect part of the environment that decision makers in Saudi Arabia face. The modules are simulations of the physical processes of oil production, crop raising, and manpower internal to the nation of Saudi Arabia. Each of these three modules are simulations in their own right. The modules simulate the effects of particular actions taken by the decision makers of the country. These three modules comprise the domestic environment of the government of Saudi Arabia. The government is conceptualized as being a controller over these three modules. In this status, the decision module, representing the government of Saudi Arabia, has the capability to modify operations of any of the three modules. Modification is accomplished either by passing control information to the modules (for example, controlling the increase in production of oil), and/or the expenditure of resources (i.e., constructing an irrigation system or building elementary schools). The decision module is conceptualized as selecting manipulables as a means for steering the three modules closer to the goals held by the decision module. At appropriate points in time, the government observes and interprets the current state of these three modules and adjusts its steering on the basis of its goals. This interpretation process is central to this paper and will be discussed in detail below. For the present, it is worth noting that the decision module is a non-numeric symbol processor. The nonnumerical nature of decision module is important in several respects. Most attempts to simulate political decision-making have required numerical representations of the decision environment. However, in an information processing framework, reliance upon a numerical representation has several drawbacks.

First, under numerical representations, each piece of information from the environment must be coded as a number. At the beginning of the enterprise, social and political phenomena are required to have numerical representations. Often these structures are chosen to represent political and social phenomena strictly on grounds of manipulative convenience. What often passes notice are the additional assumptions -- often carrying substantive implications -- assumed along with the choice of a particular numerical representation.

Second, the issues of information, processing, interpretation, and perception often become obscure or are ignored. This occurs in part because of the difficulty in distinguishing the external stimulus from the perception of it by the simulated government. Often they are treated as identical. Yet a major task for the theorist is to determine how an actor constructs a particular representation.

If the issue of interpretation and perception are to be addressed, a non-numeric symbolic representation of information from the environment is generally desirable. By preserving the essentially semantic properties of information processing, a more natural representation results.

The most natural symbolic representation of information is linguistic. The information governments deal with is largely linguistic in nature, either spoken or written. Furthermore, within computer science and artificial intelligence, language processing is the most well understood symbolic representation. Thus, it combines a natural representation of information with a relatively well understood formal structure.

The goal-seeking orientation of the decision module is also reflected in the relationship between it and its international environment. The decision module has goals for the international portion of its environment and it attempts to modify its international environment, through governmental action in the form of sentences directed toward other actors. Thus, from the perspective of the Saudi Arabian decision module, other national and non-national actors have a similar status to the oil, agricultural and human resource modules -- they are producers of symbols which must be interpreted and processed.

While the structure illustrated in Figure 2 seems to reflect a sharp partition of domestic and foreign environments, this view of the simulation is an artifact of presentation. The simulation does not distinguish between domestic and foreign environments in any fundamental sense. The simulation reacts to inputs from the international and domestic environments solely in terms of the impact upon the goals of the simulated government. While there is a certain amount of specialization within the simulation, this specialization is functional and not geographic (i.e., foreign or domestic) in nature.

Given the design of the simulation, it is possible to represent the government of Saudi Arabia as a symbolic information processing system attempting to achieve a set of goals in its environment. Of particular importance here is the manner in which the simulation exhibits the ability to interpret its environment.

The interpretative capabilities of the simulation rest upon its linguistic processing capabilities: the simulation is designed to accept English language sentences from the environment. The basic structure of the linguistic capabilities of the simulation is one of translating the external representation of the sentence into an internal representation. This translation process can be divided into three stages: the first is a syntactic analysis of the sentence. This process examines the sentence to determine whether it conforms to the rules of the grammar. If the string is syntactically correct, the processor parses the sentence into its basic syntactic elements. The second stage takes these elemental syntactic elements and produces a semantic interpretation of the sentence. This semantic interpretation deals only with the basic content of the sentence. A third stage of the process takes the semantic content of the sentence and produces its internal representation, reflecting the context in which it was generated. It is this final internal representation of the original sentence that is processed by the simulation.

The various components mentioned above will be described in detail in the next two parts of this report.

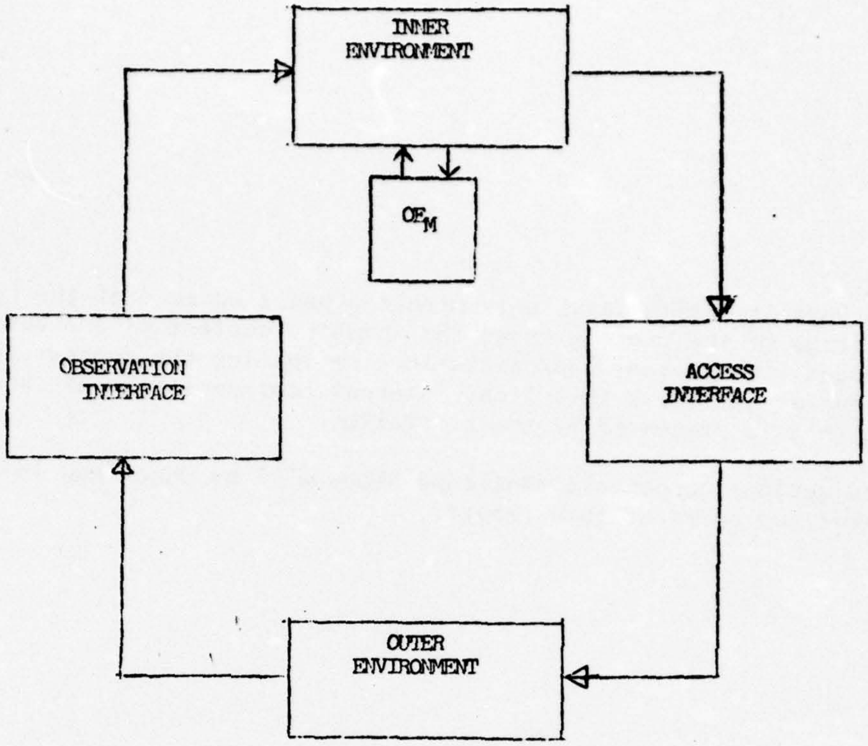


FIGURE 1
ARTIFICIAL SYSTEM

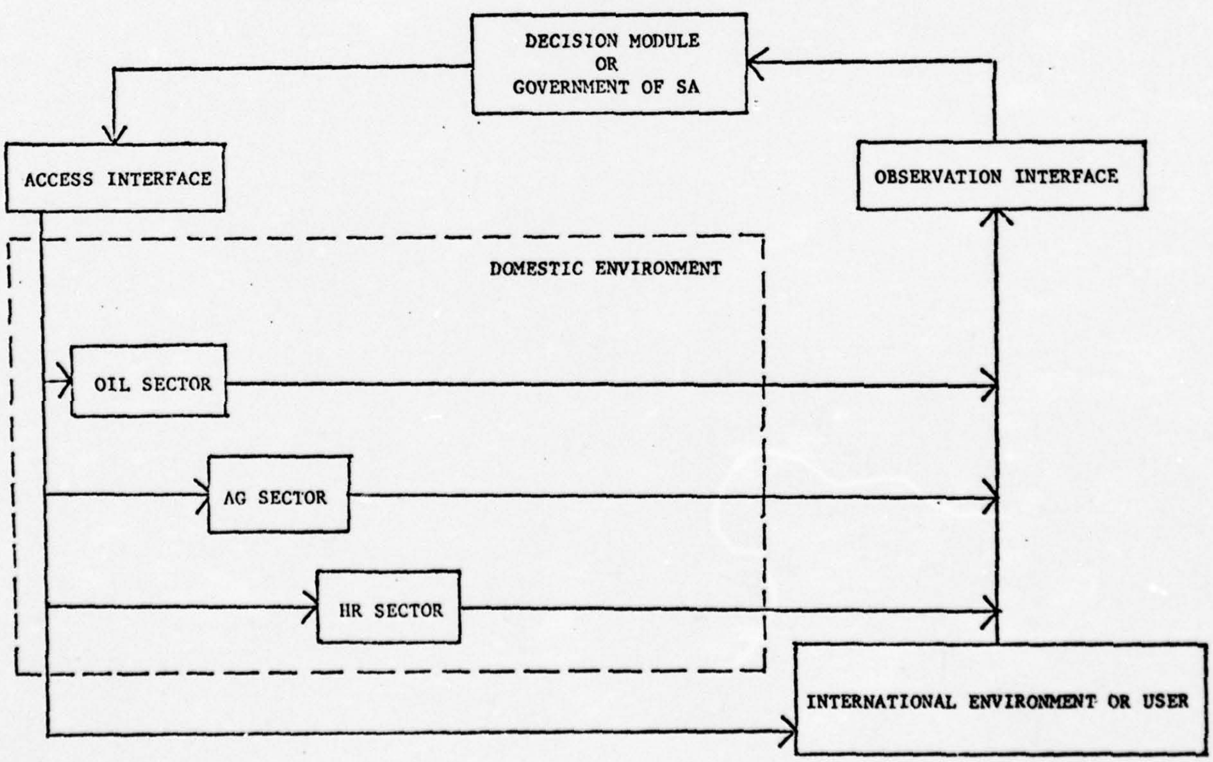


FIGURE 2
SIMULATION STRUCTURE

Part II: Overview

The next three chapters describe the simulated domestic environment of the Saudi Arabian government. Chapter 3 deals with oil, Chapter 4 with human resources, and Chapter 5 with agriculture. This domestic environment provides important inputs to the simulated Saudi decision units described in Part III.

Chapter 3 - The Oil Module

General Background and Literature Review

There is large literature on oil and oil economics. A good deal of it is summarized in Adelman (1972), and this book was used extensively during initial formulation of the oil module. The major thrust of the work is the prediction of future crude oil prices. In order to arrive at such predictions, Adelman devotes a good portion of the book to detailed examination of all facets of the world petroleum industry. His sections describing the physical exploration, development, and production processes, and the costs associated with each, were especially helpful in formulating the production component of the Project's oil module. They also provided excellent background knowledge concerning the past interaction of the international major oil companies and the producing-country governments. In his effort to predict long-run price, however, Adelman has examined the petroleum industry mostly from an economic point of view, and mostly in the aggregate. Thus, once one moves beyond his discussions of individual aspects of the oil industry one finds much less that is useful for the Project's purposes, which are concerned not with what the long-term petroleum price will be, but with how an individual producing-country government affects (and is affected by) oil operations within its boundaries. Even in his sections dealing with relations between the oil companies, the producing nations, and the consuming nations, Adelman concentrates on the effects of all three groups' actions on the price of oil. Certainly there is much that is useful as background, but little that is directly applicable to modeling the internal decision processes of particular OPEC countries.

Journals such as The Petroleum Economist[1] provided considerable and timely information on the microeconomics of the oil industry. Their information generally pertained to specific current happenings, and the bulk of the Project's information on the details of, and changes in, country-company contractual relationships originally came from such journals. They also provided data on items such as production capacity, current production, investment programs, and so on. In terms of direct utility to the Project's modeling efforts on the oil module, this literature ranked perhaps the highest. Nonetheless, the information provided helped mostly in estimating parameter values and initial variable values, and in updating the specifics of revenue-component equations, and not in modeling the internal oil-related decision processes of specific OPEC countries.

A considerable amount of informed judgment, opinion, and argument concerning the interactive behavior of the consuming countries, the OPEC countries, and the oil companies was available in a series of articles and monographs, especially in the wake of the OAPEC boycott (see, for example, Adelman, 1972-73; Aikins, 1973; Amuzegar, 1973; Bergsten, 1974; Issawi, 1972; Krasner, 1973-74, 1974; Levy, 1973; Mikdashi, 1974; Moran, 1972). Once again, however, the Project investigators were faced with information that dealt largely with the aggregate behavior (or hypothesized behavior) of these groups of actors, and not with the oil-related decision processes of particular OPEC countries.

A final example of some of the work available at the time Project substantive modules were under intensive development is those papers from the Mesarovic-Pestel Club of Rome project that dealt with the development of their own models of the world oil industry.[2] The focus of that particular project, however, is at the regional level, and thus their work was useful as background but not helpful in any direct manner with the problems being encountered in efforts to construct the Project oil module.

Although the treatment of the examples given above has been somewhat cursory, it is hoped that it served to illustrate the continuing problem faced during efforts to construct a suitable oil module. The Project's focus is explicitly on decision-making within a particular OPEC country. The oil module was developed because the oil industry is important to the decision processes in OPEC countries. Even more importantly, the form of the oil module has been determined largely by its intended purpose: to represent oil industry operations in an OPEC country as "seen" by the government in that country. What was really needed during the period in which the oil module was under development was information on which specific aspects of oil operations in a Persian Gulf producing country are of interest to its government, and how the government intervenes in, and makes decisions concerning, those aspects, so that they could explicitly be included in the oil module. It is precisely this kind of information that seemed to be missing in the various literatures that dealt with the Persian Gulf oil industry. This was probably quite predictable given for most of the oil industry's period of operation in the Gulf, the relative lack of detailed and active intervention into the industry by producing-country governments. As a result, it was not possible to use or modify an already developed model.

In order to begin constructing the oil model, it was assumed that the physical processes of finding, producing, refining, and distributing oil could be treated as a relatively distinct from, if not independent of, the economic arrangements under which these activities take place. Accordingly, the oil module could be subdivided into physical process and revenue process (country-company contractual arrangements) components, and advantage could be taken of available literature on the physical production process.

Physical Component Background and Evolution

Effort was thus first expended on creating an appropriate model for the "physical" component of the oil module. It seemed initially that the model would be relatively straightforward conceptually. A pool of oil is discovered, and an estimate is made of how much crude may be recovered from the pool. The quantity estimated is known as proved reserves.[3] Crude oil is removed from the pool (by pumping or under the influence of natural pressure) and piped to a central storage facility. From there, it is sold and loaded onto tankers or sent through pipelines, or it is refined and then sold.

Because the process just described is so similar to that presented for natural gas by Naill (1973: 220), an attempt was made to modify his work to produce an initial model for use in the "physical" component of the oil module. The result was a model similar to that shown in Figure 1. More intensive study of the concepts and linkages shown in Figure 1, however, revealed many difficult questions. Examples of such questions are:

- How large are unproven reserves and how are they estimated?
- What is the likelihood of a new pool of oil (of a given size) being discovered?
- How does one estimate proved reserves, and how accurate is the estimate?
- What is the present production capacity for a given country? Is it being expanded?
- How fast does production machinery wear out?
- How much do increases in production capacity cost?

A large proportion of the questions seemed to focus, at least indirectly, on the general problems of determining how much oil can be recovered from a given field or pool and how much new oil (in new fields or pools) will be found through exploration efforts. With respect to the first problem, it will be helpful to first consider what is meant by the term "proven reserves."[4] According to the American Petroleum Institute, as quoted by Adelman (1972: 26), proven reserves are:

> the estimated quantities of crude oil which geological and engineering data demonstrate with reasonable certainty to be recoverable from known resevoirs under existing economic and operating conditions.

Adelman goes on (1972: 26) to comment upon this definition and state that "Prove[n] reserves are that small part of oil-in-place [unproven reserves] which has been developed for production by the drilling and connecting of wells and associated facilities." He also takes care to point out (1972: 28) that "prove[n] reserves at any time are quite distinct from forecasts of what will be made into reserves later." Estimates of future cumulative production from a given field or pool are equivalent neither to current proven reserves nor to oil-in-place.

Any given estimate of proven reserves for a particular field, then, includes assumptions about the cost of production, the price at which oil will be sold, and the amount of equipment in place. A change in any one of these items may (and probably will) cause a change in the estimate of proven reserves. The estimate also depends upon assumptions about the amount of oil-in-place and the proportion of that oil that can be recovered at a given cost of production. Assumptions about both of these factors are based upon knowledge of geological factors and well performance for the field in question. Such knowledge often increases dramatically as additional wells are drilled in a new field, at least for the first few years. The additional knowledge gained generally causes revisions in the estimate of proven reserves for the field. As Adelman (1972: 30) puts it, an oil company

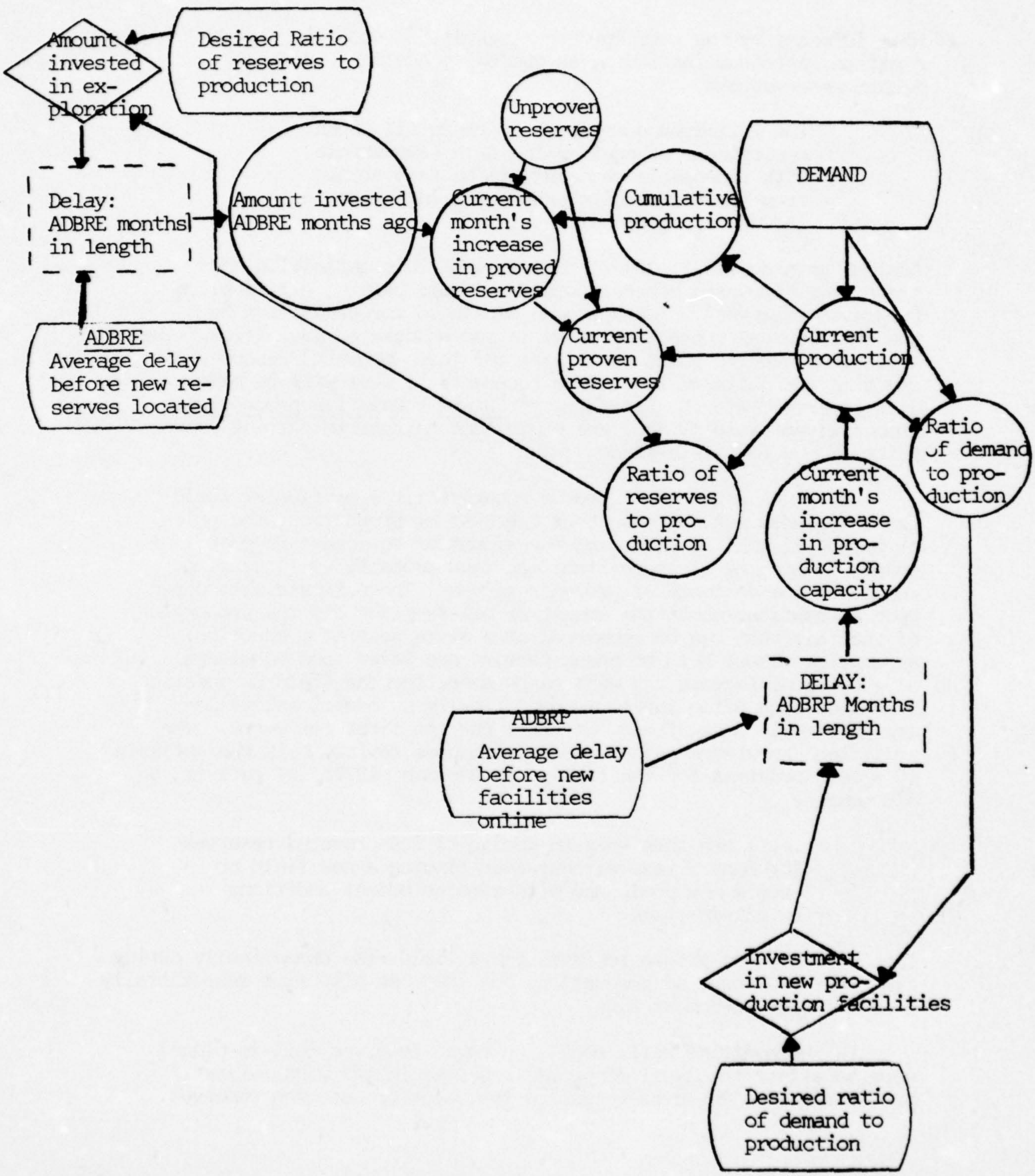
> . . . can thus keep on adding to its prove[n] reserves for many a year without ever finding a new field or even a new pool, and with zero or modest additions to oil-in-place.

Thus not only can proven reserves for a field rise dramatically during its first few years of production, but they can also rise incrementally over a longer period of time.

In the modified Naill model, unproven reserves (oil-in-place) were to affect the level of proven reserves in two ways. First, proven reserves could never exceed the value of unproven reserves.

Figure 1

Conceptual Flowchart of Revised Naill Model for Production Component



Second, as the proportion of cumulative production to proven reserves rose, the cost of obtaining additional increments to proven reserves would also rise. For use on an individual-country basis, however, this model would have required a reasonably accurate estimate of oil-in-place (unproven reserves) and proven reserves for the country, specific knowledge of the relationship among cumulative production, oil-in-place, and the cost of successful exploration for the country, and information on levels of exploration expenditure for the country. This kind of information is generally not available for Persian Gulf countries.

More importantly for the Project's purposes, it was felt that oil production in the Persian Gulf had a characteristic that made unacceptable the inclusion of any hypothesized relationship between exploration expenditure and additions to proven reserves. Oil in the Gulf lies mostly in a relatively few huge fields, and the level of proven reserves has been subject to rather large and sudden increases when each of these fields was discovered (and initially developed sufficiently for its size to be realized). Positing a relationship between expenditure on exploration and discovery of new fields seems unacceptable when the discoveries have, in the past, been relatively few and each a major peturbation. Moreover, even if such a relationship were to be posited, it would be more appropriately used in a very long-term simulation module where the timing of individual new discoveries would be less important. The Project's interests are not in developing a very long-term oil module, but instead center upon the oil industry's appearance to and effect on decision-makers in the medium term. It was decided, then, that the oil module would not include unproven reserves nor a hypothesized relationship between exploration expenditure and additions to proven reserves.[5] This approach is especially reasonable in the case of Saudi Arabia since Saudi Arabia has such large proven reserves relative to current and anticipated production rates that it seems unlikely that there will be much intensive exploration of a high cost variety in for some time.

The production component of the oil module is designed to take account of increases to proven reserves which result from development drilling, but not to attempt to account for any increases which might result from discovery of major new fields. There are two major reasons for this. First, even if a major new field were to be found, its initial impact would probably be much greater upon estimates of oil-in-place than upon estimates of proven reserves. One cannot say a great deal about ultimate recoverability (with reasonable confidence) until one attempts to define the limits of the pool or field and has performance data from wells drilled for that purpose. But in the Middle East, at least, any pool or field which would add significantly to proved reserves, would, because of geological conditions in that area, also be likely to produce huge amounts from these developmental wells. Hence an addition to proved reserves would once again tend to be associated more closely with a notable increase in production than with the initial "wildcat" well.

The second reason for ignoring the wildcatting type of exploration has been stated very clearly [1973: 8] by H.R. Warman: "It is my firm belief that the heyday of discoveries in the Middle East is past and although many large fields (by world standards) remain to be found there the bulk of the oil and the largest fields have been found." And, from Adelman (1972: 205) again, "Let us refrain from guessing what this continued [Eastern Hemisphere exploration] activity means for finding new fields. The effect of change is too great." It thus seems reasonable to permit the user to exogenously raise the level of proved reserves to simulate the change discovery of a major new field, but it seems equally reasonable not to attempt to treat wildcat exploration within the module.

Figure 2 shows the model that incorporated the revised approach to exploration and increases in proven reserves. Increases in proven reserves were explicitly linked to increases in production capacity through the parameter relating increased capacity to increased reserves (PRR). In the review of that model conducted by CACI (1975: 4-5), however, it was suggested that relating increases in proven reserves to increases in production capacity through a simple ratio was probably artificial sophistication. In the absence of detailed information permitting the articulation of a more precise relationship, it was recommended that a simple trend relationship would serve as well and be preferable because of its simplicity. This change was made. Examination of the proven reserves figures (see Figure 3) for Saudi Arabia, the country of interest, suggests that a simple trend line may indeed be used with a reasonably good fit. With the change in method of predicting increases in Saudi Arabia's proven reserves (and other minor changes that will be treated presently), the production component of the oil module evolved into its present form. That form is presented below in detail.

Current Oil Module Production Component

The logical structure of the current oil module production component is shown in Figure 4. Definitions of the variables and parameters involved are given in Table 1. The equations making up the model are listed in Table 2 and are discussed in sequence below. Following the discussion of equations, information on how initial and parameter values are estimated is given for each variable.

Figure 2

Conceptual Flowchart of Revised Production Component Model

(note: for full information on this model, see Project Research Paper # 15)

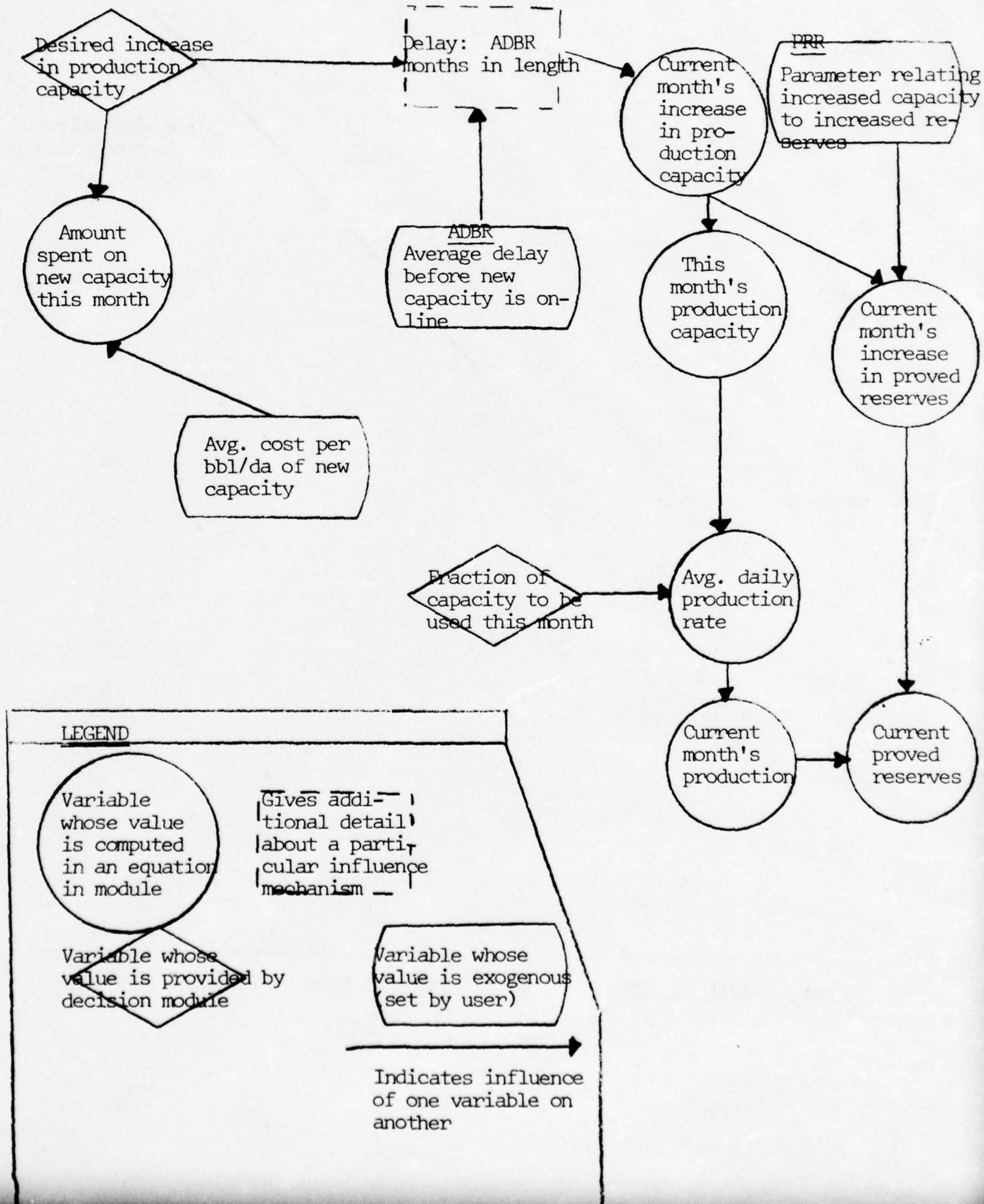


Figure 3

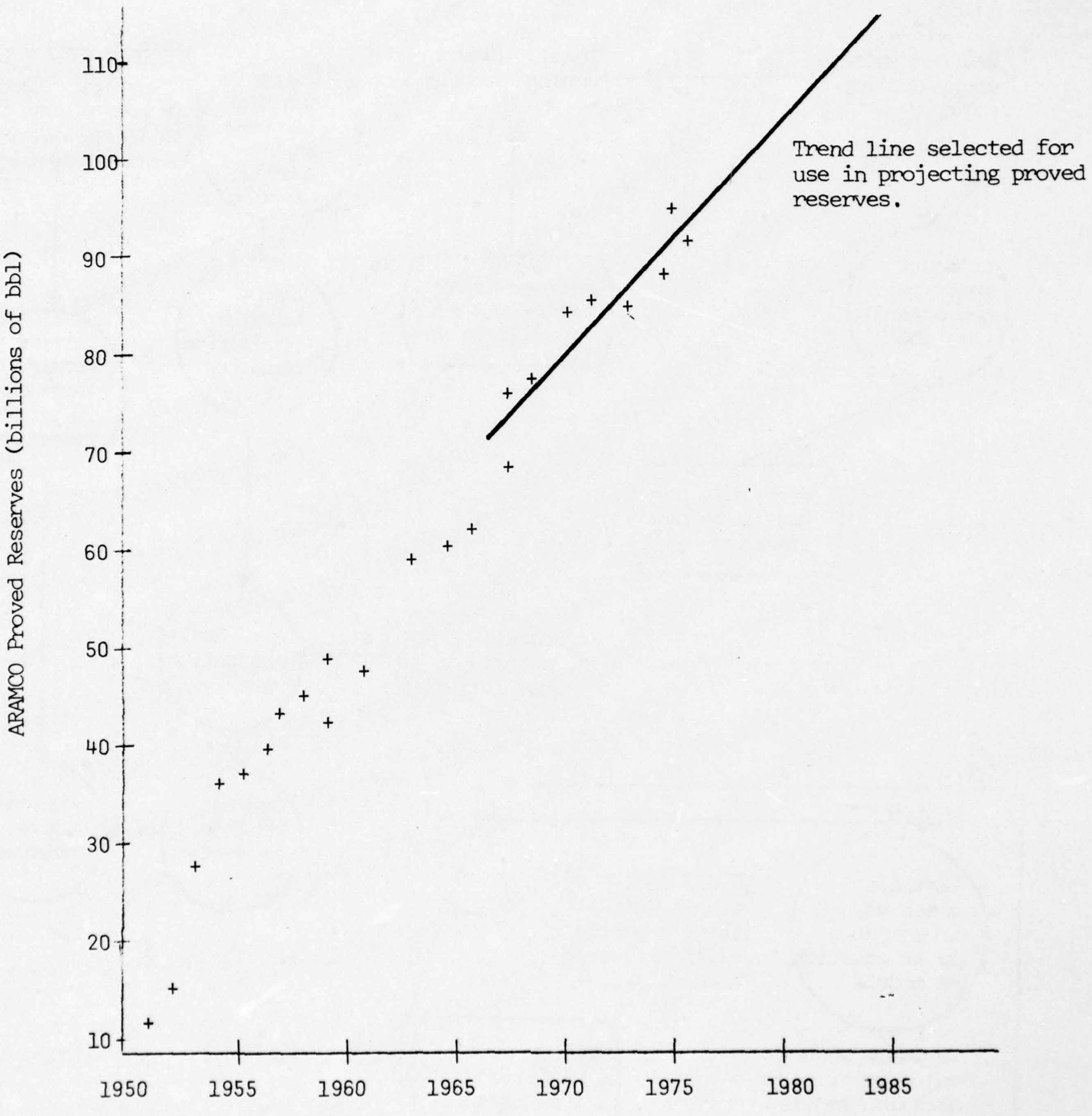
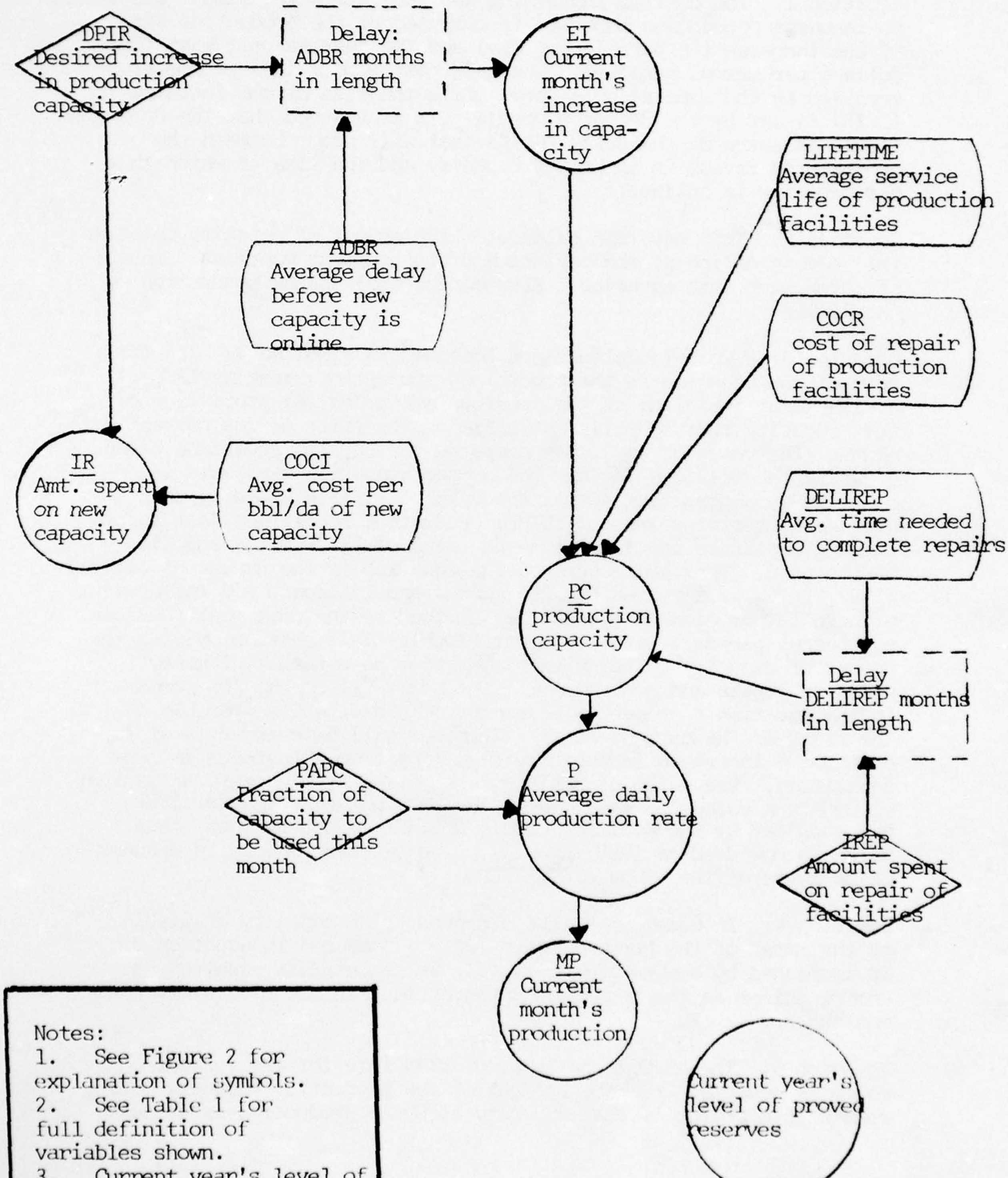

Trend line selected for use in projecting proved reserves.
ARAMCO Proved Reserves (billions of bbl)
110
100
90
80
70
60
50
40
30
20
10
1950
1955
1960
1965
1970
1975
1980
1985

Figure 4

Conceptual Flowchart of Current Production Component Model



Notes:
1. See Figure 2 for explanation of symbols.
2. See Table 1 for full definition of variables shown.
3. Current year's level of proved reserves is projected from a trend line (see text).

Equation 1: The cost of installing new facilities (equipment and wells) to increase production capacity is computed as the product of size of the increase (in barrels per day) and the average unit cost (in dollars per barrel per day). The unit cost (COCI) is a parameter supplied by the simulation's user, while the size of the increase (DPIR) is set by the decision module. It is assumed that the decision module is aware of the delay (ADBR) that will occur between the decision to invest in increased capacity and the time at which that new capacity is online.

Equation 2: This equation calculates the amount of capacity increase (E1) coming online at the beginning of the current month as a result of investment (via equation 1 ADBR months ago) in new production facilities.

Equation 3: Two calculations are combined in equation 3. The first term of the equation is the product of production capacity (PC_{t-1}) available at the first of the previous month and the proportion of that capacity that is still available at the first of the current month. The value of PC_{t-1} was computed (as PC_t) in equations 3 and 4 during the previous month. The proportion still available is computed by subtracting from 1 the value of 1/12 divided by the average number of years (LIFETIME) production facilities last before needing repair or replacement. The value of LIFETIME is supplied by the user. The second term of the equation is the amount of capital ($IREP_{t-DELIREP}$) invested DELIREP months ago in repair and replacement of worn out or disabled facilities divided by the unit cost (dollars per barrel per day) of replacement (COCR). This quotient yields the amount of capacity put back into operation as a result of money spent on repair and replacement. The sum (PC_t) of the two terms in the equation represents the amount of old capacity operable at the first of the current month. This sum will have added to it in equation 4 increases in capacity resulting from investment in new facilities. The value of DELIREP is supplied by the user, as is that of COCR. A value (possibly zero) for IREP was supplied for IREP was supplied by the decision module DELIREP months ago, and this value is now used as $IREP_{t-DELIREP}$. The decision module is assumed to be aware of the value of DELIREP.

Equation 4: In equation 4, the old production capacity available at the first of the current month (PC, as computed in equation 3) is increased by any new capacity (EI, as computed in equation 2) coming online as the result of an investment in new facilities ADBR months ago.

Equation 5: The average daily production rate for the current month is computed from the product of the production capacity (PC) and the proportion of that capacity at which production is to take

Table 1

Definitions of Variables and Parameters

Used in Production Component of Oil Module

ADBR	Months	<u>Average Delay Before Return</u>: typical number of months required before a given amount of capital invested in new production facilities actually increases output.
COCI	$/bbl/da	<u>Cost of Capacity Increases</u>: average overall cost of new facilities required for an increases of 1 bbl/da in production capacity.
COCR	$/bbl/da	<u>Cost of Capacity Replacement</u>: average overall cost, per bbl/da of capacity, of replacement or repair of production facilities already in place but worn out or disabled.
DAYS	da	<u>Days</u>: number of days in current (Gregorian) calendar month.
DALIREP	months	<u>Average Delay Before Replacement</u>: typical number of months required after a given amount of capital is invested in repair or replacement of worn out or disabled production facilities before the unusable capacity is once again available.
DPIR	bbl/da	<u>Desired Production Increase Rate</u>: the number of bbl/da production capacity is desired to increase ADBR months later.
EI	bbl/da	<u>Effective Investment</u>: the increase in production capacity that is to become operational during the current month.
IR	$	<u>Investment Rate</u>: the amount of capital to be invested in order to achieve an increase in production capacity ADBR months later.
IREP	$	<u>Investment in Replacement of Capacity</u>: the amount of capital to be invested in replacement or repair of production facilities already in place but worn out or disabled.

LIFETIME	yr	Average Production Facility Lifetime: the average number of years at the end of which production facilities are worn out.
MP	bbl	Monthly Production: actual production for the current month.
P	bbl/da	Production Rate: average actual production per day during current month.
PAPC	dimension-less	Production as Percent of Capacity: the level of production desired by producing-country government decision-makers expressed as a fraction of the current month's capacity.
PC	bbl/da	Production Capacity: maximum (average) daily production capacity for the current month.
PR	bbl	Proven Reserves: current estimate of that amount of oil-in-place that can be recovered with existing facilities and technology and at current prices.
PRINTCPT	bbl	Proven Reserves Intercept: the intercept of the trend line used for prediction of proved reserves.
PRSLOPE	bbl/yr	Proven Reserves Slope: the slope of the trend line used for prediction of proved reserves.
YEAR	yr	Current Year: current Gregorian year expressed as a 4-digit number.

Table 2

Equations Comprising Production

Component of Oil Module

The following equations are carried out sequentially by the computer:

1. $IR_t = (DPIR_t)\ (COCI)$

2. $EI_t = DPIR_{t-ADBR}$

3. $PC_t = (PC_{t-1})\ (1 - \frac{.0833}{Lifetime} + \frac{IREP_{t-DELIREP}}{COCR})$

4. $PC_t = PC_t + EI_t$

5. $P_t = (PAPC_t)\ (PC_t)$

6. $MP_t = (DAYS_t)\ (P_t)$

7. computed at the end of each year $PR_t = PRINCPT + (YEAR_t)\ (PRSLOPE)$

Notes:

t = current month.
Parameters have **no** time subscripts. They may be changed at any time by the user or may be left constant throughout the simulation run.

place (PAPC). Production capacity has been computed in equations 3 and 4, and PAPC is set each month by the decision module, which is assumed to have knowledge of the level of available production capacity at the first of the current month (including increases, if any, from equations 3 and 4).

Equation 6: The total production (MP) for the current month is computed as the product of the number of days in the current (Gregorian) calendar month and the average daily production rate (P) from equation 5.

Equation 7: (calculated only at the end of each year). The level of proven reserves (PR) available at the end of each year is calculated from a trend line. Both the intercept (PRINCPT) and the slope (PRSLOPE) of the trend line are supplied by the user.

ADBR: Many different types of equipment are required to lift crude oil from a resevoir, separate the oil from any associated natural gas, and pipe the oil to a central storage/tanker loading facility. Some pieces of equipment (such as gas-oil separators and central long-distance pipelines) are large and expensive, and one unit serves a relatively large number of wells. Other kinds of equipment (i.e., "gathering" pipelines and valves) are available in small additional increments and are built more or less from "off the shelf" materials. The use of a single parameter to represent the average construction time for new production facilities is, then, a considerable simplification.

To model all the various types of delays involved, however, would have required much more information on past capital investment than is readily available for the oil industry. Thus the single-parameter approach was taken, and ADBR was set, arbitrarily, at 3 months for Saudi Arabia. In the review of the oil module conducted by CACI (1975: 3-4), however, it was pointed out that

> . . . this value was unrealistically small and should be made larger. Just how much larger, however, depends on which of two assumptions is to be made. One possible assumption is that the increase in production capacity should result from the extension of pipelines and other gathering facilities to fields or pools that already contain drilled and capped wells and/or are near present production areas. For this type of increase in production capacity, a delay of six months may be considered reasonable. The second possible assumption is that the increase in production capacity should result from drilling in, and then building gathering facilities for, fields or pools with only negligible develop-

> ment work already completed. Bringing such relatively undeveloped areas online would require a longer delay--perhaps two years. The former assumption is better for the Project's purposes. The initial drilling and capping of wells in new fields or pools for future production is not an uncommon practice, and since daily production per well is so high in most Saudi oilfields, sizeable increases in capacity may be obtained by bringing online already initially developed areas or drilling a few new wells in or very near an already-developed area. The important restriction to bear in mind is that very large increases in capacity cannot be brought online quickly since gathering facilities already in operation would become saturated. Thus capacity-increase decisions fed into the module should be incremental and continued over a period of time to obtain moderate-to-large increases in capacity.

As a result of these recommendations, ADBR has been given a default value of six months. This value may be overridden by the user should he desire to do so.

COCI: The cost of an increase of one barrel per day in production capacity for Saudi Arabia was estimated from newspaper reports of ARAMCO's proposed capital expenditure program. That program originally called for an expenditure of \$4 billion over eight years to raise capacity by an average of 13.425 million barrels per day.[6] Thus,

$$\frac{4 \times 10^9 \text{ dollars}}{13.425 \times 10^6 \frac{\text{bbl}}{\text{da}}} = 298 \frac{\text{dollars.}}{\frac{\text{bbl}}{\text{da}}}$$

This figure was originally used in the module. Later information, however, suggested that \$2.25 billion to \$3.5 billion would be spent by ARAMCO to raise capacity by two million barrels per day.[7] The higher value yields a value of \$1750 per barrel per day, while the lower figure results in a value of \$1125 per barrel per day. The mean (\$1438) of these two values is presently used in the module as a default. The value may be overridden by the user should he desire to do so.

COCR: Because of a lack of readily available information on the cost of capacity replacement and repair, this parameter is presently assigned the same default value as the cost of new capacity--$1438 per barrel per day. This estimate is undoubtedly somewhat high, and should be revised if detailed information becomes available. The value may be overridden by the user.

DELIREP: Because of a lack of readily available information, this parameter is presently assigned the same default value as ADBR--six months. This assignment is purely arbitrary and the value should be revised, if necessary, if detailed information becomes available.

DPIR: The value of this variable is set by the decision module each month. The value set, if it is to be nonzero, is generally near 100,000 barrels per day. This latter figure was estimated from data on the ARAMCO investment program (see footnote 5) and represents the average per-month increase if capacity is to be raised by two million barrels per day over a 20-month period as envisioned in that program.[8]

E1:

IR:

IREP:

These variables' values are computed each month in production-component equations.

LIFETIME: This parameter is presently assigned an arbitrary value of seven years. It deals with the average overall wearout rate of many types of equipment (including wells) and, in a manner similar to the use of ADBR, is an extreme simplification.[9] Its use, however, is justified on the grounds that the aggregate treatment of capital expenditures is sufficient for the Project's purposes. Its value should eventually be revised, and may be overridden by the user if he so desires.

MP:

P:

The values of these variables are computed each month in a production-component equation.

PAPC: The value of this variable is set each month by the decision module in response to a user-entered demand figure.

PC: The value of this variable is computed each month in a production-component equation. The initial value presently used (for a simulation start-date of August, 1974) is taken from the previously mentioned (see footnote 14) information on ARAMCO capital investments that gave production capacity as 9.2 million barrels in April, 1974, plus an assumed increase of 300,000 barrels per day resulting from capital invested during the months of May, June, and July. The resulting estimated initial value is 9,500,000 barrels per day.

PR: This variable's value is calculated at the end of each year in a production-component equation. The initial value presently used is that for the end of 1973 of 97 billion barrels (Knauerhase, 1975: 11).

PRINTCPT: / PRSLOPTE: } The values of these two parameters were estimated from an ordinary least squares regression of ARAMCO proved reserves on the actual Gregorian year for the period 1968-1973.

This resulted in values of -3,230,866.7 for PRINTCPT and 1685.714 for PRSLOPE. The time period used for the regression was selected because it yielded a slightly more conservative (less steep) trend line than would have occurred if a longer span had been used.

Revenue Process Component Background and Evolution

The history of contractual relationships between oil companies and producing-country governments is long and complex.[10] In recent years, the revenues accruing to a country from oil production within its jurisdiction have come from three sources:

> Royalties are a flat fee, payable to the producing-country government, for each barrel of oil produced. The fee has been specified in the contracts as a given percentage of the posted price[11] per barrel.
>
> Income taxes have been levied on the profits[12] of the oil companies.
>
> Independent sales of crude oil have been made by producing countries have achieved participation in the ownership of the oil companies operating within their boundaries.[13] Large proportions of the share of production belonging to the countries have been sold back to the producing companies (at prices higher than they would have paid otherwise). Some of the country-owned crude, however, has been sold to third parties at widely varying prices.[14]

The great difficulty in constructing an appropriate model of the country-company contractual arrangements that determine the revenues accruing to a producing country as a result of petroleum production has been the rapid change in those arrangements. For example, when the revenue process component was initially developed Saudi Arabia's contractual relationship with ARAMCO had recently undergone modification in two ways. First, OPEC member states were increasingly asserting themselves with respect to setting the posted price of crude oil, and as a result that price was determined under a succession of OPEC-dominated agreements (the 1971 Teheran agreement, and the 1972 and 1973 Geneva agreements) with the international major oil companies.[15] Second, a participation agreement affecting the arrangements between Saudi Arabia and ARAMCO[16] had recently been signed, and because the Project's modules were being developed with Saudi Arabia as the referent, that agreement also had to be considered.

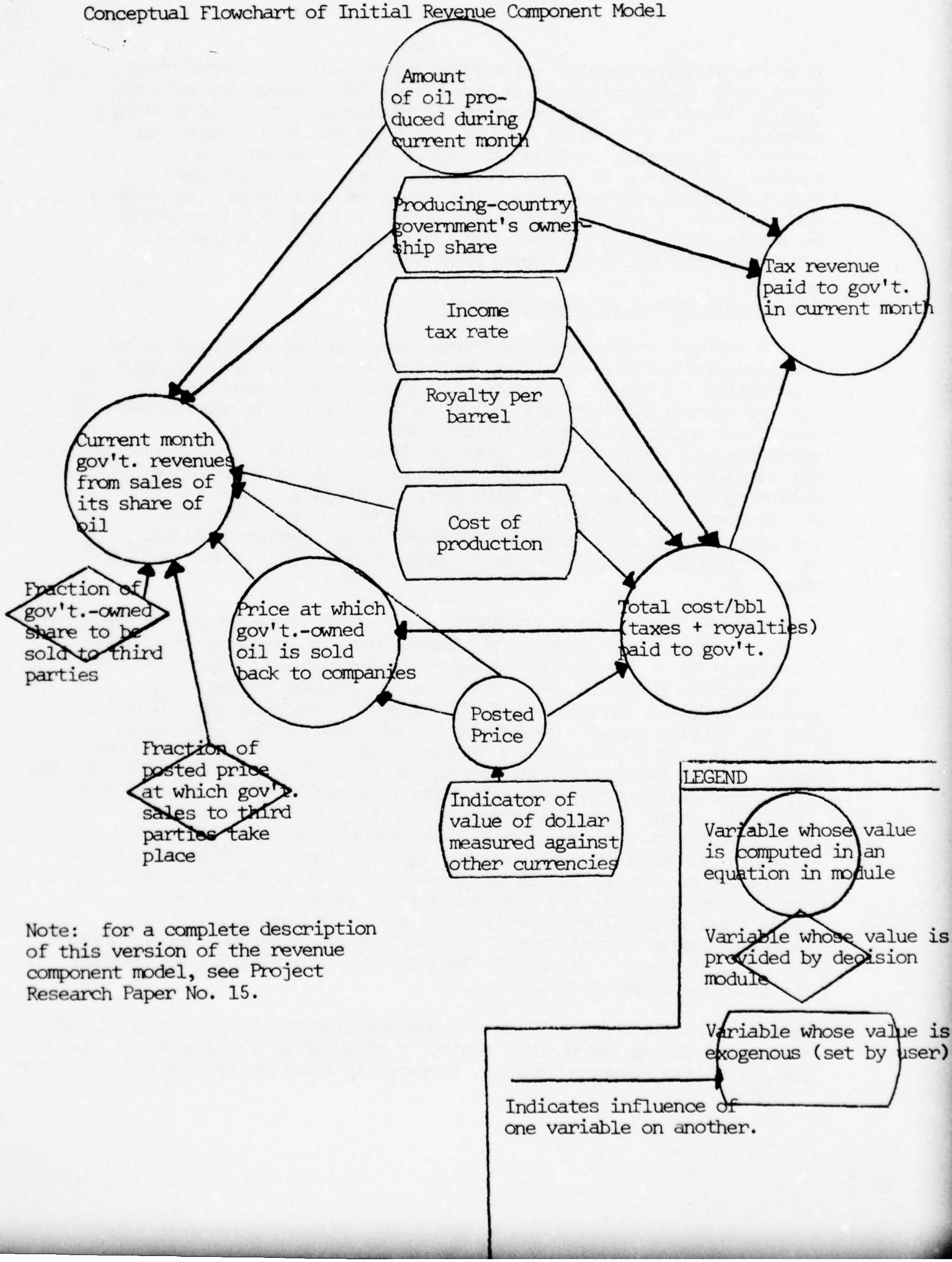
The resulting initial model incorporated all these agreements. Its structure is shown in Figure 5. It was relatively complex and its operation was described in Project Research Report No. 15 (see Appendix):

> Under those arrangements, our module would first determine the current month's posted price in dollars per barrel in accordance with the above-mentioned agreements. The terms of those agreements provided for monitoring an index based upon a group of currencies and adjusting the posted price (to compensate for inflation) whenever the index changed value by more than 1% from its value for the previous month; the value of the index would be specified by the user for the time period to be simulated.
>
> After the value for posted price (PP) has been determined, the tax revenues (TR) to be paid to the producing country would be computed using the current income tax rate (TAXRATE), royalty percentage (ROYALTY), cost of production (COP), and the government's current participation share (SHARE). Similarly, the revenue accruing to the producing country government as a result of sales of its independently owned crude oil is computed. The crude revenue (CR) is determined from consideration of the amount of crude oil sold independently by the government (INDCRUD), the price received by the government in such transactions (INDSALE), the cost of production (COP), and the price (SELBAC) paid to the governments by the companies for country-owned crude "bought back" by the companies. After completion of [the computation of] crude revenue and tax revenue, control passes back to the decision module.

That first cut at a revenue component model was completed just as the OPEC countries declared their power to simply set posted price by fiat and invalidated the Teheran and Geneva agreements mentioned earlier in this section. This action on the part of OPEC countries posed a serious problem for work on the revenue component. Producing-country governments were setting posted price, and so the value for that variable should, in one sense, come

Figure 5

Conceptual Flowchart of Initial Revenue Component Model



Note: for a complete description of this version of the revenue component model, see Project Research Paper No. 15.

from the decision module. In another sense, however, posted price remained an exogenous variable because the OPEC member governments jointly determined posted price after considerable bargaining among themselves. Thus building into the decision module a forecasting mechanism for posted price would require the inclusion of a sophisticated model of intra-OPEC bargaining. It was decided that not enough was known about the nature of that bargaining process to permit the development of such a model, and that the user would be required to supply future values for posted price on the basis of his assumptions about future OPEC behavior.

Current Oil Module Revenue Component

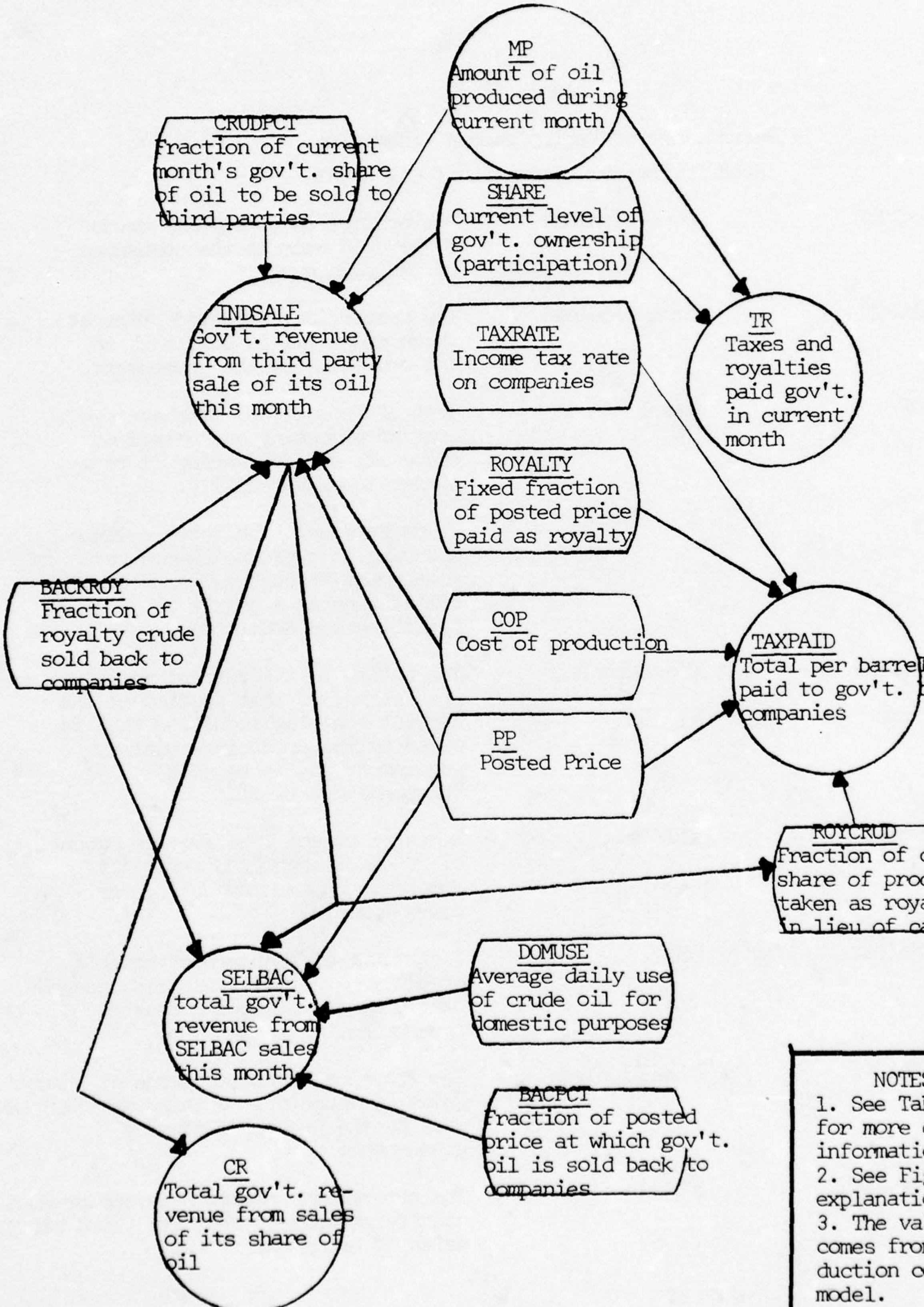
A revised revenue component model was developed that reflected the newer method of determining posted price and that also included a provision for the producing-country government to take its royalty payment in crude oil should it so desire. The structure of this newer model is shown in Figure 6 and definitions of its variables and parameters are given in Table 3. Equations comprising the model are listed in Table 4 and discussed in sequence below. Following the discussion of equations, information on how initial and parameter values were estimated is given for each variable. Equation descriptions necessarily become quite complex at times, and the reader is urged to consult Table 4 frequently while reading them.

Equation 1: The variable, TAXPAID, whose value is determined by equation 1, is the sum of all payments per barrel made by the companies to the government on the companies' share of the production. There are two components to be considered. The first is company income tax per barrel, which is the product of the current income tax rate (TAXRATE) and the imputed company profit per barrel. The latter shows up in the equation as posted price (PP) minus the cost of production (COP), minus royalty payments, which are the product of posted price (PP) and the difference between the current royalty rate (ROYALTY) and the fraction (ROYCRUD) of the companies' share of current production taken as royalty payments in lieu of cash. The second component is royalty payments per barrel which, computed again as just described, are added to the income tax per barrel to obtain the value of TAXPAID. Note that royalty payments are subtracted as an expense (like cost of production) when figuring profits subject to income tax, and then added to income tax per barrel to determine the total per barrel payment due the government. Values for TAXRATE, PP, COP, ROYALTY, and ROYCRUD are provided exogenously by the user.

Equation 2: TR, the total tax revenue accruing to the producing-country government during the current month, is computed as the product of the per barrel tax revenue (TAXPAID, computed in equation 1), the total

Figure 6

Conceptual Flowchart of Current Revenue



NOTES:
1. See Tables 3 and 4 for more detailed information.
2. See Figure 5 for explanation of symbols
3. The value of MP comes from the production component model.

Table 3

Definitions of Variables and Parameters
Used in Revenue Component of Oil Module

BACKROY	dimensionless	The proportion of royalty crude to be sold back to the companies by the government.
BACPCT	dimensionless	The proportion of posted price at which crude oil is sold back to the companies by the government.
COP	$/bbl	Cost of Production: the average cost of producing one barrel of crude oil and delivering it to a tanker-loading facility.
CR	$	Crude Revenue: the total revenue accruing to a producing-country government through sales of crude oil it owns as a result of participation contracts.
CRUDPCT	dimensionless	The ratio, to the current month's production, of that portion of the current month's production that is owned by the producing-country government and to be sold independently by it.
DOMUSE	bbl/da	Domestic usage: the average amount of crude oil required for daily domestic consumption during the current month.
INDCRUD	bbl	The amount of the current month's production that will be sold independently by the producing country government.
INDPCT	dimensionless	The fraction of posted price at which sales of crude oil to third parties are made by the producing-country government.
INDSALE	$	The net revenue received by the producing-country government from its third party sales of crude oil.

PP	$/bbl	Posted Price: the artificial price used in country-company agreements as a basis for imputing (for tax purposes only) company "profits."
ROYALTY	dimensionless	The fixed fraction of posted price that is paid, on each company-owned barrel, as a royalty to the producing-country government.
ROYCRUD	dimensionless	The fraction of the companies' share of production that the producing-country government chooses to take (in lieu of cash) as royalty payment. Its value may never exceed that of ROYALTY.
SELBAC	$	The revenue received by the producing-country government from sales of part of its share of crude oil production by the oil companies through their regular channels. Such oil is said to be "sold back" to the companies.
SELBACP	$/bbl	The actual price at which oil owned by the producing-country government, but not sold independently by it, is sold back to the companies.
SHARE	dimensionless	The ownership share held by the producing country government under the terms of a participation agreement.
TAXPAID	$/bbl	Tax paid price: the price (less production costs) paid by oil companies for their share of the oil produced. This amount per barrel is paid to the producing-country government.
TAXRATE	dimensionless	The fraction of company "profit" (on each barrel of crude oil) that is owned to the producing-country government as a tax.
TR	$	Tax revenue: the sum of all royalties and taxes paid to the producing-country government by the companies for their share of current month's production.

Table 4

Equations Comprising Revenue
Component of Oil Module

1. TAXPAID = [PP-COP- (ROYALTY-ROYCRUD) (PP)] (TAXRATE) + (ROYALTY-ROYCRUD) (PP)

2. TR = (TAXPAID) (MP) [1 -SHARE-(ROYCRUD)(1-SHARE)]

3. INDCRUD = [CRUDPCT + (1-BACKROY)(ROYCRUD)(1-SHARE)] (MP)

4. SELBACP = (BACPCT)(PP)

5. SELBAC = (SELBACP)[(SHARE + (BACKROY)(ROYCRUD)(1-SHARE)) (MP)-INDCRUD - (DOMUSE)(DAYS)]

6. INDSALE = (INDCRUD)[(INDPCT)(PP) - COP]

7. CR = INDSALE + SELBAC

Note: No time subscripts are used because all values are for the current month or are parameters.

production for the month (MP, computed in equation 6 of the production component), and the fraction of the current month's production belonging to the companies and not taken by the government as royalty crude. The latter quantity is computed as 1 minus the government's ownership fraction (SHARE), minus the product of 1 minus the government's ownership fraction (SHARE) and that fraction of the companies' share of production taken as royalties in lieu of cash (ROYCRUD). The value of SHARE is set exogenously by the user, as is that for ROYCRUD, although it would be desirable to have ROYCRUD values set by the decision module in response to conditions in the world petroleum market (especially the prevailing price for third party sales of crude oil by the government).

Equation 3: This equation determines INDCRUD, the amount of crude oil sold independently (to third parties) by the producing-country government during the current month. That quantity is equal to the product of the current month's production (MP, as determined by equation 6 in the production component) with the fraction of that production to be sold independently. The fraction to be sold independently is the sum of (a), that fraction of the current month's production that the government is normally entitled to sell independently (CRUDPCT), and (b) that fraction of the current month's production taken by the government as royalties and sold independently by it. The fraction mentioned in (b) is equal to the product of 1 minus the fraction (BACKROY) of government royalty oil to be sold back to the companies and that fraction of the current month's production taken by the government as royalties (the product of ROYCRUD and 1 minus SHARE). Values for CRUDPCT, BACKROY, ROYCRUD, and SHARE are all provided exogenously by the user.

Equation 4: The price (SELBACP) at which crude oil owned by the government is sold back to the companies for sales through their channels is computed as the product of posted price (PP) and the fraction (BACPCT) of posted price at which the transactions are to take place. The value of BACPCT is provided exogenously by the user.

Equation 5: The current month's revenue (SELBAC) accruing to the producing country government from crude oil owned by it but sold back to the companies for sales through their channels is computed. It is equal to the product of the price (SELBACP, computed in equation 4) at which the oil is sold and the amount of oil to be sold back during the current month. That amount is calculated as the sum of the government's normal share of production and its royalty oil (if any), minus the amount (INDCRUD, computed in equation 3) of oil it will sell independently, minus the amount needed for domestic consumption. The government's normal fraction of production is SHARE (set exogenously by the user, and this is added to the fraction of the current month's production representing royalty oil to be sold back, which is computed as the product of the proportion (ROYCRUD times 1 minus SHARE) of the current month's production taken as royalty oil and the fraction (BACKROY) of that oil to be sold back. The amount of crude oil needed for domestic use during the current month is equal to the product of the average daily domestic consumption rate (DOMUSE, whose value is provided by the user) and the number (DAYS) of days in the current Gregorian calendar month.

Equation 6: This equation computes the revenue (INDSALE) accruing to the producing-country government during the current month from its independent sales of crude oil. That revenue is computed as the product of the quantity (INDCRUD, computed in equation 3) of oil sold and the net per barrel revenue received by the government. Net per barrel revenue is the gross price per barrel, which is computed as the product of posted price (PP) and the fraction (INDPCT) of posted price at which the sales take place, minus the cost of production (COP). Values for INDPCT, PP, and COP are provided by the user.

Equation 7: The total revenue (CR) accruing to the producing-country government during the current month from sales of government owned crude oil. This is computed as the sum of revenue (INDSALE, from equation 6) from independent sales and revenue (SELBAC, from equation 5) from oil sold back to the companies for sales through their normal channels.

BACKROY: In periods of moderately short supply of oil worldwide, it might be that the government could sell more oil to third parties than it normally would have available for such purposes, but not all the oil it could make available if all royalties were taken in crude rather than in cash. Because the companies would also be feeling the demand for oil, however, the government might be able to sell the remaining royalty oil back to them at a price somewhere between their normal cost and the government's going price for third-party sales. BACKROY, the proportion of royalty oil to be sold back, should thus be set by the decision module for any month in which the government exercises its option to take crude oil in lieu of cash as royalties from the companies. At present, however, the decision module has not been provided with an algorithm for setting the value of BACKROY because of the lack of information on how such decisions are made. Hence BACKROY has been given a default value of 0, with the assumption that if the user wishes to introduce different values in accordance with a specific scenario he may do so.

BACPCT: The value of this parameter effectively sets the price at which all sellback transactions[17] take place. It has been given a default value of .93, which may be changed by the user at any time if he so desires. The value of .93 is used as the default because of reports[18] of sellback transactions taking place at 93%

of posted price during early and middle 1974. Because of the considerable slackening of demand since that time, .93 may be too high a value for more recent periods.

COP: The default value is set to $.10 per barrel. This is in general agreement with several estimates of Saudi production cost appearing in 1973.[19] Unfortunately, as Knauerhase (1975: 289) puts it:

> Very little is known about the actual costs of lifting crude oil, and the more we retreat into the past, the less available accurate information becomes.

See Adelman (1972) for an entire chapter devoted to the problem of inferring precise crude oil production costs from available data.

CR: The value of this variable is computed each month by an equation in the revenue component. No initial value is required.

CRUDPCT: The value of this parameter reflects two aspects of the Saudi-ARAMCO participation agreement. First, the Saudis own a fraction of each month's production equal to their share of ownership in ARAMCO. Second, ARAMCO has the option of buying back (at the sellback price) crude oil from the Saudis up to a specified maximum share of their share. The maximum fraction of the Saudis' share is specified by contract and declines each year. The initial value for CRUDPCT is .060, based upon a 60% share of ARAMCO owned by the Saudis and a maximum buyback fraction (of the 60% Saudi share) of 90%.[20]

DOMUSE: The default value of this variable is 60,000 barrels per day. Ideally, it should increase as Saudi Arabia becomes more economically developed. At present, however, its value is static unless changed by the user.

INDCRUD: The value of this variable is computed in a revenue-component equation. No initial value is necessary.

INDPCT: The value of this parameter controls the price at which the government sells crude oil to third parties. Quite obviously, that value must reflect conditions in the world petroleum market and thus, like values for posted price and demand, must be provided by the user. The default value is .93, chosen arbitrarily so that third party sales are at a price equal to the sellback price.

INDSALE: The value of this variable is computed in a revenue-component equation. No initial value is necesary.

PP: The value of the posted price parameter, as was pointed out earlier, is provided by the user according to some scenario used by him. The initial value specified is $11.651 per barrel; that value changes to $11.251 per barrel at the beginning of November, 1974, and remains at that value thereafter unless changed by the user. For a summary of changes, in posted price, especially in recent years, see Knauerhase (1975: 208-211).

ROYALTY: The value of this parameter determines the royalty per barrel paid to the government.[21] Its value is set in country-company agreements, and it must thus be supplied by the user. Its initial value is .145 until the first of October, 1974, at which time it becomes .1667. It then changes to .20 for November, 1974, and remains that unless changed by the user. The values used are the actual historical values; see Knauerhase (1975: 177).

ROYCRUD: This parameter determines the amount of the companies' share of production to be taken by the government as royalties. Ideally, the value of ROYCRUD should be set each month by the decision module in response to conditions in the world petroleum market. At present, however, the decision module has not been provided with an algorithm for setting the value of ROYCRUD because of a lack of information on how such decisions are made. Hence ROYCRUD has been given a default value of 0, with the assumption that the user will introduce different values should he wish to do so. Values introduced by him should be no lower than 0 and no greater than the value of ROYALTY.

SELBACK: The value of this variable is computed in a revenue component equation. No initial value is needed.

SELBACP: The value of this variable is computed in a revenue component equation. No initial value is needed.

SHARE: This parameter's value is determined by the country-company participation contract.[22] Its initial value is .60, the actual value in effect as of August, 1974. Later values should be provided by the user, if necessary, to reflect progress toward the 100% Saudi ownership agreed to in principle in December, 1974.

TAXPAID: The value of this variable is computed in a revenue component equation. No initial value is required.

TAXRATE: This parameter, representing the income tax rate imposed by the government, has an initial value of .55. Its value changes to .6575 on the first of October, 1974. It then changes to .85 for November, 1974, and remains that unless changed by the user. The values used are the historical values; see Knauerhase (1975: 177).

TR: The value of this variable is computed in a revenue component equation. No initial value is required.

Footnotes

1. Formerly known as Petroleum Press Service.

2. See, for example, Hughes (1974).

3. The estimate is made subject to assumptions that will be discussed below.

4. At times in this paper (usually in quotations), the term "proved reserves" will be used. It is identical in meaning with the term "proven reserves."

5. Exploration expenditures are not included in the oil module.

6. See "Aramco Program Seen in Jeopardy." New York Times, August 9, 1973.

7. See Thomas O'Toole, "Disaster Seen if Arabs Reimpose Oil Embargo." Washington Post, April 8, 1974.

8. Because ARAMCO had been in the process of expanding capacity before the embargo, it is assumed that the 6 month delay normally involved before investment produces results was not necessary when investment was resumed in April, 1974.

9. Obviously, different types of equipment wear out at different rates, and to employ an "average" value for LIFETIME is similar to assuming infinite divisibility for a lumpy commodity. Nonetheless, it seemed appropriate not to attempt increased sophistication because of the lack of readily available information and the fact that highly accurate point predictions of costs are not required for the oil module's intended purpose.

10. See Knauerhase (1975: 156-178, 208-211) for a detailed history of oil price agreements.

11. Posted prices are not actual prices at which sales of crude oil take place. They are an amount that is treated, in country-company contracts, as if it were the actual price at which transactions take place, so that the level of per-barrel taxes and royalties is known in advance to both companies and governments. See Knauerhase (1975: 165-168) for a discussion of posted price and its use.

12. The actual profits of an operating company such as ARMACO are determined by the actual prices at which it sells crude oil to its parent companies (and others) and its actual costs and expenses. The "profit" per barrel against which the income tax rate is applied, on the other hand, is an artificial figure arrived at through subtraction of expenses from <u>posted</u> price.

13. In Saudi Arabia, as is often the case in other Persian Gulf oil-producing countries, the oil production activities within the country are carried on by the international major oil companies themselves, but by a company (ARAMCO) that is jointly owned by four of those companies and the government. ARAMCO is an independent company with respect to investment, costs, profits, and so on.

14. Just after the OAPEC embargo, at a time of worldwide short supply in crude oil, some OPEC countries were able to sell small amounts (relative to their total production) of crude oil to third parties at prices considerably above the posted price. This phenomenon was short-lived, however, and the prices dropped back below posted price after a time.

15. The Teheran and Geneva Agreements were efforts to protect payments to the producing-country governments from the effects of worldwide inflation. The Teheran Agreement provided for the adjustment of payments at a fixed rate, while the Geneva Agreement tied the adjustment to changes in value of the dollar (measured against a basket of currencies). See Knauerhase (1972: 173-4) for additional detail.

16. Saudi Arabia's share in ARAMCO was scheduled to begin at 25 percent and increase to 51 percent according to the following schedule:

1973-1977	25%
1978	30%
1979	35%
1980	40%
1981	45%
1982	51%
After 1982	51%

See Knauerhase (1972: 174-75) for other details of this original participation agreement. Later, however, the agreement was superseded by one that called for a 60 percent share for Saudi Arabia in July, 1974 (see <u>Time</u>, July 1, 1974). Still later, an agreement-in-principle was reached for 100 percent ownership of ARAMCO by Saudi Arabia (see <u>Time</u>, December 16, 1974).

17. Both royalty crude and the government's normal share of production may be sold back.

18. See Time (July 1, 1974) for one report of imminent buy back transactions at 93 percent of posted price.

19. See Adelman (1972), Issawi (1972), and "Boom Times in the Gulf," Washington Post, July 22, 1973.

20. The appropriate value of CRUDPCT is not always easy to determine. The value used as an initial value is based on data appearing in The Petroleum Economist. Different values would be arrived at, however, using the information given by Knauerhase (1975: 175).

21. Remember that the government may also take this proportion of the company's share of oil produced.

22. See footnote 16 for the original schedule for changes in the value of SHARE.

Chapter 4 - The Human Resources Module

Human Resources in Saudi Arabia

INTRODUCTION - Part I

Human resources in Saudi Arabia are modeled here as a flow process (see R.E. Wendell, August 1974). From the flow process perspective the population of Saudi Arabia at any given time as divided into a collection of mutually exclusive and exhaustive categories. Persons "flow" from one category to another over a time horizon according to specified transitional constants. To illustrate, a person might move from intermediate education to secondary education with a probility of .2, whereas probability of moving from secondary to intermediate might be .0. A matrix containing all transition probabilities, called the total transition matrix, together with a baseline vector of numbers of persons within each category generates vector descriptions of Saudi human resources.

Notation:

t = time index

p^t = population at t

n = number of categories in human resources description vector

T^t = an (nxn) matrix of transition constants. This matrix will be assumed to be filled with real numbers rather than functions of time.

M^t = an (nx1) vector description of Saudi human resources at t. Note that the sum of entries equals population at t.

Basic Relationship:

$$M^{t+1} = T^t * M^t$$

Vector description of human resources at t+1 equals total transition matrix multiplied by vector description at t.

Discussion

Several tasks present themselves. One is to select the categories which make up the vector description of the human resources sector. This problem was addressed in a pragmatic manner. While categories were chosen, in part, according to the existence of data, another important consideration was that we would like to be able to address questions of industrial, oil, and agricultural expansion with these categories. The vector selected m1, . . ., m15, is:

m1 = persons in unstructured pool
(there are persons about whom we have no further information)

m2 = " " elementary school

m3 = " " intermediate school

m4 = " " secondary school

m5 = " " teacher training school

m6 = " " technical and adult school

m7 = " " universities (Saudi and non-Saudi)

m8 = petroleum wage earners
(these are persons who are employed as laborers through executives in the petroleum field)

m9 = non-petroleum wage earners
(this includes wage earners in industries and manufacturing (other than petroleum))

m10 = civilian governmental employees
(these are the civil servants who administer the various Saudi programs)

m11 = military governmental employees

m12 = non-industrial wage earners
(these people might be employed in shops or as agricultural workers on someone else's land)

m13 = self-employed non-agricultural
(this could include shop owner and merchant-trader types)

m14 = self-employed agricultural
(the bulk of this category is subsistance and sometimes referred to as traditional farmers, herders, etc.)

m15 = persons having moved through human resources
(this could include both retirees and those who have died, left the country, and otherwise dropped from sight).

The next problem is to collect data to estimate a baseline M vector and transition constants. Collection of data and specification of a baseline M vector are in Part 2. The estimation of transition constants is found in Part 3.

BASIC DATA - Part II

The second section of "Human Resources in Saudi Arabia" will consist of the data used for the analysis. There are two broad kinds of data used for the analysis. First, there are relatively "hard" data which are reported in some standard source, such as a statistical abstract. Secondly, there are derived data. These are data generated by the Project for Theoretical Politics. In the following exposition, direct data will be presented first, followed by derived data. For a complete taxonomy of data types used in this paper see Project for Theoretical Politics memo of August 20, 1975.

The first bit of data is about the Saudi Arabian educational system. Other bits of primary data include work force division sizes as a percentage of the total work force and United Nations population estimates. These pieces of direct information are used to generate Table IV.

Table I - Educational Data

Year	m2	m3	m4	m5	m6	m7	TOTAL
69/70	383,644	43,455	8,917	9,631	50,521	14,604	510,429
68/69	252,207	33,547	6,913	2,173	44,932	12,416	457,570
67/68	234,726	30,676	5,834	2,093	44,134	10,903	415,115
66/67	212,674	20,279	3,428	3,438	45,913	9,399	295,131
65/66	193,140	18,497	2,876	5,245	36,877	7,917	264,552
64/65	174,514	14,832	2,484	7,556	37,407	6,479	243,272
63/64	156,780	13,768	2,290	6,876	28,619	5,177	213,510
62/63	139,338	11,148	1,997	5,576	25,440	4,601	188,100
61/62	122,905	9,229	1,547	4,395	19,570	3,391	
60/61	104,203	7,875	1,136	3,497	11,184	2,899	

Data for this table are taken from the Saudi Arabian Statistical Abstract 1970.

Table II - Manpower Data

Manpower Category	Percentage of Total Work Force
Petroleum wage earners	1.0
Non-petroleum, industrial wage earners	.8
Civilian governmental employees	9.0
Military employees	6.0
Non-industrial wage earners	8.2
Self-employed, non-agricultural	1.0
Self-employed, agricultural	74.0
TOTAL	100.0

	Number of Persons 1964	1972
Private		1,140,000
Public		160,000
TOTAL	1,000,000	1,300,000

Category percentages are taken from Rugh, 1973.[1] Total labor estimates fall between those in the Hammad (1972) dissertation and Rugh (1973: 10).

[1] "Emergence of a New Middle Class in Saudi Arabia" The Middle East Journal, Vol. 27, No. 1.

Table III

Population[2]

	1963	1972
Population	6,420,000	8,200,000

[2] United Nations Demographic Yearbook 1973

Table IV

Year	Population	Education	Labor	Unstructured Pool
1963	6,420,000	188,100*	970,874	5,261,026
1964	6,597,000*	213,510*	1,000,000	5,383,490
1965	6,781,000	243,272*	1,030,000	5,537,490
1966	6,986,000	264,552*	1,060,900	5,642,548
1967	7,164,000	295,131*	1,092,727	5,776,142
1968	7,359,000	415,115*	1,125,509	5,818,376
1969	7,563,000	457,570*	1,159,274	5,946,156
1970	7,773,000	510,429*	1,194,052	6,068,519
1971	7,988,000	---	1,229,874	---
1972	8,200,000*	---	1,250,000	---
1973	8,437,000	---	1,304,773	---

*indicates direct data

Notice in Table IV Population column that two entries are marked with astericks. These are type 1 (direct data) data. Using these as reference points an annual growth constant of 1.028 (type 5 or Fitted Data) gives a smooth population growth from one constant to the other. Thus, the constant and initial values are used to generate the entire population column. These data are level 2 (Derived Data).

Similarly, Table II has numbers of persons in the entire Saudi work force (here work force includes educational system). The fixed points for 1964 and 1972 are level 1 data. A growth constant, level 5, is used to generate data in Table IV (Unstructured Pool). This is done by simply subtracting total work force from total population. The unstructured pool constitutes level 5 (Fitted Data). Estimates of labor force size except for 1964 and 1972 are level 2 (Derived Data).

Educational Data is direct (level 1). The labor column of Table IV is fitted by subtracting education from total work force. Thus, labor is level 5 (Fitted Data).

From Tables I, II, and IV, a baseline data vector for 1970 is constructed.

$$M^{1970} = \begin{bmatrix} 6{,}068{,}519 \\ 383{,}644 \\ 43{,}455 \\ 8{,}917 \\ 9{,}631 \\ 50{,}521 \\ 14{,}604 \\ 11{,}940 \\ 9{,}552 \\ 107{,}465 \\ 71{,}640 \\ 97{,}912 \\ 11{,}941 \\ 883{,}600 \\ 0 \end{bmatrix} *$$

*See Part I

CONSTRUCTION OF TRANSITION CONSTANTS - Part III

Recall the basic relationship of the flow model, $M^{t+1} = T * M^t$. For the purpose of vector and transition probability estimation, the human resources module decomposes into (1) unstructured pool; (2) educational system; and (3) labor force.

$$\begin{bmatrix} \text{pool} \\ \text{----} \\ \text{education} \\ \text{----} \\ \text{labor} \end{bmatrix}^{t+1} = \left[\begin{array}{c|c} A1 & A2 \\ \hline \begin{array}{c|c} A7 & A3 \end{array} & A2 \\ \hline \begin{array}{c|c} A8 & A6 \end{array} & A5 \end{array}\right] * \begin{bmatrix} \text{pool} \\ \text{----} \\ \text{education} \\ \text{----} \\ \text{labor} \end{bmatrix}^{t}$$

Transition Sub-blocks

A_1 and A_2 together give us ml^{t+1} as a function of m^t. Because this is an unstructured pool of persons it is assumed that a growth constant is acceptable. This is to say that the size of the unstructured pool is known, but the precise transitions causing size change are not known. Therefore, A_1 iwll be a constant and A_2 a vector filled with zeros. ml^{t+1} is modeled as a function of only ml^t.

A_3 - is intra-educational transitions. Here flow through the Saudi educational system is modeled.

A_4 - is labor to education transition. The constants for moving from labor back into education are here.

A_5 - this is the intra-labor transition matrix. Here constants for moving from one sector of labor to another are given.

A_6 - education to labor matrix. These constants model flows from the Saudi educational system into the labor sector.

A_7 - this block gives movement from the unstructured pool at t into the educational system at t+1.

A_8 - this block models direct movement from the unstructured pool at t into the labor force at t+1.

Table V - Cateogry Data Used for Estimation (cont.)

	m8	m9	m10	m11	m12	m13	m14
1965	103,000	8,000	92,700	61,800	84,460	10,300	762,200
1966	106,090	8,240	95,481	63,650	80,994	10,609	785,066
1967	109,273	8,487	98,345	65,500	89,604	10,927	808,620
1968	112,551	8,742	101,296	67,530	92,922	11,255	832,900
1969	115,927	9,004	104,335	69,560	95,060	11,593	857,900
1970	119,405	9,274	107,465	71,640	97,912	11,941	883,600

Columns m8, . . ., m14 are generated from percentages, Table II and from labor cateogry entries, Table IV.

Estimation Procedure for Transition Constants

The construction of transition constants that provide a reasonable representation of the data in Table V and yield yearly vector predictions is the task at hand. Procedures with various error minimization techniques and known statistical properties are available. To illustrate we go through the teacher training institutions estimation, m5. It is known that these institutions are of secondary level. Because of this, m5 is assumed to be a function of itself, i.e., those who have begun the teacher training program and have neither matriculated nor dropped out, and of intermediate education, m3. It is expected that people don't jump from elementary to secondary education. Accordingly, m2 is given zero for a transition constant. Similar reasoning holds for the unstructured pool. We don't expect people to back up in the educational system resulting in the zero transition from universities. Although people might move from one secondary sort of education to another, it is not modeled into our transition matrix, hence zeros for m4 and m6. Finally, we don't allow movement from the labor pool back to teacher training. Such movement is modeled into adult education.

Level 4 data (Selected Data) is a cornerstone of this modelling effort. Features that are believed to be a part of the Saudi system are modelled in. Once this sort of conventional wisdom is exhausted other parameters are produced as level 5 (Fitted Data) information.

Due to the nature of matrix algebra every variable in the system is a function of 15 variables. Most of the transition constants can be selected according to a wisdom criterion (e.g., often times transition constants are zero). Remaining transition constants are computed so that available data are matched. This data matching, an error minimizing procedure, consists of (1) computing absolute deviations, (2) summing the deviation, (3) averaging the sum, and (4) dividing by averaged input pool size. This procedure is the subject of the following table.

Transition Constant Estimation

$$m_i(t+1) = x_1(m_i t) + x_2(m_j t)$$

Time	Size of m_i category	$x_1 m_i(t)$	Error
t+1	n_1	$x_1 n_2$	$\lvert n_1 - x_1 n_2 \rvert$
t	n_2	$x_1 n_3$	$\lvert n_2 - x_1 n_3 \rvert$
t-1	n_3	$x_1 n_4$	$\lvert n_3 - x_1 n_4 \rvert$
t-2	n_4	$x_1 n_5$	$\lvert n_4 - x_1 n_5 \rvert$
t-3	n_5	$x_1 n_6$	$\lvert n_5 - x_1 n_6 \rvert$
t-4	n_6	$x_1 n_7$	$\lvert n_6 - x_1 n_7 \rvert$

x_2 = average error/average mj

Σ of error
average error
average of mj

Re-estimation of Transition Constants

For any of a variety of reasons a user of this simulation might wish to alter transition constants found in the Total Transition Matrix. Suppose, for example, it is decided that more than 52 percent of thepersons in intermediate schools in any given year are in intermediate school the following year (see element (3,3) of the Total Transition Matrix). A user might be tempted to simply ask a programmer to alter this element. While this can be done from a purely programming perspective, there are substantive considerations which preclude this action. Substantively, it is poor form to either create individuals as they move from elementary to intermediate education. It seems unlikely that more persons could come from elementary education at t+1 than were there at t. Similarly, given a number of persons in elementary education at t, 100 percent of them are someplace at t+1. Poor modeling technique might leave some individuals unaccounted for at t+1. Persons are brought in through element (1,1), the unstructured pool. Persons are eliminated by passing into row 15. Return attention to column 3 of the Total Transition Matrix with the desired upward re-estimate of element (3,3). As the matrix now stands, something (in terms of this model) happens to 100 percent of the individuals in intermediate school at time t. Thus, 52 percent remain in intermediate school, 1 percent become petroleum wage earners, 19 percent move through the system, etc. The important point is (1) everyone goes some place, and (2) there are not more people in the model at t+1 coming from intermediate education than were in intermediate education at t.

The rule of thumb is that excepting column 1 (where persons are created) and column 15 (where persons are eliminated) the sum of the elements of a column must equal 1. The conservation law of the human resource module is that for categories 2-14, persons are neither created nor destroyed. This law is satisfied when the sum of entries for a column is equal to 1 (please note that all entries are positive rational numbers). Modifications to the initial structure of the Human Resources Total Transition Matrix should be done in accord with the rule:

$$(e_i \mid i = 2, \ldots, 14)(\, e_j \mid j = 1, \ldots, 15\,)[\Sigma_j = 1]$$

i = matrix column　　　j = matrix row

Estimations

ml: estimation of unstructured pool

As already mentioned, this category is treated as if ml^{t+1} is a function of ml^t. The following procedure for estimation was used: the absolute value of yearly data (see Table IV) minus average size of unstructured pool was taken, summed and divided by its n. This number, an average absolute deviation was divided by average site of pool yielding a constant.

Year	ml	Average Size	Deviation
1964	5,383,490	5,684,034	300,544
1965	5,537,490	5,684,034	146,544
1966	5,642,548	5,684,034	41,486
1967	5,776,142	5,684,034	92,168
1968	5,818,376	5,684,034	134,342
1969	5,946,150	5,684,034	262,116
1970		5,684,034	

162,867/5,684,034 = .022

$ml^{t+1} = 1.022ml^{t}$

Total Deviation = 977,200

Total/n = 162,867
where n = 6

m2: elementary education

It was decided that $m2^{t+1} = f(ml^{t}, m2^{t})$. Furthermore, the form and content were chosen as:

$$m2^{t+1} = .75m2^{t} + x_1 ml^{t} + c_2$$

.75 was chosen due to the nature of Saudi education. It is patterned on the U.S. scale of 1-6 elementary followed by three years of intermediate and secondary, respectively.

If the dropout rate in elementary school were zero a transition constant of something over .84, depending on failure to matriculate, would be accurate. Presumably, there is some dropping out of elementary school.

1970 was the first year for which female statistics are available. Therefore, constants are based on male only data. Baseline data, however, include female students.

t+1	$m2^{t+1}$	$x_1 m2^t$	Error
1970	268,689	189,155	79,534
1969	252,207	176,045	76,162
1968	234,726	159,506	75,220
1967	212,674	144,855	67,819
1966	193,140	130,889	66,241
1965	174,514	117,585	56,929

Sum of Error = 421,905
Average Error = 70,317.5
Average of ml = 5,684,034
x2 = 70,317.5/5, 684,034 = .01237

m3: intermediate education

$m3^{t+1} = x1\ m3^t + x2\ m2^t$

There are two variables which input persons into intermediate education. One is intermediate education itself. These are people in intermediate education who neither drop out nor graduate within a single time change. The second input is from elementary education. A portion of those who graduate from elementary education go on to intermediate levels. Ten percent of the persons from elementary education (about two thirds of those who graduate each year) are assumed to advance to intermediate levels. This transition constant is, of course, level 4 data. The rate at which persons in intermediate education a t are in intermediate education at t+l is fitted.

.1 is picked for x2 and x1 is derived.

$m3^{t+1}$	$.1*m2^{t}$	Error
38,930	18,916	20,014
33,547	17,605	15,942
30,076	15,951	14,125
20,279	14,486	5,793
18,497	13,089	5,408

Sum of error = 61,282
Average error = 12,256.4
Sum of m3 = 117,231
Average of m3 = 23,446.2

x_1 = Ave. Error/Ave m3 = 12,256.4/23,446.2

x_1 = .5228

m4: secondary education

$m4^{t+1} = x_1 m4^t + x_2 m3^t$ is the assumed relationship. There are two variables which input into secondary education at t+1. One is intermediate education. A portion of those who graduate from intermediate facilities go on to secondary education. The second input is secondary education itself. Some students who do not graduate at a given year return to secondary institutions. Assuming class size to be constant and no dropouts or failures the returning constant would be .66. Some attrition is assumed. Picking .5 for x_1, x_2 is derived.

t+1	$m4^{t+1}$	$x_1 m4^t$	Error
1970	8,479	3,457	5,022
1969	6,913	2,917	3,996
1968	5,834	1,714	4,120
1967	3,428	1,438	1,990
1966	2,876	1,242	1,034
1965	2,484	1,145	1,339

Sum of error = 18,101
Average error = 3,016.8
Sum of m4 = 131,599
Average of m4 = 21,933

x_2 = 2,016.8/21,933 = .1375

m5: teacher training schools

$m5^{t+1} = x_1 m5^t + x_2 m3^t$ is the assumed relationship. The teacher training program is three years. A perfectly smooth system (i.e., no dropouts, constant entering class size, no failures) would suggest a transition constant of .66 from teacher training at t to teacher training at t+1. Some leakage, a substantial dropout rate, is assumed. The incoming students are from intermediate levels of education. .5 is picked for x_1; x_2 is derived.

t+1	$m5^{t+1}$	$x_1 m5^t$	Error
1970	9,631	1,087	8,544
1969	2,173	1,047	1,126
1968	2,093	1,719	374
1967	3,438	2,623	815
1966	5,245	3,778	1,467
1965	7,556	3,438	4,118

Sum of error = 16,444
Average error = 2,740.7
Sum of m3 = 131,599
Average m3 = 21,933
x_2 = 2,740.7/21,933 = .1249

m6: technical and adult school

$m6^{t+1} = x_1 m6^t + x_2 m13 + x_3 m1$

Technical and adult education is the one point in the Saudi educational system where persons who have moved through education into the labor force are brought back to be re-educated. A transition constant of .1 from self-employed non-agricultural is level 3 (area expert) data. The programs are in general secondary, implying a three year course of study. A level 4 decision is made for the return of technically educated to that level. Level 5 data is used to fit a flow constant from the unstructured pool into these schools.

	$m6^{t+1}$	$.5m6^t$	.1*m13	Error
1970	50,521	22,466	1,159	26,896
1969	44,932	22,067	1,126	21,739
1968	44,134	27,957	1,093	20,084
1967	45,913	18,439	1,061	26,413
1966	36,877	18,704	1,030	17,143
1965	37,407	14,310		

Sum of Error = 112,266
Ave. error = 22,453.2
Ave. m1 = 5,684,034
x_3 = .004

m7: university

$m7^{t+1} = x_1 m7^t + x_2 m4^t + x_3 m6^t$. The body of the university students are modeled as coming from (1) the university itself; (2) secondary schools, and (3) technical and adult schools. This is level 4 data. Because of the four year nature of university education, .7(level 4) is chosen. Level 4 data gives .1 for movement from secondary into university. This leaves the transition from technical and adult education to be fitted (level 5 data).

$t+1$	$m7^{t+1}$	$x_1 m7^t$	$x_2 m4^t$	Error
1965	6,479	3,624	248	2,607
1966	7,917	4,535	288	3,104
1967	9,399	5,542	343	2,756
1968	10,903	6,579	583	3,741
1969	12,416	7,631	691	4,094
1970	14,604	10,691	848	3,065

Sum of error = 41,803
Ave. error = 6,934
Sum of m4 = 237,432
Ave. m4 = 39,572
x_3 = 6,934/39,572 = .1749

m8: petroleum wage earner

$$m8^{t+1} = x_1{*}m8^t + x_2 m2 + x_3 m4 + x_4 m7 + x_5{*}m1 = .9{*}m8 + .001m2 + .01m3 + .01m4 + .001m7 + xm1$$

Very little hard evidence (level 1 data) exists on the makeup of the petroleum wage earner pool. However, it seems reasonable to assume (level 4 data) the petroleum wage earners at t+1 are made up of petroleum wage earners at t; some elementary, secondary, and university students; and finally, some members of the unstructured pool. It is assumed (level 4 data) that wage earning categories are relatively stable. Thus, .9 is chosen for a yearly return rate. Small amounts are chosen (level 4) for the movement from educational categories into petroleum wage earning. Finally, the movement from the unstructured pool into the petroleum wage earning cateogry is fitted (level 5).

	$m8^{t+1}$	$.9m8^{t}$	$.001m2^{t}$	$.01m3^{t}$	$.01m4^{t}$	$.001m7^{t}$
1970	119,405	104,334	268	389	848	14
1969	115,927	101,296	252	335	691	12
1968	112,551	98,346	234	301	583	11
1967	109,273	98,376	212	203	343	9
1966	106,090	95,481	193	185	288	8
1965	103,000	90,000	174	148	248	6

	Error
1970	13,522
1969	13,006
1968	13,076
1967	10,897
1966	12,430

Sum of error = 62,961
Ave. error = 12,592.2
x = .0022

m9: non-petroleum wage earners

$$m9^{t+1} = x_1 m9^t + x_2 m3^t + x_3 m6^t + x_4 m7^t + x_5 m1^t = .9{*}m9^t + .01{*}m3^t + .01{*}m6^t + .001{*}m7^t + x_5{*}m1^t$$

The non-petroleum wage earning category follows almost the same logic as did the petroleum wage earning category. Yearly category stability intermediate education, technical education, university, and the unstructured pool are assumed to input into the non-petroleum wage earning pool. A constant of .9 (level 4) models stability of the pool. The unstructured pool is fitted (level 5) to (level 4) selected values in m3, m6, and m7.

	$m9^{t+1}$	$m9^t$	$m3^t$	$m6^t$	$m7^t$	Error
1970	9,274	8,104	307	449	12	402
1969	9,004	7,868	203	441	10	482
1968	8,742	7,638	185	459	9	451
1967	8,487	7,416	148	369	8	546
1966	8,240	7,200	138	374	6	522
1965	8,000	6,990	111	350	5	544

Sum of error = 2,947
Ave. error = 589
x_5 = .000104

m10: civilians employed by government

$$m10^{t+1} = x_1*m10^t + x_2*m2^t + x_3*m5^t + x_1*m1^t + .9m10^t + .01*m2^t + .3*m5^t + x_4*m1^t$$

Civilian governmental employees at t+1 are made up of civilian governmental employees at t, teacher training at t, elementary education at t, and the unstructured pool at t. This is level 4 data. Yearly stability is .9 and is level 4. The unstructured pool is fitted (level 5) in around with the constant for m2 and m5 which are level 4.

	$m10^{t+1}$	$.9*m10^t$	$.01*m2^t$	$.3*m5^t$	Error
1970	107,465	96,719	2,522	652	7,572
1969	104,335	91,166	2,347	628	10,244
1968	101,296	88,511	2,127	1,031	9,627
1967	98,345	85,933	1,931	1,574	8,907
1966	95,481	83,430	1,745	2,267	8,039

Sum of error = 44,389
Ave. error = 8,877.8
x_4 = .00156

m11: military personnel

$$m11^{t+1} = x_1 m11^t + x_2 m4^t + x_3 m6^t + x_4 m1^t$$

$x_1 = .9,\ x_2 = .3,\ x_3 = .01$

Military personnel at t+1 is a function of military personnel at t, secondary school at t, teacher training at t, and the unstructured pool. This information is level 3 (area expert) data. Yearly military stability is .9 (level 4). .3 is the constant for transition from secondary school into the military. .01 is the constant for transition from technical and adult into the military. These two constants are level 3 data. The transition from the unstructured pool is fitted.

	$m11^{t+1}$	$m11^t$	$m4^t$	$m5^t$	Error
1970	71,640	62,600	2,544	22	6,474
1969	69,500	60,780	1,750	21	6,949
1968	67,530	59,000	1,028	34	7,468
1967	65,650	57,290	863	52	7,445
1966	65,200	55,020	745	76	7,359

Sum of error = 35,695
Ave. error = 7,139
$x_4 = .00126$

m12: non-industrial wage earners

$$m12^{t+1} = x_1 m12^t + x_2 m3^t + x_3 m5^t + x_4 m6^t + x_5 m1^t$$

$x_1 = .9,\ x_2 = .01,\ x_3 = .01,\ x_4 = .1$

The non-industrial wage earners at t+1 are a function of the non-industrial wage earners at t, intermediate school at t, teacher training at t, technical school at t, and the unstructured pool at t. Yearly stability of the non-industrial wage earners, transition from intermediate, teacher training, technical are level 4. The unstructured pool is level 5.

	$ml2^t$	$ml2^{t-1}$	$m3^{t-1}$	$m5^{t-1}$	$m6^{t-1}$	Error
1970	97,912	85,554	335	217	449	11,357
1969	95,060	83,030	301	209	441	10,479
1968	92,922	80,644	203	344	459	11,272
1967	89,604	78,295	185	325	369	10,430
1966	80,994	76,014	148	756	374	3,702

Sum of error = 47,240
Ave. error = 9,448
x_5 = .00166

ml3: self-employed non-agricultural

$ml3^{t+1} = x_1 ml3^t + x_2 ml$
$x_1 = .8$

The self-employed non-agricultural pool at t+1 is a function of that pool at t and of the unstructured pool at t. This is level 4 data. Yearly stability is .9 and level 4. The transition constant from the unstructured pool into self-employed non-agricultural.

	$ml3^{t+1}$	$.8ml3^t$	Error
1970	10,609	8,240	2,369
1969	10,927	8,487	2,440
1968	11,255	8,742	2,513
1967	11,593	9,004	2,589
1966	11,941	9,274	2,667

Sum of error = 12,578
Ave. error = 2,515.6
x_2 = 2,515.6/5,684,034 = .0004

ml4: self-employed agricultural

$ml4^{t+1} = x_1 ml4^t + x_2 m2^t + x_3 ml^t$ is the assumed relationship. The self-employed agricultural pool at t+1 is a function of selkf-employed agricultural at t, elementary school at t, and the unstructured pool at t. Yearly stability of this pool and transition from elementary school are level 4 data. The transition from the unstructured pool is level 5 data.

.9 and .1 are picked for x_1 and x_2. x_3 is derived.

t+1	$ml4^{t+1}$	$x_1 ml4^t$	$x_2 m2^t$	Error
1965	762,200	666,000	15,678	80,522
1966	785,066	685,980	17,451	81,635
1967	808,620	706,559	19,314	82,747
1968	832,900	727,758	21,264	83,880
1969	857,900	749,610	23,472	84,818
1970	883,600	772,110	25,271	86,219

Sum of error = 499,821
Ave. error = 83,303.5
Ave. ml = 5,684,034
x_3 = 83,303.5/5,684,034 = .0147

ml5: persons having moved through human resources sector.

Once people have entered this category they are of no interest to us. No records are kept. $ml5^{t+1}$ is conveniently a function of all other variables at t.

Change of the Human Resources Transition Matrix by Decision-Makers

The term "government" implies that there is something to be controlled or governed. Accordingly, in the simulation of the Saudi Arabian government (called decision module in these reports) - human resources interaction is constructed such that the decision module implements some control over the total transition matrix.

As implemented in the accompanying simulation, decisions are made in a production system format (see Research Paper No. 28). The specific process has the following 5 components. (1) a current value (some element of human resources vector) is input into the decision process; (2) this value is compared with some desired level; (3) a relation between actual and desired levels is stated (e.g., secondary education is very low, low, medium, high, and very high); (4) the relation is input into a decision production system, and (5) appropriate action (change of matrix element) is taken. Five section s of human resources are looked at: (1) education; (2) self-employed in agriculture; (3) petroleum production workers; (4) military employees; and (5) civilian governmental workers.

The problems with the implementation of this procedure are several. The manner in which the actual Saudi government attempts to deal with the human resources aspects of that country are not known. Thus, the simulated structure of control should properly be seen as how the Saudi government might go about trying to control its manpower makeup. This part of the simulation is level 4 (or selected) data.

All changes must be in accord with the conservation principle (see Re-estimation of Transition Constants section for this principle and explanation). Therefore, columns 2-14 of the transition matrix must sum to 1 in any implemented matrix change. A sample output is included.

EDUCATIONAL SYSTEM AT EXTREME LOW
INCREASES WILL BE MADE IN ELEMENTARY ED.
STUDENTS COME FROM THE UNSTRUCTURED POOL
SINCE SITUATION IS DRASTIC, INCREASES ARE LARGE

TOO FEW SELF-EMPLOYED IN AGRICULTURE
LEVEL WILL BE INCREASED DRASTICALLY
BUDGET ALLOTMENTS WILL BE MADE ALSO

PERCENT OF PEOPLE IN OIL TOO FEW
INCREASE PETROLEUM BUDGET ALLOCATIONS GREATLY
PETROLEUM PRODUCTION IS DANGEROUSLY LOW

MILITARY PERSONNEL DANGEROUSLY LOW
BUDGET ALLOTMENTS WILL BE INCREASED
SITUATION COULD BECOME SERIOUS

TOO FEW CIVILIANS IN SAUDI GOVERNMENT
APPROPRIATE ALLOCATIONS WILL BE MADE
OPERATIONS IN GOVERNMENT MAY BOTTLENECK

END OF DECISION MODULE

Saudi Arabia: Human Resources
A One-Year Projection

PERSONS IN UNSTRUCTURED POOL	5,965,329
PERSONS IN ELEMENTARY ED	545,038
PERSONS IN INTERMEDIATE ED	50,500
PERSONS IN SECONDARY ED	10,433
PERSONS IN TEACHER TRAINING	10,894
PERSONS IN TECH AND ADULT ED	52,059
PERSONS IN UNIVERSITIES	18,586
PETROLEUM WAGE EARNERS	30,684
NON-PETROLEUM WAGE EARNERS	9,996
CIVILIAN GOVT. EMPLOYEES	111,990
MILITARY GOVT. EMPLOYEES	93,891
NON-INDUSTRIAL WAGE EARNERS	102,912
SELF-EMPLOYED NON-AG	12,674
SELF-EMPLOYED AG	941,017
PERSONS MOVED THROUGH SYSTEM	166,695

TOTAL TRANSITION MATRIX

Transition Matrix

Basic Data at T

Unstructured pool	.989716	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elementary school	.0124	.75	0	0	0	0	0	0	0	0	0	0	0	0	0
Intermediate school	0	.1	.52	0	0	0	0	0	0	0	0	0	0	0	0
Secondary school	0	0	.1375	.5	0	0	0	0	0	0	0	0	0	0	0
Teacher training school	0	0	.1249	0	.5	0	0	0	0	0	0	0	0	0	0
Technical & adult school	.004	0	0	0	0	.5	0	0	0	0	0	0	.1	0	0
University	0	0	0	.1	0	.1479	.7	0	0	0	0	0	0	0	0
Petroleum wage earners	.0022	.001	.01	.01	0	0	.001	.9	0	0	0	0	0	0	0
Non-petroleum wage earners	.000104	0	.01	0	0	.01	.001	0	.9	0	0	0	0	0	0
Civilian Gvt. employees	.00156	.01	0	0	.3	0	0	0	0	.9	0	0	0	0	0
Military personnel	.00126	0	0	.3	0	.01	0	0	0	0	.9	0	0	0	0
Non-industrial wage earners	.00166	0	.01	0	.01	.1	0	0	0	0	0	.9	0	0	0
Self-employed non-agricultural	.0004	0	.01	0	0	0	0	0	0	0	0	0	.85	0	0
Self-employed agricultural	.0147	.1	0	0	0	0	0	0	0	0	0	0	0	.9	0
Persons having gone through system	0	.04	.19	.09	.19	.24	.298	.1	.1	.1	.1	.1	.05	.1	0

The Agriculture Module: Introduction

The next simulation module to be described is that dealing with agricultural production in Saudi Arabia. While this section concentrates on the agriculture module, it is important to keep in mind that this module is only one of three domestic simulation modules which when taken together with user supplied international events provide the context in which the decision module operates.

While oil is clearly a dominant factor in the Saudi Arabian economy, economic development (or stagnation) depends heavily upon the modernization of the agricultural sector. Thus the agriculture module has been designed to aid in identification of the various information and material flows in agriculture production process that influence decision-makers' choices of policies and to project consequences of these choices.

The method used in the development of the simulation module has been a "building block" approach in which the array of variables and relationships comprising the agriculture sector is conceptually grouped into several sequentially-linked "logical components" (or building blocks) to simulate various facets of the production process. Four such components are included in the present version: resource allocation, modernization, production, and consumption/demand components. The output from each component serves as either an input to another component or a performance measure, or both. The final outputs of the model thus include not only physical outputs, but also a set of performance measures. It is this set of measures which the decision-makers evaluate and compare with policy goals when choosing their policies and programs for the next time period. The module is structured to simulate the production of field crops (specifically wheat, the principal crop and food staple). Parameter values as well as initial values for the variables have been collected for Saudi Arabia.

The Agriculture Module - Background

Agriculture constitutes a major sector of both the economy and the social structure of Saudi Arabia. After oil, it is the largest single contributor to the national accounts (i.e., the national income, the GNP, the balance-of-payments, etc.). And, whereas the oil sector represents the major source of revenue, the agricultural sector is the principal source of employment and individual income. More than half of the population derives its livelihood directly from agricultural production. Despite this rather sizable input of labor into the agricultural sector, agricultural productivity remains rather low. Winter grains such as wheat and barley (the principal grain crops in these countries), for example, rarely yield more than fifteen bushels per year, even in a relatively good year.[1] At such levels of productivity, it is difficult for Saudi Arabia to produce enough to meet the present needs of its population.

Considerable efforts are thus being made to modernize and develop the agricultural sector. If these efforts are to succeed, however, several rather formidable obstacles must be overcome. One such obstacle which has long constrained agricultural production is the relative lack of adequate water supplies. For the most part, Saudi Arabia has depended upon rainfall to provide the water needed for crop production. However, the arid nature of the climate results in the rainfall being both low and highly variable over time. Many areas, in fact receive so little rain as to make the production of rainfed crops well-nigh impossible. As a result, the amount of cultivable land is limited to a very small percentage of the total land area. And where this land is actually put under cultivation, the utilization of this land for rainfed crops (which the major share of the crops grown in most of these countries are) requires the adoption of such practices as placing the cropped area in fallow during alternate growing seasons. Under such conditions it is hardly surprising that yields have been low.

The alternative to this dependence upon rainfall for crop production is the extension of irrigation to the areas to be cultivated (both present and potential). But to bring these areas under irrigation requires alternative sources of water in sufficient amounts to meet the water requirements of the area (and crop) to be irrigated. However, Saudi Arabia has no rivers, lakes, etc., of any potential significance in this respect.

Another potential source of groundwater is from underground streams and lakes. Information on how extensive the supply of this water is, however, rather scanty. A more certain source of potential irrigation water is seawater. But the production costs involved in tapping this source, as well as those associated with groundwater, are substantial. The cost of producing groundwater, for example, has been estimated at \$130.00 per acre-foot.[2] This contrasts sharply with the cost of desalinated water which, given present technology, costs an estimated one dollar per 1000 gallons, or about \$326.00 per acre-foot.[3] As the need arises to dig deeper wells, and as desalination technology advances, however, the difference in the costs of these two alternative sources is likely to diminish.[4] But for the present time (and for the foreseeable future), it is the production of groundwater which, in terms of cost, appears to constitute the more practical solution to the water problem.

Whatever the source, it is abundantly clear that the development of irrigation is an essential component of any effort to raise agricultural productivity. However, expanded irrigation is not the only prerequisite for increased agricultural production. If the expansion of irrigation in the cultivated areas is to be of any value, it must be accompanied by a number of additional but equally important production inputs.

For example, there is general lack of soils suitable for cultivation. Suitable soils are about as scarce as water. As a consequence, only a small fraction of the land is truly cultivable. Even in those areas where cultivation is feasible, the suitability of the soil is limited. In particular, there are two aspects of the siol which pose major limitations upon agricultural production. First, with continued wetting and drying out, the soil has a tendency to accumulate a high concentration of salt. Second, the soils are very low in nitrogen content. Nitrogen is necessary to sustain high production in these soils. As a consequence of both limitations, the productivity of the soil tends to be exhausted rather quickly with the result that much of the cultivated land must be placed in fallow during alternate years. Moreover, even when this land is cropped, the resulting yields tend to be quite low.

Clearly, then overcoming this second obstacle constitutes another major prerequisite for increased agricultural production. But again, no single input will be sufficient to achieve this. Instead, there are several separate but closely interrelated inputs which should help improve the suitability of the soils for production. Among these is, first of all, the construction of a drainage system for "flushing" harmful salts out of the soils. In conjunction with this, there is a nedd to improve use of land and water. What this specifically entails is the adoption of such practices as land leveling, flood control, and moisture conservation. Additionally, more extensive use must be made of fertilizers, particularly nitrogen fertilizers. Both potassium and phosphorus are available but not in sufficient amounts to sustain a wide variety of crops at high production levels. From oil, however, the needed amounts of nitrogen fertilizer could be derived; although this would require sizable investments in the development of the appropriate production facilities. Finally, with increased fertilization and irrigation, new varieties of crops could be introduced which are of the high-yield type.

All of the inputs identified above, including the extension of irrigation, are directed at raising the per acre yields of the cultivated land. However, raising per acre yields represents only one aspect of the overall problem of increasing agricultural production. Another equally important aspect of this problem is that of raising the per capita productivity of labor.

As was noted earlier, a major share of the population (and thus the labor force) is engaged in agriculture (see also the description of the human resources module). Yet, the per capita productivity of agricultural labor is presently quite low. Faced with insufficient water supplies and poor soils, the individual farmer, of course, is not going to be very productive. Even with the necessary inputs to overcome these two obstacles, he is still not likely to be very productive. To raise the per capita productivity of agricultural labor in these countries at least two obstacles must be overcome. The first of these relates to the availability of labor in sufficient numbers to support an intensive effort to expand agricultural production.

Of those employed in the agricultural sector, most are engaged in traditional subsistence farming. With agricultural production thus being directed primarily at meeting the food needs of the individual household (or production unit), the labor input required to produce this food is provided principally by the household itself. And, more often than not, this labor is sufficient to meet the labor requirements for subsistence farming. With the movement away from subsistence farming and toward expanded production, however, ". . . the need for labor will increase so considerably that present surpluses (if any exist at all) will hardly suffice to satisfy the new requirements.[5] Put somewhat differently, raising production yields may create another problem of shortages of labor. The situation is further aggravated by the fact that the agricultural sector loses part of its labor supply each year. This loss of labor results not only from normal attrition (e.g., death, retirement, etc.), but also from movement from the rural areas to the cities.

How, then, is theproblem of labor shortages to be overcome? One way, of course, is to substitute machinery for human labor, i.e., to "mechanize" the agricultural sector. At present the level of mechanization is rather low; farmers still depend largely upon human and animal power.

To reiterate a point made earlier, the introduction of any single input (such as farm machinery) is not by itself sufficient to bring about the desired changes in agricultural production. Thus, ". . . mechanization would accomplish relatively little unless accompanied by better irrigation and drainage, greater fertilizer use, better crop varieties, better control of weeds and crop diseases, and by other components of a technologically advanced agriculture. . . "[6] Nor is the input of these factors of production together enough. There must also be a willingness on the part of the individual farmers to adopt these production inputs. What this essentially boils down to is the existence of economic opportunities that are rewarding to these farmers.

As Schultz (1964) has noted, traditional agriculture (which agriculture in Saudi Arabia predominantly is) has a certain built-in resistance to any change in the existing state of the art: "The concept of traditional agricultures implies long-established routines with respect to all production activities."[7] Because farmers in traditional agriculture have a wealth of experience with these routines to draw upon, the risks and uncertainties associated with the production possibilities of traditional factors of production are minimal. With the introduction of new factors of production, these farmers are faced not only with having to break with the well-established practices of the past, but also with having to cope with risks and uncertainties which are as yet unknown.[8] As a result, they are likely to be rather hesitant to adopt these new factors. Yet, it is only through experience that they will be able to learn what the risks and uncertainties are inherent in these factors.

From one perspective, willingness of individual farmers to adopt the new production inputs depends largely upon recognition of (1) the payoffs to their production activities, and (2) the costs (as well as the supply) of these inputs. What this essentially means is that there must be a system of prices which will enable farmers to make a reasonable margin of profit, and, at the same time, to obtain the necessary new inputs at prices that permit this profit margin. It is this margin of profit, then, that provides the necessary inducement, or lack thereof, to adopt the new production inputs.

In Saudi Arabia, however, such a system of prices is, for the most part, missing. Prices for farm products generally tend to be depressed and distorted. Moreover, the costs of the required inputs remains quite high. The overall effect of the present system of prices thus has been to leave farmers in with relatively small margins of profit. As a result, there is little incentive for them to produce much more than what is necessary to meet their own consumption demands, let alone to purchase the new production inputs.

Clearly, the establishment of a more efficient system is essential to overcome this final obstacle. But again, the overcoming of this one obstacle is not, by itself, enough to bring about an increase in production. True, an efficient system of prices is likely to lead to an increased willingness on the part of farmers to grow more, but their efforts will not get very far unless there are adequate supplies of the necessary production inputs available.

In sum, then, the essence of agricultural development in Saudi Arabia appears to lie in:

> . . . the application of a package of separate but closely interrelated programs, technologies, and processes; it is their interrelationship which is truly significant . . . Any single program may have limited and sometimes even negative effect, if taken by itself, but may be highly productive if combined with other programs in proper proportions and proper timing.[9]

The problem facing decision-makers thus is one of finding that proper combination of programs, in the proper sequence, which will produce the results they seek.

As the preceding discussion indicates, the effort to modernize the agricultural sector is no simple matter. There are numerous physical, economic, social and political factors, the dynamic interactions between which affect the decision-makers' choices of developmental policies and pro-rams. To provide a clearer picture of how this complex array of factors and their interrelationships affect these choices, a simulation model of the agricultural sector in Saudi Arabia was constructed. What this model purports to offer is (1) identification of the essential information and material flows influencing the decision-makers' choices, and (2) analysis and projection of the consequences that their choices might have for the performance of the agricultural sector.

To simplify the picture even further, attention in the construction of this model has been confined to the production of but one crop: wheat. This narrowing of focus is based, in part, on the fact that wheat constitutes the principal crop grown in terms of both the quantity produced and the amount of crop land devoted to it. Moreover, wheat represents the major staple in the diet.

In constructing the agriculture module, a "building-block" approach has been employed.[10] Basic to this approach is the assumption that the referent system is composed of several functionally interrelated "building-blocks." Linking these components are the outputs of the components themselves. That is to say, each component yields an output (or set of outputs) which serves either as an input to another component in the system, or as a measure of the component's performance. Collectively, the performance measures generated by these components comprise a "performance vector" which, in turn, serves as an input to the decision stratum (i.e., as the information upon which decision-makers' base, for the most part, their choices for the next time period).

The Agriculture Module: Description of Simulation Components

This section will describe the four components (resource allocation, modernization, production, and consumption/demand) which make up the agricultural sector model. Simplifying assumptions have, of necessity, been made in each component. However, for the sake of clarity each component's description will be brief and (for the most part) the simplifying assumptions will be considered in a separate section at the conclusion.

Considerable revision of the module have been undertaken. The changes correct errors which were discovered in earlier versions and also make the module more appropriate for use in simulating the wheat sector of Saudi Arabia. Still, the model should be considered an initial effort.

A. Resource Allocation

The first component (or "building block") deals with the allocation of resources for wheat production. The first of these is the allocation of land.

In the module, the amount of cultivable land available is assumed to remain constant throughout the simulation run. This assumption is based on the assumption that it will be some time (say thirty years or so) before there is any significant progress towards expanding the amount of cultivable land. Not all of this cultivable land, of course, is actually cultivated at any one time. Both the nature of the soils and the prevailing farm practices necessitate the placing of some of this land in fallow each growing season.

A distinction is made between rainfed land, which is farmed with traditional methods, and irrigated land, which is farmed with modern methods. It is assumed that for Saudi Arabia the amount of rainfed land available is constant throughout a simulation run. The decision module may only influence the amount of this land that is used for wheat production. This is expressed in the following equation:

TOTRFAW = P1*TOTRFA (R1)

where: TOTRFAW = rainfed land to be used for wheat production (hectares)

TOTRFA = total rainfed land (hectares)

P1 = the proportion of total rainfed land to be used for wheat production (dimensionless)

On rainfed land in most of Saudi Arabia, however, cropland may be used only every other year. Thus we have the equation:

RFAWEAT = 0.5*TOTRFAW (R2)

where: RFAWEAT = the amount of rainfed land available for wheat production in any given year (hectares)

The allocation of irrigated land is somewhat more complex; the decision module must determine how much irrigated land is available each year as well as decide how much of land available is to be devoted to wheat production. The amount of irrigated land available at any time is a result of past expenditures on irrigation development, and hence the amount of land available at some future time is dependent upon present expenditures. The module includes the following assumptions about irrigation development projects:

1) Any development project will take a known time to complete.

2) A project provides no additional irrigation capability until construction is complete.

3) Construction cost of a project accrues in equal annual installments during the construction period.

Thus the following equations represent the process of planning for a new irrigation development project:

```
IRRNU = BUDI/COSTI                      (R3)
CALL INPIPE (IRRIG, IRRNU, IRRDELA)     (R4)
CALL UNICOST (IRRCOST, BUDI, IRRDELA)   (R5)
```

where: IRRNU = the amount of water to be provided by a given new irrigation development project (m^3/year)[m^3 = cubic meters].

BUDI = the total amount budgeted for the (entire) cost of the project ($).

COSTI = the cost per m^3 per year of the irrigation development project ($/$m^3$/year).

CALL INPIPE invokes a computer subroutine which delays the appearance of the new irrigation water until a certain number of iterations (equal to the number of years needed for construction of the project) has occurred.

IRRIG = a variable which is part of the INPIPE subroutine.

IRRDELA = the number of years required for this particular project to be completed (years).

CALL UNICOST invokes a computer subroutine which keeps track of both the total annual costs for all irrigation development projects underway at a given time, and the number of years remaining until each project is completed.

IRRCOST = a variable which is part of the UNICOST subroutine.

It should be apparent that the model must also generate a figure for any new irrigation water which becomes available during the current iteration. This is done through the following equation:

```
IRD = OUTPIPE (IRRIG)                   (R6)
```

where: IRD = irrigation development rate; the amount of water becoming available as a result of the completion of one or more irrigation development projects during the current iteration (m^3/year).

OUTPIPE (IRRIG) invokes a computer subroutine which determines, from stored information on earlier irrigation development project planning decisions, how much new water becomes available during the current iteration.

The following equations provide for the determination of how much irrigated land will be available and for the allocation of part of that land to wheat production. The equations also allow for the assumption that irrigated land resulting from recent irrigation development projects should tend to be double-cropped. Thus, track is kept of both the actual land devoted to wheat and the cropped land devoted to wheat, where the latter is the number of physical hectares times the average number of crops grown on them per year.[11]

IRP = IRD/IRR + IRP (R7)

IRRWEAT = NUCROP*IRP*P2 + OLDCROP*IRA*P3 (R8)

TOTWEAT = RFAWEAT + IRRWEAT (R9)

LUC = TOTRFA + IRA + IRP (R10)

LCW = RFAWEAT + IRA*P3 + IRP*P2 (R11)

IRRTOT = IRA + IRP (R12)

where: IRP = new irrigated land resulting from the completion of irrigation-development projects (hectares).

IRR = the amount of water required for very high yield wheat projection assuming double-cropping (m^3).

IRRWEAT = total irrigated cropped land allocated to wheat production (hectares).

NUCROP = cropping ratio (ratio of cropped land to physical land) for new irrigated land (dimensionless).

OLDCROP = cropping ratio for old irrigated land (land irrigated but not as part of a modern irrigation development project) (dimensionless).

IRA = total old irrigated land (hectares).

P2 = proportion of new irrigated land to be allocated to wheat production (dimensionless).

P3 = proportion of old irrigated land to be allocated to wheat production (dimensionless).

TOTWEAT = total cropped land allocated to wheat production (hectares).

LUC = total physical land under cultivation (hectares).

LCW = total physical land allocated to wheat production (hectares).

IRRTOT = total irrigated physical land under cultivation (hectares).

B. The Modernization Component

As has been noted, the development of a single input (e.g., water) is not by itself sufficient to bring about increased agricultural production. Instead, a number of separate (but closely interrelated) modernizing inputs are required, including fertilizers, farm machinery, improved seed varieties, etc. In order to explore the impact of these modernizing inputs upon agricultural production, a "modernization" component has been built into the model. This component focuses specifically on the impact of two such inputs on the production of wheat in the five countries: fertilization and mechanization. The principal output of this component is a measure of productivity (yield per hectare).

There are two main influences on productivity of land if water is adequate. They are the level of fertilization and the level of mechanization. The levels of usage of fertilizer and modern machinery and the effects of those levels of usage enter into this component through the following equations:

RFERT = BUDF/GVPFERT (M1)

FERTA = 1000* RFERT/IRRWEAT (M2)

RMECH = BUDM/GVPMECH (M3)

ATP = (1-(1/WEAROUT))*ATP + RMECH (M4)

POWU = ATP/IRRTOT (M5)

YPHM = MIN (YLDF(FERTA), YLDM(POWU)) (M6)

YPH = (YPHT*RFAWEAT + YPHM*IRRWEAT)/LCW (M7) where: RFERT = the amount of fertilizers obtained by the government for a given year (metric tons).

BUDF = the amount budgeted (and spent) by the government for purchase of fertilizers during a given year ($).

GVPFERT = the government's price of fertilizer. This is a weighted price for nitrogen, phosphate, and potash fertilizers purchased in the proportion 5:2:2 ($/metric ton).

FERTA = the fertilizer application rate (kg/hectare).

IRRWEAT = the amount of irrigated cropped land devoted to wheat (see earlier definition in Resource Allocation component) (hectares).

RMECH = the amount of mechanization obtained by the government for a given year (hp).

BUDM = the amount budgeted (and spent) by the government for the acquisition of new and replacement tractors during a given year ($).

GVPMECH = the government's price of farm tractors ($/hp).

ATP = available tractor power. This is the total of all available operative tractors (hp).

WEAROUT = the average expected useful life of a tractor (years).

POWU = the average rate of power (tractor) utilization (hp/hectare).

IRRTOT = total irrigated land (hectares).

YPHM = yield per hectare (modern). This is the average yield for land farmed with modern methods (kg/hectare).

MIN( ) is a function which selects the lowest of the values enclosed in parentheses. Here it selects either YLDF (FERTA) or YLDM (POWU), whichever is lower.

YLDF (FERTA) = a function which relates he wheat yield to fertilizer application rate, assuming adequate water and mechanization (see Appendix I) (kg/hectare).

YLDM (POWU) = a function which gives the wheat yield possible with any given level of mechanization, assuming adequate water and fertilization (see Appendix II) (kg/hectare).

YPH = average overall yield for wheat (kg/hectare).

YPHT = yield per hectare (traditional). This is the average yield on rainfed land with traditional methods (kg/hectare).

LCW = total land in wheat production (hectares).

With regard to the above equations, two points should be kept in mind. First, there is no provision for the accumulation of fertilizers over time. Such a provision may easily be added if it should turn out to be needed. However, it is assumed that because of the low quality of the soils in these countries farmers will use all the fertilizer they are able to get. Second, it is assumed that the productivity of traditional (rainfed) land will remain constant throughout the simulation run since so little of that land is susceptible to modern capital-intensive methods. This is the case for wheat in Saudi Arabia, at least.

C. The Production Component

The third component in our model deals with production and with the returns (or losses) to the farmers and to the government as a result of wheat production activities. The following set of equations makes up this component:

YLD = .ØØ1*YPH*LCW (P1)

OUTC = PCON*YLD (P2)

OUTE = YLD-OUTC (P3)

GVCOST = (GVPFERT-FMPFERT)*RFERT + GVPMECH*RMECH - FMPMECH*ATP)*
(LCW-RFAWEAT)/(IRP + IRA) (P4)

TINC = DMPRICE*YLD - FMPFERT*RFERT - FMPMECH*ATP
(P5)

INCPC = TINC/SALF (P6)

INCH = TINC/LCW (P7)

LABP = YLD/SALF (P8)

where: YLD = total production actually achieved (metric tons).

OUTC = quantity of wheat produced which is allocated to domestic consumption (metric tons).

PCON = proportion of wheat production allocated to domestic consumption. This is a policy variable expressed as a decimal value between Ø and 1.Ø (dimensionless).

OUTE = quantity of wheat produced which is available for export (metric tons).

GVCOST = net cost to the government of subsidizing modern wheat farming practices through provision of fertilizer and machinery ($).

FMPFERT = farm price of fertilizer. This is the price paid by the farmer ($/metric ton).

FMPMECH = farm price of mechanization. This is the cost to the farmer of using 1 hp for one year ($/hp-year).

TINC = total income (net) for all farmers ($).

DMPRICE = domestic price of wheat (price received by farmers) ($/kg).

INCPC = average net income from wheat per agricultural person ($/man).

SALF = size of the agricultural labor force engaged in growing wheat.

INCH = average net income from wheat per hectare of land used in wheat production ($/hectare).

LABP = a measure of labor productivity: the average yield per person engaged in growing wheat (kg/man).

D. Consumption/Demand Component

This final component in our proposed model essentially represents a budgetary accounting mechanism. It takes information on production outputs (from the production/marketing component) and computes the values for several variables measuring the overall performance of the production process being modeled. Put more simply, the purpose of this component is to compute the final set of variables comprising the performance vector. These variables include the value of crop exports (Equation C1) and the demand for food imports (Equation C3).

VALEXP = WP*OUTE (C1)

DWHEAT = BASED*(POPI/100 + ELAST*(INDXPCE/POPI - 1.0) (C2)

IMPORT = DWHEAT - OUTC (C3)

POPI = (1 + POPGR)*POPI (C4)

where: VALEXP = total value of wheat exported ($).

WP = world price for wheat ($/metric ton).

DWHEAT = consumption demand for wheat for the current year (see Asfour, p. 25) (metric tons).

BASED = consumption demand for food in a base year (metric tons).

POPI = index of population for the current year relative to the base year (dimensionless).

ELAST = elasticity coefficient of demand for wheat (dimensionless).

INDXPCE = index of total private consumption expenditure for the current year.

IMPORT = imports of wheat required during the current year in order to meet demand.

POPGR = annual proportional increase in population (expressed as a decimal value)(dimensionless).

E. Discussion

Perhaps the most critical change present in this revised model of the agricultural sector is that of ignoring the microeconomic behavior of the individual farmer. It is assumed that the adoption of modern farming methods will occur only when heavy subsidization of the required inputs and intensive efforts by agricultural extension teams are present. This seems reasonable, since the adoption of modern methods as a result of extnesion work alone has been minimal in Saudi Arabia.[12] In addition, since there exists no true country-wide price and/or transport system, the price paid to the farmer in a subsidized program will likely be controlled (either directly or indirectly) by the government.

Thus, it is assumed that:

(a) all fertilizer is bought by the government and resold to to the farmers;

(b) all tractors and other mechanized equipment is bought and maintained by the government, and rented to individual farmers;[13] and

(c) the government pays the total cost of constructing and operating water development projects.

It is further assumed that the government is willing to absorb a reasonable loss in subsidizing the production of wheat in order to lessen the country's dependence on imports.

Thus the module may be seen to be structured almost totally around the decision-making. The costs involved are costs to the government. The computed average income per person engaged in wheat production, for instance, is really more a social indicator for the policy-maker than a measure of earned income and economic strength in a free market sector. The government controls the farmers' incomes through setting prices on wheat, fertilizer, and machinery.

To the extent that this image of the agricultural sector in Saudi Arabia is correct, the module may not be too far off the mark. If these simplifying assumptions are found to be unwarranted, however, then considerably more detail may be necessary in the model. Given the difficulty of obtaining reliable (let alone extensive) data on Saudi Arabian agriculture, however, this module seems a reasonable beginning.

Appendix 1

Yield Response to Fertilizer Assuming Adequate Water and Level of Mechanization

The function used in the agriculture module for giving the yield response to level of fertilization (assuming water and mechanization level are sufficient) is necessarily a hypothetical one. The following comments present the assumptions made in hypothesizing this particular response curve.

First, it was assumed that the shape of the curve would be one in which the slope was steep initially, was less steep and approximately linear through a middle range, fell to zero as some point of maximum possible yield was passed through, and became increasingly negative beyond that point.[1]

Second, the slope of the approximately linear portion of the curve was taken to be 15 kg/kg. This figure was arrived at on the basis of . estimates indicating that approximately 2 pounds of nitrogen and .8-1.0 pounds each of P_2O_5 and K_2O would be needed per bushel of wheat produced.[2]

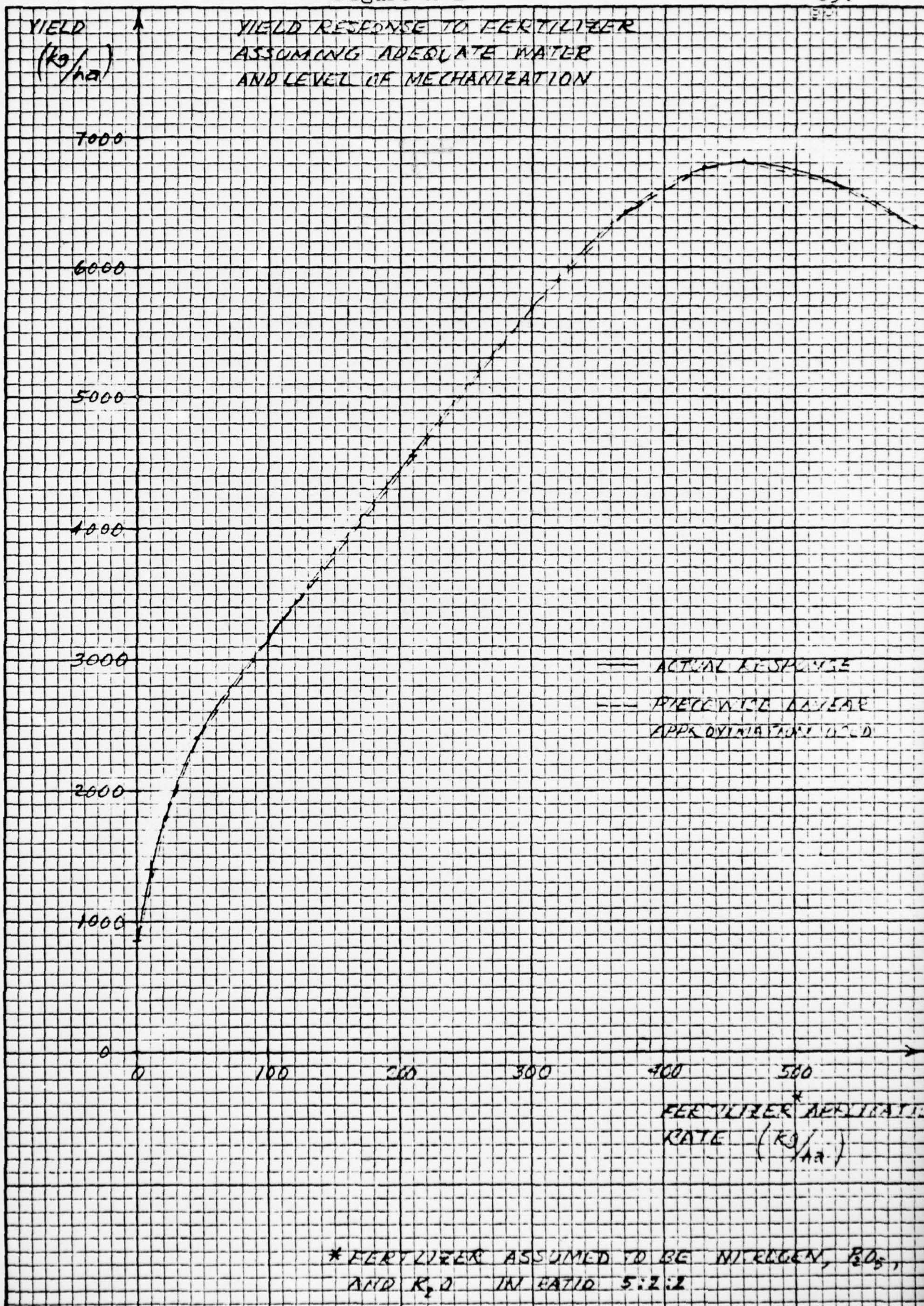
Third, the point of maximum yield was assumed to be slightly greater than the 6720 kg/ha shown in Table 6.3 of Seifert, et al (p. 60). No assertion is made here that this is an accurate estimate of the point of maximum yield; it is simply a point of relatively high yield arbitrarily selected for use in order to permit testing general behavior.

Four, points on the low end of the curve were selected on the basis of an assumptionof 1400 kg/ha with very little fertilizer and 870 kg/ha with no fertilizer. The first figure comes from Clawson, Landsberg, and Alexander (p. 299). The second is estimated from the same work (p. 228), and is used with the assumption that yields in years from 1951-1957 reflect a virtually zero level of fertilizer utilization.[3]

Fifth, the use of seed varieties responsive to high fertilization levels is assumed.

Once again, the response function shown in Figure A-I is hypothetical, but its general shape should be currect, and the curve itself may be easily changed on the basis should more accurate data become available.

Figure A-1


YIELD
(kg/ha)
ASSUMING ADEQUATE WATER
AND LEVEL OF MECHANIZATION
7000
6000
5000
4000
3000
2000
1000
0
0
100
300
400
500
RATE (kg/ha)

A-I Footnotes

[1]See United Nations Food and Agriculture Organization, The State of Food and Agriculture (1968), pp. 90-91 and especially Table III-5. Note that Table III-5 either assumes zero output if no fertilizer is applied or else has incorrect figures for total crop output. Since the table is hypothetical and meant only to illustrate the text, however, it was assumed that these errors should not prevent the inference concerning the shape of the fertilizer response curve underlying the table.

[2]See Clawson, et al, p. 145. See also United Nations, FAO, p. 89. These figures also provide the basis for the assumed 5:2:2 (N, P_2O_5, K_2O) ratio.

[3]See also Asfour, pp. 62-63 and 73-74. Approximately 10 kg/ha of fertilizer was used in Saudi Arabia in 1961.

Appendix II

Mechanization Constraint on Yield Response to Fertilizer Assuming Adequate Water

The function (shown in Figure A-2) for mechanization level required to reach various production levels is even more speculative than that for yield response to fertilizer. It is assumed here that mechanization is required if high yields are to be obtained; the process of obtaining such high yields requires many more operations (irrigation, fertilization, mechanical harvesting, tillage, etc .) than are required in traditional agriculture. Moreover, high levels of mechanization should permit double-cropping in Saudi Arabia.[1]

Exactly what levels of mechanization are required for particular levels of output (assuming adequate water and fertilizer), however, is highly speculative. Estimates of the need for various levels of mechanization are couched in phrases such as ". . . underpowered at 0.5 horsepower per hectare, and that 1.0 horsepower per hectare would represent overpowering . . ."[2]

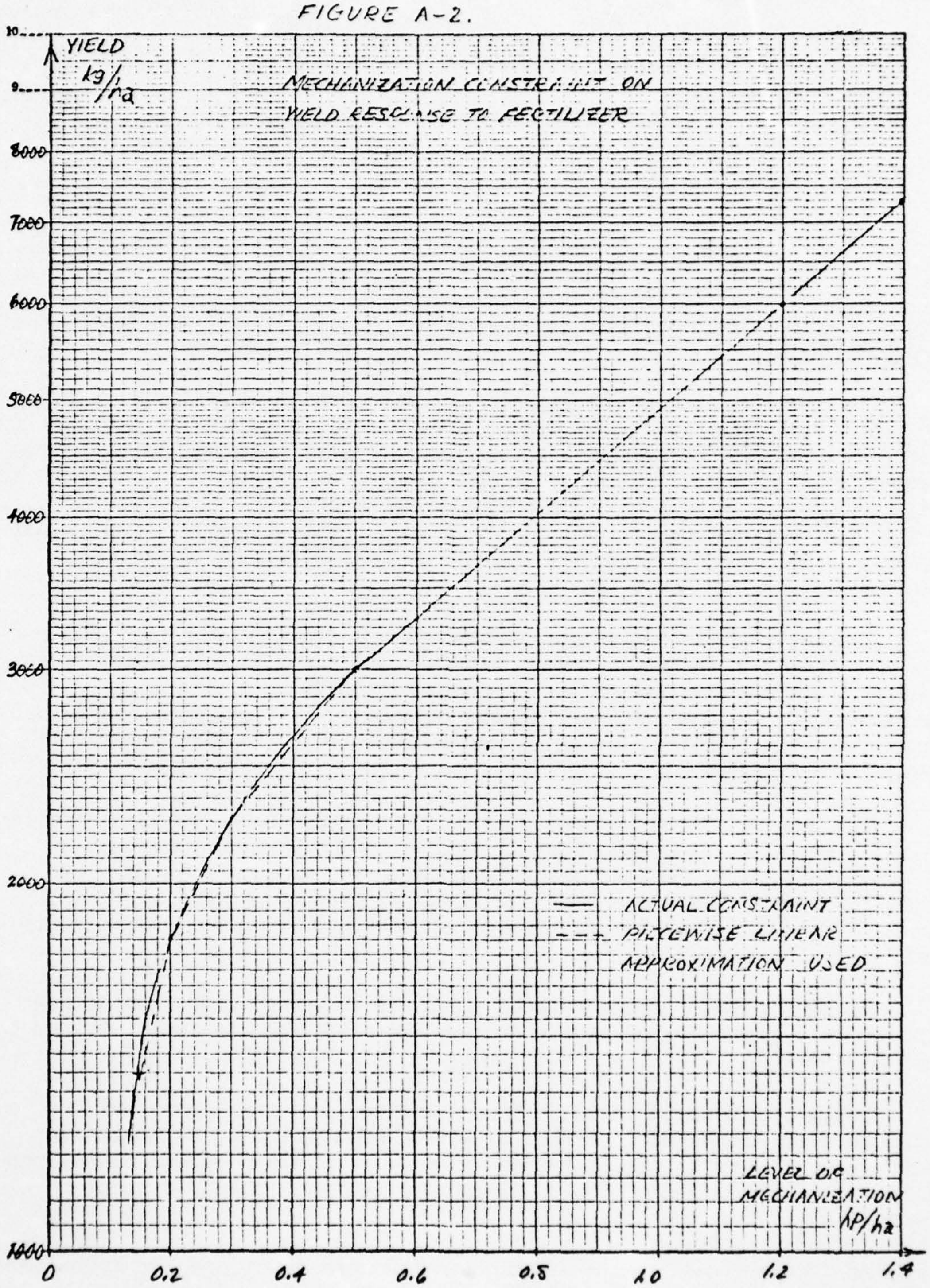
The function used in the model at this time takes its shape from a plot of hp/ha vs. average aggregate yield of major food crops for several nations.[3] Few nations show power utilization levels greater than 1.0 hp/ha, but a level of 1.0 hp/ha generally is associated with only 2300-3400 kg/ha yields. Yields of 5000$^+$ kg/ha are shown only for nations using 1.7-2.1 hp/ha.

Hence for this effort a power utilization level of 1.2 hp/ha was arbitrarily chosen as necessary to achieve a 6000 kg/ha yield, Ø.5 hp/ha for a 3000 kg/ha yield, and Ø.2 hp/ha for an 1800 kg/ha yield.

Mechanization and fertilizer are treated as mutual constraints; a high level of fertilizer cannot produce a high yield if mechanization sufficient to permit efficient performance of other required operations is not available, and mechanization is of limited utility without fertilizer.

As is the case for the fertilizer response function, the mechanization constraint function can easily be revised when better data becomes available.

FIGURE A-2.



A-II Footnotes

[1]See Seifert, et al, p. 63.

[2]Clawson, Landsberg, Alexander, p. 149.

[3]United Nations FAO, p. 93.

Footnotes

[1] Clawson, Marion, Hans Landsberg and Lyle Alexander (1971) The Agricultural Potential of the Middle East. New York: American Elsevier Publishing Co., Inc. p. 2.

[2] Clawson, Landsberg and Alexander, p. 115.

[3] Ibid.

[4] As Clawson, Landsberg and Alexander have indicated, it is estimated that the costs for producing groundwater from pumped deep wells runs between $250 and $370 per acre-foot (1971, p. 115). In contrast, Fried Edlund (1971) suggest that with the development of a large-scale single purpose plant based on oil or gas, the cost of desalination could be brought down to around 25 to 35 cents per 1000 gallons, which is equivalent to $81 to $114 per acre-foot.

[5] Brenner, Y.S. (1971) The Economics of Agricultural Development. Ithaca, N.Y.: Cornell University Press, p. 50.

[6] Clawson, Landsberg and Alexander, p. 41.

[7] Schultz, T.W. (1964) Transforming Traditional Agriculture. New Haven: Yale University Press, p. 33.

[8] Ibid.

[9] Clawson, Landsberg and Alexander, p. 111.

[10] By a "building block" approach, we refer specifically to the modeling approach developed by Glen Johnson, et al, namely "the generalized system simulation approach."

[11] It is important to keep track of this distinction (between cropped and physical land).

[12] See Seifert, et al, p. 54-55, and Asfour, pp. 73-74.

[13] See Asfour, p. 73, Saudi Arabian Monetary Agency, p. 49, and Saudi Arabian Central Department of Statistics, pp. 72-73.

Part III: Overview

The five sections of the chapter comprising Part III provide a detailed description of the simulation of the government of Saudi Arabia. The first two sections describe the linguistic processing capabilities of the simulation. As discussed in Chapter 2, interpretation plays an important part in the view of governmental decision-making underlying the current effort. The first section describes the linguistic processing from a syntactic and semantic point of view. The second section is concerned with the process of providing interpretations to the input sentences from the simulation user. Sections 3, 4, and 5 provide a discussion of the structure of the processing mechanism which generates the simulated responses of the government of Saudi Arabia. Section 3 is concerned with the abstract character of the processing mechanism. Sections 4 and 5 discuss the behavior generated by the simulated Saudi decision units.

Chapter 6 - The Decision Module

Section 1: The Language

Natural Language Input: Structure and Process

Any attempt to simulate the behavior of a government must design a manner for external information to be given to the simulation. In the present case, the simulation was constructed to accept English sentences as the input from the environment. The purpose of this section is to illustrate and explain the process by which sentences are interpreted and processed by the simulation. The basic process is one of translating the external representation of the sentence into an internal representation suitable for machine manipulation. This translation process can be divided into three stages. The first is a syntactic analysis of the sentence. This process examines the sentence, determines whether it is in an appropriate form, e.g., grammatical, and parses the sentence into its elemental syntactic features. The second analysis takes these elemental features and the sentence structure and produces a semantic interpretation of the sentence. In other words, the process extracts the meaning from the sentence. The third process takes the semantic content of the sentence and produces a representation of it which reflects the content and consequences of the sentence in the context in which it was generated. It is this final internal representation of the original sentence that is processed by the simulation.

Thus the structure of the linguistic processing can be represented by three mappings. The first maps sentences into syntactic elements. The second maps these syntactic elements into semantic interpretations. The third and final mapping takes semantic interpretations and produces a representation suitable for machine manipulation. Thus each stage of the processing uses the output from the previous stage as input. This process is illustrated in Figure 1.

Sentence → Syntactic Elements → Semantic Interpretation → Internal Representation

Figure 1

The Analysis of Syntax

The act of communicating implies the transmission of meaning (Cf. Pepinsky, 1974). Furthermore, the very concept of transmission implies that there exists some sort of structure (Cf. Pepinsky, 1976). While there are many methods of communicating or transmitting meaning, e.g., verbal, body movements, text, or electronically, any method invokes some sort of structure. Communicating with a computer simulation is no different. Such communication is invariably structured in one of two ways: either through numeric or symbolic representations. Clearly, numbers can be thought of as symbols, but there is an important distinction between treating '5' as an integer and treating it as merely an abstract symbol. Within the social sciences the method of representation is invariably numeric. For example, the simulations of Forrester (1971), Meadows, et al (1972), or Mesarovic and Pestel (1974) all are based upon numeric representations. On the other hand, in the field of artificial intelligence symbolic representations predominate, e.g., Winograd (1972), and Ernst and Newell (1969). In the present instance, inputs to the simulation are in terms of symbolic representations.

When a symbolic as opposed to numeric representation is chosen, additional design questions are raised. This is a result of the tendency for computer languages to be ready to easily accept numeric representations without further specification of the process of internal representation by the simulation designer. Numeric structures tend to be more universal, simple, and well understood than the more general and complex symbolic structures. Because of the small number of different types of numeric representations, i.e., integers, reals, or complex, program designers need only invoke pre-existing processing structures to accept and interpret the inputs. But because of the complex and specialized nature of symbolic representations only very general aspects of the processing structure needed to interpret them can be constructed by program language designers. As a result, issues pertaining to the structuring of the symbolic inputs must be directly addressed by the simulation designer.

As discussed more fully in Project Reports Nos. 20, 26, and 28, the basic character of the symbolic inputs to the simulation was conceived to be actions by other actors in the outer environment of Saudi Arabia and certain non-event descriptions of the state of certain environmental factors, e.g., the price of wheat. Furthermore, these events and descriptions were conceived as sentences in the English language. As a result of this design goal, the only pre-existing facility of the language that we could use in accepting and interpreting these symbolic inputs was the character set. The character set was specified as the twenty-six letters, and ten numerals, and the punctuation symbols " ", ".", ",", and "?".

In order to decrease the size and complexity of the processing mechanism, these elemental symbols were grouped into higher-level pre-defined classes of root words, real numbers, and punctuation symbols. Thus the input processing of the simulation recognizes as inputs,words, numbers, and punctuation symbols. This was accomplished by giving the simulation program a list of the words and symbols it was to consider as part of the vocabulary of the language it must accept as inputs. The full vocabulary of the simulation is given in Figure 2 Note that because the programming language used, SPITBOL, already had the concept of a number predefined, there was no need to explicitly invoke the concept of a number in the vocabulary. As discussed below, the specification of the language was not an a priori affair. Instead the inputs required for the processing mechanism of the decision module specified the nature and content of the vocabulary: a justification and discussion of the content of the vocabulary of the language accepted by the simulation will be found there.

Clearly the simple specification of the vocabulary of the language is not sufficient to specify the content of the language. Not all possible strings of words are considered sentences. As discussed above, communication implies the structuring of meaning. The structure imposed upon written language is called a grammar. This structure or grammar imposes the constraint that all strings of symbols conveying meaning must be sentences in the language, i.e., be grammatical. Notice that this constraint does not in general hold for the linguist. He must concern himself with the empirical fact that some ungrammatical strings do in fact convey information. For example, "Home go I will now" is not an English sentence, yet it would tend to be recognized by a speaker of the English language as standing in some sort of weak identity with "I will go home now." For a discussion of the theoretical problems raised by examples such as these see Chomsky (1965).

The grammar of a language must define the set of acceptable ordering of the words in the vocabulary. But as indicated above, the grammar itself will not indicate the meaning or content of the sentence, nor will it specify under what condition a sentence might be uttered. The question arises as to how the set of sentences in the language is to be constructed. Given the design goal of machine implementation, there are two possible methods for defining this set. One option is to enumerate the sentences one by one, storing this list in the program. The simulation program could then examine the sentence, compare it with the exhaustive list of possible sentences, and judge whether the string of words is a sentence. The second option is to define an effective (in the algorithmic sense) procedure for generating the sentences. Thus instead of listing each sentence, a procedure or algorithm would be specified which would generate the set. The first option is reasonable only if the corpus of the language is extremely small. But if the language is large (more than a few sentences) this process of enumeration has several serious drawbacks. First, it is possible that the language may consist of an infinite number of sentences. If this is the case, the enumeration approach is in principle impossible. Second, if the language is to be extended and made larger, each new sentence must be entered if the enumeration approach is used. On the other hand, if the algorithmic approach is taken, a single rule has the potential for generating a very large number of sentences. Thus the addition of a single rule may increase the language significantly. Thus the time and effort required to increase the corpus of the language is minimized if the algorithmic approach is taken. Third, under the enumeration approach the entire set of sentences must be searched in order to determine whether a string of words is part of the language. On the average, one-half the sentences must be searched for every test. If the language grammar is specified in an algorithmic fashion, there is no search per se. The recognition process can be structured such that syntactic categories, e.g., verbs, nouns, and adverbs, can be invoked in determining the status of the string of words. For example, every sentence must have a verb. The algorithm need only scan the words in the string to determine if there is a verb present. In this instance the scanning time is a function of the number of words in the vocabulary and the number of words in the sentence. But given the nature of most languages, the number of sentences is much larger than the number of words and/or lengths of sentences. The fourth and final advantage of the algorithmic approach is that unless the process of interpretation is a very simplistic one, the structure of the sentence will be involved in the determination of the semantic content of the sentence. Because the algorithmic approach produces a structural analysis during the process of determining the status of the string of words, further analysis of the structure is unnecessary. This is not the case if sentences are recognized by an enumerative approach.

As a result, a grammar of the language is specified in an algorithmic or in Chomsky's terms, generative form (Chomsky, 1957). This grammar will have the quality of being well specified in the sense that given any string of words, the rules of the grammar will allow a determination of the status of the string to be made based solely upon the structural characteristics of the words. The grammar of the simulation language is given in Figure 3 The grammar is a phase-structure grammar written in the Bacus-Naural metalanguage (BNF) (Cf., Chomsky, 1965). A phrase structure grammar is a grammar in which the constituent parts of a sentence are defined hierarchically in terms of words, phrases, and sentences. Every sentence can be represented as a string of phrases, and every phrase represented as a string of words. This arrangement has the advantage that if the first phrase in the string of words is incorrectly formed, it is known that the string of words cannot be a sentence and examination of the string can be stopped at that point. There are two types of symbols in the grammar in Figure 3 , terminals and non-terminals. The terminal symbols are defined in terms of words in the language which the grammar defines, e.g., verbs, nouns, etc. Non-terminal symbols are metalinguistic entities used to describe the structure of the language itself. Non-terminals are defined in terms of terminal symbols. In the BNF specification of the grammar, the symbol "::=" is a meta-linguistic symbol for definition. Thus, PREP-PH (a prepositional phrase) is a non-terminal symbol defined as PREP AGENT. Concantenation is implied if any two symbols are separated by a blank. Thus

PREP AGENT identifies an instance of a preposition followed by a member of the class of agents. PREP's and AGENT's are terminal symbols because they are defined in terms of words in the vocabulary or lexicon of the language. Notice that it is also possible for non-terminal symbols to be defined in terms of other non-terminal symbols. For example, the non-terminal SENTENCE is defined in terms of NOUN-PH's and PREP-PH's. The final meta-linguistic convention is that the symbol "|" stands for alternation. Thus a NOUN-PH is defined as either an instance of an AGENT or a NOUN. An important and very powerful feature of the BNF meta-language is that it allows recursive definitions to be used in constructing the grammar. For example the symbol AGENT is defined as ACTOR | AGENT ACTOR. It is this ability to recursively define structures in the language that allows a finite grammar to define an infinite language.

The basic vocabulary of the language consists of verbs and nouns. In addition there are prepositions and various modifiers, e.g., will, not. Notice that no adverbs or adjectives are included in the lexicon. In order to minimize the complexity of the processing demands, these word types were not included. Where adjectives were necessary, compound nouns were created using hyphens. For example, political, economic, and military support were each entered as separate compound nouns, i.e., political-support, economic-support, military-support. Furthermore, articles were not included in the language. Thus some of the sentences in the language have a stilted quality, e.g., US sells arms to SA.

To illustrate how the grammar in Figure 3 serves to define the set of sentences of the language, consider the sentence: "US will sell arms to Iran." (The meanings of the various terms, e.g., VERB2 or VERB3, will be discussed in detail below. For the purposes of this illustration the only interpretation necessary is given contextually by their use in the grammar). "US" is defined in the grammar as an instance of an AGENT. The grammar further specified that AGENT can be treated as a NOUN-PH (noun phrase). The next two words in the string can be represented in the grammar as a VERB3-PH as follows. "Sell" is a VERB3 and "will" is a MOD. The grammar specifies that the combination MOD VERB3 is a VERB3-PH. The next two words in the string can be grouped into a PREP-PH by the following route: "to" is an instance of a PREP and "Iran" is an AGENT. PREP AGENT is defined to be a PREP-PH. We thus have representations for all the words in the string arranged in the following order: NOUN-PH VERB3-PH PREP-PH. As can be seen in the first definition in the grammar, such a string of non-terminal symbols defines a SENTENCE. Thus the string, "US will sell arms to Iran" is a sentence in the language. The non-terminal SENTENCE is considered the goal symbol in this grammar. A string of words is considered a sentence if and only if there exists a grouping of the words in the sentence into phrases such that the sequence of phrases is defined as an instance of a SENTENCE by the grammar.

It is possible to "work backwards" through the grammar to generate arbitrary sentences. Simply start with the non-terminal SENTENCE. Arbitrarily pick one of the alternate structural forms for a SENTENCE. Take each non-terminal appearing in that string and arbitrarily pick one of the symbols appearing of the right side of its definition. This process is continued until each symbol in the string has been replaced by words in the language itself. If one were to systematically go through the various possible combinations in this grammar, the entire set of sentences comprising the corpus would be generated.

It should be clear from an inspection of the grammar that it is not a generalized grammar for the English language. Furthermore the meta-linguistic variables, e.g., VERB2, do not conform to standard grammatical categories (Cf., Chomsky, 1965). This grammar is a specialized construction designed especially for the demands of the simulation. The primary design goal was to produce as simple a grammatical structure as possible while at the same time defining a language of sufficient complexity and breadth to serve as inputs to the simulation's decision model.

In the language there are two general types of sentences, agentive and stative. Agentive sentences are intended to represent the behavior of an actor or group of actors in the outer environment of Saudi Arabia. These sentences were considered analogous to the raw data upon which events datasets are built (Cf., Hermann, et al, 1974 , and PTP Research Paper Nos. 20, 26, and 28). They are descriptions of actions. The second type of sentence, stative, describe characteristics of the state of the outer environment. These sentences do not describe specific actions, but refer to the price of wheat, the demand for oil or the prevailing interest rate for Saudi investments for example.

The structure of agentive sentences is that of actor and action. There are two types of agentive sentences reflecting the different syntactic requirements of the verb. Verbs such as attack require two other grammatical elements to form a complete sentence, e.g., Egypt attacks Israel. As can be seen in the grammar, verbs of this type require an AGENT and a NOUN-PH. These verbs are classified as VERB2 verbs in the grammar. They express the action by one actor on some other object. The second class of verbs require three additional grammatical units to form a sentence. The verb "sell" is an instance of this type, i.e., US sells arms to SA. These verbs, classified as VERB3, require an AGENT, a NOUN-PH, and a PREP-PH. Sentences of this type cover instances where an actor does something to an object directed at another actor. Notice that this classification of verbs is not a partition, since the verbs "sign" and "affirm" are classified as both VERB2 and VERB3. In addition, the grammar prohibits constructions which would be considered sentences in normal English. For example, "SA purchases arms." is not a sentence with respect to the grammar.

The grammar allows several variations on the basic agentive sentences. Modifiers indicating negation or future time are permitted, as are interrogative forms. The two modifiers, "will" and "not" allow the following constructions: US will sell arms to SA, and US will not sell arms to SA. Coupled with the basic declarative form, the language allows present action (US sells arms to SA), future intentions (US will sell arms to SA), and negative intention (US will not sell arms to SA). The language does not include references to past action or intention, e.g., US would not sell arms to SA or US would have sold arms to SA. (Notice that while the grammar does not reflect verb-subject tense agreement, all example sentences have conformed to standard English usage. In fact the grammar implemented in the simulation does require tense agreement, as well as the plural construction allowed by recursive definition of AGENT. These details have been suppressed in order to clarify the presentation of the grammar.) Interrogative sentences are formed by placing the modifier "will" at the front of a simple declarative sentence, e.g., Will SA buy arms from US? As is indicated in the definition of interrogative sentences (INTER), no other modifiers can be used. Thus sentences of the type: Will not SA buy arms from US? are not in the language. It is also permissible to include a WORTH-PH (worth phrase) in the agentive sentences. This allows constructions such as: US will sell arms worth $5,000,000 to SA.

The second major sentential classification is stative sentences. Because their purpose is to describe the state of a particular aspect of the environment, their form is much simpler. Following the practice of Forrester (1971), outer environmental states are divided into rate and levels. The grammar requires that level stative sentences have in addition to the noun and level, the units in which the level is expressed. Examples of level stative sentences are: Oil price is $7.00 per barrel and Fertilizer price is $.46 per ton. Rate sentences also must have a specification of the units in which the rate is expressed, but they do not require the time unit necessary to interpret rates. To have included time as well as units would have necessitated the inclusion of an additional sentential form. In order to minimize the complexity of the grammar, these time units are built into the interpretation of the sentences.

While this grammar does prohibit many constructions from being considered sentences, and does define a class of sentences capable of being given an interpretation, the complete corpus that it defines is too large. For example, according to the grammar the following string is considered grammatical: US will buy security-treaty to SA. If the grammar is to serve its purpose, such constructions must be disallowed. It is clear what the problem is with "US will buy security-treaty with SA." First, security-treaties are not in general purchased. While it might be possible to construct scenarios where it would be conceivable that security treaties could be purchased, for the limited domain of the simulation such circumstances can be excluded. The second problem with the "sentence" also has to do with the nature of the verb. Specifically, an object is not "purchased to" some actor. The correct expression is "purchased from." The language specified in Figure 3 is insensitive to verb-object and verb-preposition agreement. Obviously such features must be taken into account if the inputs to the simulation are to resemble English sentences.

There are two constraints involved in solving this problem of unintelligible sentences. The first is that whatever form the solution might take, it should not increase the number of different sentential forms. There are currently two declarative forms, two interrogative forms, and two stative forms. The addition of more structural variations increases the complexity of the grammar. Because more complex grammars require a more complex and costly computer program to implement them, it is desirable to keep the grammar as simple as possible. The other constraint has to do with the structure of the program for recognizing grammatical from ungrammatical strings of words. In particular, it would be desirable to have a grammar constructed in a manner such that the string of words need only be scanned once, in a linear manner in order to determine its status with respect to the grammar. Two and three pass grammars necessarily require more time to process a string of words. Grammars constructed in a manner requiring backup facilities in the program implementing that grammar, increase processing time. Thus any solution should not increase the categories in the grammar or require non-linear multi-pass scans.

One obvious solution to this problem would be to sub-categorize verbs and nouns. Since the problem is one of verb-object and verb-preposition agreement, by introducing a sufficient number of categories, agreement could be guaranteed. But this solution will work only at the expense of increasing the number of different sentential forms. This violates the first design constraint.

But clearly, any solution to the problem must in some manner increase the specificity of the grammar. It must prohibit certain groupings of words. But there is a solution that allows agreement between verbs, nouns, and prepositions which does not require modifications to the structure of the grammar itself. This solution is to augment the grammar with another set of rules which allows agreement to be taken into account. Notice that the agreements both involve the verb of the sentence. Certain verbs require objects having certain characteristics, and certain prepositions. Thus once the verb has been specified, the admissible class of objects and prepositions has been narrowed. Certain verbs, because of their nature require objects having certain characteristics. Security treaties simply are not sold. Whatever object is to be used with the verb sell, it must have the property of being a thing of substance. Security treaties are abstract things, while airplanes are not. It is possible to point to an airplane and touch it. It is not possible to touch a security treaty. It is possible to touch the text of a treaty, or the paper on which it is written, but not the treaty itself as an abstract concept. This fact that verbs require objects having certain properties is generalized into what Chomsky has called syntactic features (Chomsky, 1965). Each word in the lexicon is assigned syntactic features. The grammar is augmented to include the restriction that once the verb has been specified, only those words having features consistent with those specified with the verb are acceptable. The verb becomes the key element in distinguishing sentences from non-sentences. Notice that this is consistent with the use of the verb in differentiating agentive from stative and VERB2 from VERB3 sentences. The syntactic features used in the augmentation of the grammar are: abstract, count, and animate. Each feature is further modified by a + or -, indicating whether the feature applies to the word. In the case of nouns, the determination is based upon the nature of the noun. In the case of verbs it is based upon the types of objects the verb may be used with. The particular collection of syntactic features has no a priori justification. It is simply a collection that distinguishes proper agreement with respect to the grammar and lexicon. The syntactic features for each entry in the lexicon is given in Figure 4.

A noun is +abstract if it is not a thing of substance. Thus security treaties are assigned the feature +abstract, while airplanes are assigned the feature -abstract. A noun is +count if a plural construction exists for it. Thus airplanes are +count while military aid is -count. The final feature is animate. A noun is +animate if it denotes an individual or collection of individuals. Thus airplane is -animate and armed-forces is +animate.

Verbs are classified according to the nature of the objects that must be present if the verb is used in a sentence. Often the entire set of three features is not necessary to specify agreement with the verb. For example it is possible to buy airplanes and oil even though airplanes is +count and oil is -count. Furthermore, some verbs, like give, accept +abstract objects as long as the object is also -count, e.g., political-support, in addition to any -abstract object regardless of its count attribute. Notice also that once the verb has been specified, the preposition required in VERB3 constructions necessarily follows. Thus the required preposition is included in the specification of the syntactic feature of the verb.

Notice that by using the verb as the key to agreement within the sentence, the linear scan constraint is achieved. All those grammatical units that are involved in agreement are found after the verb. Thus once the verb has been scanned, the class of admissible objects and prepositions have been identified. Thus agreement can be determined without resort of either multiple or non-linear scanning of the input string.

Another use of syntactic features is involved in whether a noun may be assigned a worth phrase, i.e., US sells arms worth $4,000,000 to SA,or a value/unit phrase,Oil price is $4.00 per barrel. Nouns are assigned the attribute "worth" if a worth phrase may be included in the sentence. Notice a worth phrase is in general an optional inclusion in the sentence. The only instance where it is required is when the receiving agent is Saudi Arabia. The simulation requires them in this case in order to ensure the Saudi budget accurately reflects Saudi purchases. In addition, if a noun has the attribute "value" it can be used in a stative sentence, e.g., Oil price is $4.00 per barrel. In the case of the stative use of nouns, the unit that must be included is also indicated as a syntactic feature.

The final use of syntactic features indicates whether the verb is capable of accepting more than one actor. For example, it is possible for more than one nation to sign or affirm treaties and agreements with another nation. This possibility is allowed by including the attribute "joint" to the verbs sign and affirm. This allows constructions such as US, France, SA sign security-treaty. Both sign and align are given two entries in the lexicon. This is to allow the alternative construction, US signs friendship-treaty with SA. In one case the verb is treated as VERB3 , and as a VERB2 in the other.

As was indicated above, the purpose of the grammar is not simply to define the input language accepted by the simulation but also to serve as the basis for the specification of a computer program that recognizes exactly those sentences that are generated by the grammar. The program must not only determine whether the string of words is a sentence in the language but it must also parse the sentence into its basic syntactic categories. The structure of that analyzer will be described and its behavior will now be discussed.

The analyzer was constructed as linear one-pass parser. This means that the sentence is scanned only once from beginning to end with no stopping and backing up. As was indicated above, this design is more efficient that either non-linear or multi-pass parsers. Because of the nature of the grammar, by examining the first word in the sentence, the parser can determine in which of the three general classes of sentences the string could possibly belong: declarative, interrogative, or stative. If the first word is one of the actors in the lexicon, it is known that if the string is to be grammatical it must be a declarative sentence. If the first word is "will," the sentence must be an interrogative sentence. If the first word is a noun with the syntactic attribute value, the string must be a stative sentence. If the first word in the sentence is not an actor, will, or a value noun, no further processing is attempted since the sentence must, by the definition of sentence given in the grammar, be ungrammatical. The remainder of the discussion of the parser will fall into three parts. Each part will discuss the process of parsing one of the three types of sentences determined from an examination of the first word in the sentence.

If the first word in the string is an actor, the sentence is a declarative sentence. Under the definition of a declarative sentence, the second word must either be another actor, a verb, or a modifier. If it is none of these, processing stops for it must be ungrammatical. Because the grammar does not limit the number of actors that can be assigned to the agent of a sentence, the parser continues scanning the string, accumulating all the actors until it reaches a verb or modifier. If in the scanning for actors, the parser encounters a word that is neither an actor, a verb, nor a modifier, processing ceases. Once the actors have been collected and the verb and its modifiers, if any found, the parser determines whether the verb has the attributes allowing more than one actor, i.e., is it a joint verb. If it is not a joint verb and there are more than one actor, an error is signaled and processing stops. Conversely, if there is only one actor in the sentence, then the parser assumes that the verb form is the alternate version, because both in cases if joint form of the verb is used, then by definition of the language, it must have the VERB2 classification. If on the other hand, the non-joint variant is used, it has the VERB3 characteristics.

Once the verb of the sentence has been found, its syntactic attributes, along with its VERB2 or VERB3 status are stored for use in the analysis of subsequent parts of the string. Regardless of the classification of the verb or its syntactic features, the next group of words must comprise a noun phrase. Noun phrases may either consist of a simple noun or a noun followed by a worth clause. Thus the parser examines the noun. If none is found, the parsing stops. If a noun is found, its attributes are checked against the requirement of the verb. If there is no agreement, processing stops. Depending upon the nature of the noun, the parser checks for the presence of the optional worth clause. If it is present and the noun does not have the correct attributes an error is signaled and processing stops. If it is present and in agreement with the noun in terms of units, the phrase is parsed and its contents stored.

At this point the parser examines the verb. If the verb is a VERB2 verb, there must be no further unscanned words in the string. The parser checks for the obligatory period which ends or semi-colon all declarative. (The distinction between periods and semi-colons will be discussed below.) If it is present, the parser terminates operation and passes control to the semantic interpreter. If the verb is a VERB3 verb, then the parser expects a prepositional phrase of the form PREP ACTOR. The parser compares the next word with the obligatory preposition specified in the syntactic features of the verb. If it is present, it continues scanning searching for a single actor. If it finds an actor, it has completed the processing of the string and after an inspection for the end symbol passes control to the semantic interpreter. If at any time, the type of word expected by the parser is not found, the parser signals an error and halts its processing. Upon reaching the end symbol for a declarative sentence, the parser has accumulated the following syntactic elements: actor(s), modifiers, verb, object (for VERB3's), and target.

This example of the parsing of a declarative sentence illustrates the advantages of the single-pass linear parsing process. At each point during the processing of the string, the parser has expectations for what type of word is to follow. If at any point those expectations are not fulfilled, it signals an error. Thus it need not parse a sentence any further than the first error. For example, it need not backtrack to determine consistency or agreement. When it reaches a point where agreement is involved, it has already been determined what words will fulfill the agreement requirement. This condition of linearity would have been violated had verb-noun agreement been handled in terms of what verb is required with a noun instead of what noun is required with a given verb.

If the first word of the string is "will," the sentence must be an interrogative sentence. The parsing of an interrogative sentence is identical to the parsing of a declarative sentence with the following two modifications: first, modifiers of the verb, i.e., will or will not, are not allowed in the interrogative construction. Second, the sentence must end with a question mark.

If the first word of the sentence is neither an actor nor "will," then it is assumed the sentence is a stative sentence. If that word is not a noun with the attribute, value, the parser signals an error. If the noun can be used in a stative sentence, the next word in the string is read. Depending upon the noun it may be either "rate" (as in interest rate), "demand" (as in oil demand), or "price" (as in mechanization price). If it is none of the above, an error is signaled. The next word must be the verb. In stative sentences the only allowable verb is "is". The verb must be preceded by the numeric value of the noun. If the second word is "rate," the number must either be a decimal (.07) or a percentage (7%). The parser treats these as equivalent forms. If the second word is "price," a dollar value is expected. If the second word is "demand" a simple numeric is expected. If the parser does not receive the form of the numeric expected, an error is signaled. After the numeric has been parsed, the next word must either be "per" followed by the units, simply the units, or the end of the sentence. If the second word of the sentence was "price," the numeric must be followed by "per" with the correct units as specified in the attributes for the noun. If the second word was "demand" the next word must be the unit specified in the noun attributes. If the second word was "rate" the sentence must end. If any of these expectations are not fulfilled, an error is signaled. After the words or group of words have been parsed, the stative sentence must end. All stative sentences end with a period. Upon finishing the scan of a stative sentence, the parser has identified the following syntactic categories: the noun, the noun type (rate, demand, or price), the numeric, and the units. This information along with the basic sentence type is passed to the semantic interpreter.

This concludes the discussion of the grammar and the structure of the parser. The next step in the processing is the generation of the semantic interpretation. The semantic interpreter takes the basic syntactic elements generated by the parser and the sentence type and produces what is known as a semantic kernel. The kernel is a uniform representation of the underlying content of the sentence. It is important to remember that the semantic kernel does not represent the full meaning of the sentence as perceived by the decision module. For example, it does not consider the context within which the sentence was generated. The kernel only serves as a representation of the content of the sentence in a more or less standard form that allows further processing to capture the meaning of the sentence reflecting both the content and the context.

Semantic Analysis

As discussed above, language can be considered to be a medium for the structuring and transmission of meaning. The purposes of the syntactic analysis are to distinguish sentences from non-sentences and to produce a syntactic decomposition of sentences. But parsing a sentence into its elemental syntactic elements does not provide the analysis of the meaning of a sentence. The purpose of the semantic interpreter is to take the outputs from the syntactic analysis and produce a semantic representation of the content of the sentence.

The semantic interpreter takes the basic syntactic elements of the input sentence and produces as output, a semantic kernel. This kernel is a representation of the semantic content of the sentence. Two aspects of these semantic kernels must be emphasized. First, they are not complete representations of the underlying semantic content of the sentence. Second, their structure and the method by which they are generated were both designed specifically for the input language which the kernels must represent and the processing mechanism used to model the Saudi government.

The only input the semantic interpreter receives is the syntactic analysis of the input sentence. As a result of this, the interpreter can only produce a portion of what would normally be considered the semantic content of the sentence. In any form of communication, the context of the communicative act plays a large part in determining the meaning or the characterization of the semantic content of the sentence. The present case is no different. The context does play a role in the final determination of the content and impact of the sentence. But the semantic interpreter is insensitive to that context. Thus the semantic kernel produced by the analysis of the syntactic elements of the sentence cannot represent the totality of the semantic content of the sentence. What the interpreter produces is a representation of the semantic content of the sentence isolated from the context in which it was generated. For example consider the sentence, "US will not sell arms to Israel." Given the context of current US-Saudi relations, that sentence would carry with it the implication that the United States was behaving in a manner that was desired by the Saudis. The semantic interpreter is not designed to produce that implication because that implication depends upon a knowledge of the current Middle East context. What the semantic interpreter produces is a kernel representing the simple statement that the United States will not sell arms to Israel. Thus the interpreter produces a representation of what could be called the "simple content" of the sentence, and not the sentence-in-context. The last mapping in Figure 1, the state interpretation mapping takes the semantic kernel and produces the full semantic interpretation representing the context as well as the content.

The second important aspect of the semantic interpreter is its limited and specialized nature. The semantic interpreter and the concept **of a semantic** kernel were not designed to resolve or even raise fundamental issues in the theory of linguistics or the mechanical understanding of language. Its purpose was simply to provide the basis for language input to the simulation. Although the semantic kernels do have a strong similarity to the conceptual basis for language understanding developed by Schank (Schank, 1972, 1973; Schank and Reiger, 1974) they were formulated independently of Schank's work and the issues in semantic and language understanding he confronted. The issues that were relevant in the conceptualization of the semantic interpreter and the kernels were strictly dictated by the simulation itself. The design objective was to produce a mechanism for representing the semantic content of the input sentences, given the output from the syntactic parser and the requirements and capabilities of the processing mechanism used to model the government of Saudi Arabia.

In order to illuminate the underlying motivation for the semantic interpreter and the kernels it generates, consider the following examples of input sentences: (1) US will sell arms to Israel; (2) US sells arms to Israel; (3) US will not sell arms to Israel; (4) Will Israel buy arms from US; (5) Israel will buy arms from US; (6) Israel buys arms from US; (7) Israel will not buy arms from US; (8) Will US sell arms to Israel? All eight of the sentences have as a common attribute the transfer (buying or selling) of some object. Furthermore, all are concerned with the transfer of arms from the United States to Israel. As a result it would be expected that all eight sentences would result in semantic kernels with the basic core that the meaning of the sentence concerns the transfer of arms from the United States to Israel. But clearly, all 8 sentences should not result in the **same kernels.** The 8 differ in the actor initiating the sentence. The United States is the implied speaker in sentences 1-4, while Israel is the speaker in 5-8. The sentences also differ in references to time. Sentences 1, 3, 4, 5, 7, and 8 are future oriented while 2 and 6 are present oriented. A negative intention characterizes sentences 3 and 7. Sentences 4 and 8 are interrogative, while the remainder are declarative. Whatever else may be true of the semantic interpreter, it must not represent these sentences in an identical manner. In each of the eight, the basic transfer of arms from the United States to Israel is modified or expressed in a different manner.

Notice that with respect to the grammar in Figure 3 , these eight sentences exhaust the ways in which the transfer of arms from the United States to Israel can be expressed. It follows that the interpreter must be prepared to produce eight different kernels for each basic unit of meaning. In this case the basic unit of meaning was the transfer of arms from the United States to Israel. But it would not be expected that each basic meaning would require a separate semantic kernel. For example, the language allows any actor to replace Israel or the United States in the examples. At present there are seventeen actors in the lexicon of the language. Disallowing the possibility that a nation could sell arms to itself, there are 272 variations possible for each of the eight sentences, or 2176 possible sentences in all. Because each of the 2176 sentences has a common core the transfer of arms from one nation to another, it would be expected that the semantic interpreter would generate semantic kernels with a common structure for each of the 2176 sentences.

In addition to arms, there are nine other nouns capable of being bought or sold. This increases the domain of the basic kernel to 21,760. Finally, it is possible to transfer objects without buying or selling, e.g., giving, providing, accepting. This increases the number of sentences involving transfers to 54,400. The obvious question is how is the semantic content of each of these 54,000 sentences to be represented in an efficient manner?

The method used for representing the content of the sentences is designed to take advantage of the common characteristics of the set of sentences -- the transfer of an object from one actor to another. The basic kernel structure, or root, contains a symbol indicating the transfer of an object from one actor to another. The kernel structure for the physical transfer of an object is: TRANSFER(AG1,AG2,OBJ). "TRANSFER" indicates that this kernel concerns the transfer of a physical object. The convention used in the construction and interpretation of TRANSFER kernels is the transfer from AG1 to AG2. Finally, "OBJ" is the variable standing for the object to be transferred. In the case of the eight sentences given above, each would generate the root, TRANSFER(US,IS,ARMS).

The common characteristic of all 54,400 sentences, the transfer of a physical object, is identified by examining the verb of the sentence. This is provided by the syntactic parser. But clearly the verb itself is not sufficient, for it is possible to give political support which does not involve the transfer of a physical object. Thus the semantic interpreter uses the verb as well as the attributes of the object of the noun phrase (Cf. Figure 4). If the verb is buy or sell, it follows from the syntactic attributes of these verbs (Cf. Figure 4), only nouns having -abstract attributes are accepted with these verbs. -Abstract nouns, by definition must be physical objects. If the verb is not buy or sell but give, provide, or accept, the semantic interpreter uses the object of the noun phrase to determine whether the transfer kernel is applicable.

The semantic interpreter again uses the verb in order to determine the proper assignment of AG1 (the sending actor) and AG2 (the receiving actor). If the verb is "give," "sell," or "provide," the first actor in the sentence is the sending actor, e.g., US sells arms to IS. The second actor is assigned to AG2. If on the other hand the verb is "accept" or "buy," the assignments are reversed with the first actor assigned to AG2 and the second to AG1, i.e., IS will buy arms from US.

The final assignment in the root of the kernel is the object to be transferred. The semantic interpreter simply assigns the object of the noun phrase identified by the parser.

Notice that by invoking the verb in the determination of the appropriate kernel and through the use of variable assignments in the kernels, much of the combinatorial explosion reflected in the 54,400 different sentences has been eliminated. The entire set has been partitioned into eight equivalence classes. The eight sentences given above involving the transfer of arms from the United States to Israel illustrate the eight sets.

The final problem to be confronted is generating kernels that identify to which of the eight sets a given sentence belongs. In the example sentence, each would result in an identical kernel root: TRANSFER(US,IS,ARMS). The solution then is to augment the root to reflect the basic differences between the eight sentences. The eight sentences differ in three respects. A sentence may be interrogative or declarative, may be positive or negative, or it may be future or present. (Note: these attributes are not independent. If a sentence is negative, it must also be future, e.g., US will not sell arms to IS.) These three attributes are indicated in the kernel in the following manner: TRANSFER(AG1,AG2,OBJ)/present or future, positive or negative/declarative or interrogative/. The sentence: US will sell arms to IS would generate the following kernel: TRANSFER(US,IS,ARMS)/ 1,+/DEC(US). A 1 indicates future reference, a 0 indicates present. A + indicates a positive sentence, while a - is used for negative sentences. "DEC" indicates the sentence is a declarative sentence, while "INT" is used for interrogative. In addition, the implied speaker of the sentence is indicated in "DEC" and "INT." Using these conventions, the eight example sentences would generate the following semantic kernels: (1) US will sell arms to IS, TRANSFER(US,IS,ARMS)/1,+/DEC(US)/; (2) US sells arms to IS, TRANSFER(US,IS,ARMS)/0,+/DEC(US)/; (3) US will not sell arms to IS, TRANSFER(US,IS,ARMS)/1,-/DEC(US)/; (4) Will IS buy arms from US? TRANSFER(US,IS,ARMS)/1,+/INT(US); (5) IS will buy arms from US, TRANSFER(US,IS,ARMS)/1,+/DEC(IS); (6) IS buys arms from US, TRANSFER(US,IS,ARMS)/0,+/DEC(IS); (7) IS will not buy arms from US, TRANSFER(US,IS,ARMS)1,-/DEC(IS); and (8) Will US sell arms to IS? TRANSFER(US,IS,ARMS)/1,+/INT(IS). Thus each of the 54,400 sentences has been assigned a unique semantic kernel in an efficient manner.

In total, there are eight semantic kernel roots generated by the semantic interpreter. The basic key to the generation of the kernels is the verb in the sentence. Because the modifiers applied to the kernel roots are identical, only the roots will be discussed. The eight kernel types are: TRANSFER, SUPPORT, FORCE-DISPLAY, ATTACK, RECOGNIZE, ALIGN, RATE, and LEVEL.

As discussed above, TRANSFER kernels have the syntax, TRANSFER (AG1,AG2,OBJ). This kernel is used to indicate the transfer of physical objects from one actor to another. TRANSFER kernel is generated if the verb is "buy" or "sell," of the the verb is "give," "provide," or "accept" and the object is -abstract.

A SUPPORT kernel is generated in the content of the sentence is some type of non-physical support. Examples of sentences that result in SUPPORT kernels are, "US gives political-support to SA," and "IRAN will not give economic-aid to Egypt." The verbs in this instance are "give," "provide," and "accept" with +abstract objects. The syntax of the kernel is: SUPPORT(AG1,AG2,TYPE). AG1 and AG2 are assigned in the same manner as they were assigned in TRANSFER kernels. The variable TYPE is the form of support given. The two example sentences would result in the following kernel roots: SUPPORT(US,SA,POLITICAL) and SUPPORT(IRAN,EGYPT,ECONOMIC).

A FORCE-DISPLAY kernel is generated if the verb is "mobilize," as in "IS mobilizes armed-forced against Egypt," or "alert" as in "Egypt alerts armed-forces against IS." The kernel syntax is: FORCE-DISPLAY(AG1,AG2). AG1 indicates the actor undertaking the force display and AG2 indicates the target of the display. The example sentences have the following kernel roots: FORCE-DISPLAY(IS, EGYPT), and FORCE-DISPLAY(EGYPT,IS).

An ATTACK kernel is generated if the verb is "attack," or "disrupt." The kernel syntax is: ATTACK(AG1,AG2). Example sentences and their kernel roots are: "IS attacks EGYPT" (ATTACK(IS,EGYPT)), and "KUWAIT-INSURGENTS disrupt KUWAIT" (ATTACK(KUWAIT-INSURGENTS,KUWAIT)). The assignment of AG1 and AG2 is identical to that in the FORCE-DISPLAY kernels. AG1 is the initiator and AG2 is the target.

If the sentence involves diplomatic recognition, a RECOGNIZE kernel is generated by the semantic interpreter. The only verb in this instance is "recognize," e.g., "EGYPT will not recognize IS." The kernel syntax is identical to ATTACK kernels. For the example sentence, the interpreter would generate the root: RECOGNIZE(EGYPT, IS).

An ALIGN kernel is generated if the verb of the sentence is "sign" or "affirm." By the nature of the language, these two verbs can only be used if the sentence is concerned with treaties or agreements between actors. The root form of the kernel is ALIGN((ACTOR),TYPE). The extra set of parentheses is used because it is possible for the ACTOR variable to include more than two actors. The parentheses serve to delimit the actors from the type of agreement. For example, "US signs friendship-treaty with SA" will result in the following root kernel: ALIGN((US,SA),FRIENDSHIP). If the VERB2 version of "sign" or "affirm" is used, e.g., "SA, Egypt, Syria sign security-treaty" the root would be ALIGN((SA,EGYPT,SYRIA),SECURITY).

The six kernels discussed above are generated in the case of agentive sentences. The last two kernels, RATE and LEVEL are generated by the semantic interpreter in the case of stative sentences. Because of the nature of the syntax in the stative case, no modifiers are generated with the kernel root.

If the sentence is stative and the first noun phrase is either "oil demand" or "interest rate," a RATE kernel is generated. The syntax for a RATE kernel is: RATE(OBJECT,VALUE). Thus the sentence: "Oil demand is 11,000,000 barrels," would generate the kernel RATE(OIL,11000000).

If the first noun phrase deals with the price of oil, mechanization, wheat, or fertilizer, a LEVEL kernel is generated. LEVEL kernels have the following syntax: LEVEL(OBJECT,VALUE). Given the sentence, "Oil price is $11 per barrel," the semantic interpreter would generate the kernel, LEVEL(OIL,11).

It was noted above that the semantic interpreter is sensitive only to the content of the sentence. The context of the sentence plays no role in the generation of the semantic kernel. The semantic kernels represent only the simple or surface semantic content of the sentence. The final stage in the language processor is the generation of what is called the state interpretation. The state interpreter takes the semantic kernel and the context in which the sentence was generated and produces an interpretation of the sentence reflecting both its content and context.

State Interpretation

As discussed above, language can be considered a medium for the transmission of meaning. But the meaning of a sentence cannot be discovered solely by an examination of the sentence itself. While it is true the content of a sentence provides an important basis for interpretation, it is not sufficient. Sentences are uttered within a context. It is this context and the content of a sentence that jointly determine meaning. For example, consider the sentence

"US will sell arms to IS." That sentence could be considered to express United States support for Israel. It would be expected that Saudi Arabia would interpret it as such. But depending upon the circumstances, additional interpretations would be given. If that sentence were generated during some future Arab-Israeli conflict, Saudi Arabia would interpret the action of the United States as ignoring the Saudi threat of an oil embargo. If the United States had previously refused to sell arms to Israel, the Saudis would interpret it as a shift in the position of the United States. If there were no active conflict, the Saudis would be expected to frown upon the action, but not interpret it as a direct challenge to them. If a peace treaty were to be signed between the Arabs and Israel, the sentence would probably be interpreted as a concession to Israel to encourage Israel to sign the treaty. Thus, depending upon the context, the interpretation will differ. The question is: What is the nature of this context and how is it to be represented in the simulation?

Context can be considered to be the current description of the environment in which the sentence was generated. In the preceding example, the context was provided by describing the environment: a future Middle East conflict, a previous refusal to sell arms, a peace treaty pending ratification. In each case, a description of the environment was the context. But clearly, to simply invoke the context does not determine the interpretation of the sentence. The presence or absence of an active Middle East conflict varies the interpretation. But precisely how and why the interpretation varies cannot be determined from a simple description of the environment. Something else is required.

Each of the example uses of context invokes as background knowledge, conceptions of the causal operation of the environment. This notion of the causal operation of the environment does not involve some fundamental conception of causality, but rather a conception of how the environment works. Consider the example in which the United States agrees to sell arms to Israel. The background knowledge invoked is that to refuse and then later agree is to change the position held at the earlier point in time. These causal conceptions could be considered to be simple or direct contextual interpretation rules. There is another more complex conception of the working of the environment in the case of the sale of arms to Israel during an Arab-Israeli conflict. Presumably the Saudis would interpret that action on the part of the United States to be threatening. But clearly to sell arms is not by itself threatening. But to sell arms to an enemy is threatening. Or for example, if a group of Middle Eastern nations, not allies of Saudi Arabia, were to form a military alliance, the Saudis would be expected to interpret that development as a threat to Saudi security. But clearly, security treaties are not by themselves threatening. These non-direct interpretations that depend upon the nature of the parties involved, e.g., friend or enemy, are examples of the more complex types of background conceptions of how the environment works. But each type invokes some conception as to the nature of the operation of the environment. In the case of simple or direct conceptions, the knowledge involves assumptions and beliefs as to the nature of actors, intentions, and action. In the case of non-direct or complex conceptions, the background knowledge involves expectations as to what behaviors are to follow as a result of the action.

Notice that in all the examples given above, the interpretation of the sentence involves a change in the description of the environment. If the United States sells arms to Israel during a Middle East war, then the description of the environment is changed in two ways: the United States is selling arms to Israel, and the United States is ignoring the threat of an oil embargo. Thus the interpretation of a sentence is represented in the simulation as a change in the description of the environment.

The use of the context in determining an interpretation then involves two aspects. The first is a description of the current state of the environment. The second involves conceptions of how the environment works. Thus to speak of an interpretation of the semantic kernel reflecting the context of the original sentence necessitates that a description of both the state of the environment as well as the causal operation of the environment be involved. The method by which each of these is represented in the simulation program will be the next topic.

The decision module of the simulation maintains a data structure containing the current description of the outer environment. This data structure is called the short-term image (STI). It is the transient image of the current environment. Changes in the environment cause changes to be made in the content of the STI. The STI contains symbols, called state knowledge elements. Each symbol represents a description of an aspect of the current outer environment. Examples of state knowledge elements are: significant military threats exist, the US is willing to provide arms, US withdraws political and/or military support, nation X is hostile, a threat of an oil embargo has been given. Note that all state knowledge elements are intended to represent the description of the environment from the perspective of the government of Saudi Arabia. The full list of state knowledge elements, 204 in all, can be found in Table . At any point in time, the STI contains those state knowledge elements that are considered to be true of the environment. As noted above, the state interpretation of a sentence involves a change in the description of the outer environment. Given that the description of the environment is constructed by the simulation in terms of the state knowledge elements in Table 1 , it follows that a state interpretation of a sentence must involve changing the state knowledge elements in the STI. Depending upon the sentence, elements may be added and/or deleted from the STI. For example, in the case of the United States selling arms to Israel during a Middle East war, two elements must be added to the STI -- the United States is selling arms to Israel, and the United States is ignoring the threat of an oil embargo. Furthermore, if there were a state knowledge element indicating that the United States had previously refused to sell arms to Israel, that state knowledge element must be deleted.

The STI itself is structured as a linear list of limited size. Thus the conjunction of all those elements represents the description of the state of the outer environment. When there is a change in the environment, resulting in the satisfaction of a new state knowledge element, that element is entered into the first position in the STI. If the STI were filled to capacity when a new element is to be entered, the last element in the STI is deleted. This mechanism ensures that the STI contains only the most recent information. Old information is deleted or "forgotten." As a result of the fact that once an element has been deleted from the STI it cannot be restored, the decision module is designed to group or chunk state knowledge elements. In this way information required for the operation of the deicsion module is preserved, but old information is lost or deleted. For example, one state knowledge element is: the US formally guarantees Saudi security, no insurgent groups operate within Saudi borders, and all Middle Eastern states sign treaties of friendship with Saudi Arabia. By grouping or chunking information into more meaningful chunks, the system has the capability to maintain a fairly complex and complete description of the environment within the limited space of the STI. Because the structure of the simulation reflects to some extent the bureaucratic divisions within the Saudi government, there are more than one STI. There is a separate STI for military, economic, human resources, fiscal, agriculture, oil, development, and foreign aid. The structure of the STI and the architecture of the decision module is discussed at greater length below.

The process of providing a state interpretation of a sentence involves the modification of the contents of the STI based upon the semantic kernel and the contents of the STI. Thus the interpretation of a sentence is the modification of the STI. Because the STI must contain members of the set of state knowledge elements (Table 1), the process of state interpretation is a function with a domain consisting of semantic kernels and STI contents and a range of STI contents. The precise nature of the function is specified by the conceptions of the causal operation of the outer environment mentioned above. Because the purpose of this section is to discuss the technical aspects of the implementation of the linguistic processor, the conceptions themselves (or interpretative rules) will be discussed below. In what will follow, the nature of the rules will be discussed, and their operation discussed. But for a discussion of the substantive content of the rules and their justification, refer to section two .

The structure of the interpretative rules is of the form: semantic kernel and STI contents → changes in STI contents. For example if the semantic kernel is TRANSFER(AG1,AG2,ARMS)/0,+/DEC() (an arms transfer takes place from AG1 to AG2), and if AG2 is in the Middle East and is not an ally of Saudi Arabia, then state knowledge elements representing (1) AG2 has exhibited a hostile act; and (2) significant military threats to Saudi security exist, are placed in the STI. This is an example of the complex or non-direct interpretative rule discussed above. A simple or direct interpretative rule is: if there is a kernel, TRANSFER(US,SA,ARMS)/1,-/DEC(US), and if the STI contained an element indicating the United States had previously sold arms to Saudi Arabia, the element indicating that the United States had withdrawn support from Saudi Arabia would be placed in the STI. In addition, the STI element indicating the previous sale of arms from the US to Saudi Arabia would be explicitly deleted. This is to ensure the contents of the STI are not contradictory.

In summary, the state interpretation of a sentence involves the modification of the description of the state of the outer environment. This modification of the description is accomplished by invoking state interpretation rules conditional upon the semantic kernel generated from the semantic interpreter and the current state description of the outer environment.

Summary

This section has described the mechanisms used to implement a linguistic processor that accepts sentences and produces interpretations of those sentences from the perspective of the Saudi Arabian government. On input, the sentence is checked for grammaticalness and is parsed into its syntactic elements. These syntactic elements are analyzed by the semantic interpreter. The interpreter produces a semantic kernel which represents the simple or surface content of the sentence. The state interpreter then takes the semantic kernel and produces an interpretation of the kernel that reflects the content of the kernel as well as the context in which it was generated. This interpretation involves the modification of the current description of the state of the outer environment from the perspective of the decision module. As will be discussed in section three, the processing mechanism of the decision module generates behavior conditional upon the description of the outer environment. As a result of the linguistic input and the interpretation of sentences within a context, the simulation operates upon an image of the environment and not the environment itself. And as a result of the condition qualities of the interpretation, the simulation has the capability for reacting differently to different environmental contexts. It is not simply a static processor. Given the same input sentence, the simulation will not necessarily produce the same outputs. The behavior of the simulation reflects past experience.

Section 2: The Interpretation Rules

The purpose of this section is to describe the substantive content of the state interpretation rules. As was discussed above, state interpretation rules determine modifications in the STI of the Saudi decision module. The set of interpretation rules can be conceptualized as a function with a domain of semantic kernels and STI contents. Recall that semantic kernels are representations of the basic or surface semantic content of the input sentences. The STI is a list consisting of state knowledge elements. The entire list of elements was given in Table 1. The range of the interpretation function is the set of possible STI contents. Thus the state interpretations specify how the STI is to be modified given the semantic kernel representation of the input sentence. It is these rules that provide the mechanism by which Saudi decision module updates its image of the current state of its environment.

The discussion of the state interpretation rules will proceed along the following basis. The discussion will be grouped by semantic kernel. Within the discussion of each semantic kernel group, the relevant STI will be discussed. For example, the first kernel to be discussed will be the TRANSFER kernels. Within that discussion, the military STI will be discussed, followed by the economic and development STIs. Then SUPPORT kernels will be discussed. In this way, the discussion will proceed along the basis of the substantive domain of the rules.

There are 46 state interpretation rules dealing with military transfers of arms and supplies. These may be found in Table 2. Because of the large number of state interpretation rules, each rule will not be discussed individually. Instead, in order to keep the discussion in manageable proportions, groups of rules and their motivation will be discussed. But to clarify the syntax and interpretation of the rules, a few of the rules will be described in detail.

ST1 indicates that if there is a semantic kernel indicating an arms transfer from AG1 to AG2, and if AG2 is a Middle Eastern government but is not an ally of Saudi Arabia, then the state knowledge elements, MC5 and MCO(AG1) are to be placed in the STI. According to Table 1, MC5 is a symbol signifying the belief that a significant military threat exists to Saudi security. MCO(AG1) is a predicate state knowledge element. AG1 is the variable name of the government transferring arms to the hostile Middle Eastern government. If, for example, AG1 were France and AG2 were Libya, then the symbol MCO(FRANCE) would be placed in the STI. The justification behind this interpretation rule is: "A friend of enemy is my enemy." This interpretation rule is an example of the non-direct or complex interpretation rule discussed in the technical description of interpretation rules. This type of interpretation rule is termed non-direct because it is not a simple recording of the semantic kernel content into the STI, but rather represents an interence based upon the context of the arms transfer.

An instance of a direct interpretation rule is SI22. This rule states that if the United States offers to transfer arms to Saudi Arabia (FUT indicates future reference) then the symbol MC25 (U.S. is willing to provide arms) is placed in the STI. This is a direct rule since the state interpretation is no more than the encoding of the semantic kernel in the STI.

The four state interpretation rules following SI22 illustrate one of the major uses of state interpretation rules -- maintaining STI consistency. MC140, MC70, MC180, and MC135 all have to do with the refusal of the United States to provide military support to Saudi Arabia. If the United States subsequently offers to provide arms, these symbols must be masked in the STI to prevent the Saudi decision module from operating on obsolete information.

Because the simple or direct type of interpretation rule represents a majority of the state interpretation rules, each rule will not be discussed. In general, they involve either a simple representation of the semantic kernel in the STI, or they function to keep track of interaction sequences. An example of this record-keeping function is illustrated in SI15. The condition portion of the interpretation states that if the United States refuses to sell arms to Saudi Arabia, and if there is a symbol in the STI indicating that the Saudi government has requested the United States resume its discontinued support, a symbol indicating that efforts to persuade the United States to resume its support have failed is placed in the STI. Because these rules are straightforward they will not be discussed in detail.

The primary non-direct state interpretation rules are SI2, 3, 11, and 30. SI2 and SI3 deal with the case of an arms transfer from a Warsaw Pact government to a government that is currently perceived as hostile by the Saudi decision module (MC0). The state interpretation resulting is that the Warsaw Pact states are politically unsuitable as arms sources. SI3 differs from SI2 in that if a Warsaw Pact government had previously offered to sell arms to Saudi Arabia, that request is masked by the Saudi government.

SI11 will result in the state knowledge element, significant threats exist to Saudi security being placed in the STI, if some government provides arms to another actor currently engaged in armed conflict with Saudi Arabia. Again, this is an example of the "friend of my enemy" situation discussed above.

If an ally of Saudi Arabia offers arms to the Saudi government when they are faced with an active hostile attacker, the STI is modified to reflect the belief that existing security ties offset threats to Saudi security. This is represented by SI30.

Those state interpretation rules which result in the modification of the economic STI are all concerned with the support of Israel. The state knowledge elements written in the economic STI serve as the basis for the determination of the varying degrees of economic threats and reprisals directed against supporters of Israel.

The state interpretation rules that write symbols in the development STI are all of the direct form. The rules can be divided into two groups. The first group, IMD43-45 are concerned with offers by Iran to sell consumer goods to Saudi Arabia. These rules are concerned with recording the sequence of interactions between Iran and Saudi Arabia. The second set of rules deal with the provision of arms by Iran to insurgent groups operating within the borders of Kuwait and Iraq. Again, their function is to keep track of the interaction sequences.

The SUPPORT kernels parallel the TRANSFER kernels dealing with arms. In the case of the military section, if the support is military, then the kernel is treated as a transfer of arms. IMD15, 17, 19, and 24 are all concerned with support for the Arab governments from the United States and other Western governments.

The state interpretation rules that modify the economic STI are all concerned with support to Israel. As in the case of military transfers, the decision to impose economic threats and punishments is guided by these interpretation rules.

The support interpretation rules that modify the foreign aid or development STIs are all concerned with Iran's suitability as an acceptable foreign aid recipient or trading partner. The rules are sensitive to Iran's relations with other governments in the Persian Gulf. If the Iranian government supports insurgent groups within these states, the Saudi decision module places elements in the STI indicating the degree of support and the status of threats and reprisals against Iran. All of these state interpretation rules are of the simple or direct type. Their primary purpose is to keep a record of interaction sequences.

FORCE-DISPLAY kernels deal exclusively with one of two environmental situations. The military force display kernels deal with threats to Saudi security (SI39), or with the initiator and parties to an Arab-Israeli conflict (IMD2, IMD4, and IMD11). The single interpretation rule that modifies the fiscal STI concerns whether or not Israel is currently hostile. This information is used in determining the Saudi investment strategy.

State interpretation rules that are invoked by ATTACK kernels involving a modification of the military STI are all concerned either with the presence of an actor engaged in armed conflict with Saudi Arabia or Israel. Because these are all direct or simple interpretation rules they will not be discussed in detail.

Sentences dealing with diplomatic recognition result in RECOGNIZE kernels. The state interpretation rules using these kernels are concerned with other governments' recognition of Saudi Arabia and the recognition by the Israeli government of the PLO as a legitimate political actor. If a government refuses to recognize Saudi Arabia, the Saudi decision module places a state knowledge element in the military STI indicating that the government is hostile and unsuitable as an arms source (SI 49, 50, 51, 52). If the Israeli government recognizes the PLO, a symbol is placed in the fiscal STI indicating a resolution of the Middle East conflict. This state knowledge element is used by the fiscal section to determine Saudi investment policy (SI5 3, 54).

The state interpretation rules using ALIGN kernels reflect one of three types of concerns of the Saudi decision module about political and military alignments in its international environment. If a group of Middle Eastern nations, excluding Saudi Arabia, forms a military or security pact, if the members are not allies of Saudi Arabia, and if the United States is not a party to the agreement, then a state knowledge element indicating threats to Saudi security exist (MC5), in the environment (MC0) and are placed in the military STI. This is expressed in SI55. A second concern of the Saudi government is with the presence or absence of aliances between Saudi Arabia and other friendly governments (SI 55-62). The possible alignment partners specified by the state interpretation rules are (1) the United States, (2) other Western governments, or (3) Middle Eastern governments. The final concern of the Saudi decision module with international alliances and expressions of support involves the government of Israel (SI 63-69). As in the case of military or political support, these state knowledge elements are written into the economic STI. They serve as the basis for decisions involving economic threats and sanctions in light of support for Israel during a Middle East conflict.

The final class of state interpretation rules involve stative case sentences. As discussed previously, stative sentences are concerned with descriptions of certain characteristics of the international environment that cannot be directly expressed as the action of some actor. Stative sentences involve the price and demand for oil, the price of fertilizer and tractors to the Saudi government, the current interest rate on Saudi investments, and the current world price for wheat. All the state interpretation rules invoked by these stative sentences are of the direct type. When a stative kernel (either rate or level) enters the state interpreter, the information contained in the kernel is directly transferred to the appropriate STI. In the case of oil demand and the price for oil, the corresponding state knowledge elements in the oil STI are modified. The current import prices for fertilizer, wheat, and mechanization are written in the agriculture STI. The interest rate, representing the average return on both long and short-term investments to the Saudi government are written into the STI of the fiscal section. As currently implemented, the Saudi decision module does not generate a specific reaction to the content of the stative kernels. It merely accepts changes in the STI.

With the execution of the state interpretation rules, the language processing of the Saudi decision module is completed. The process started with an analysis of the structural characteristics of the input string. A description of the syntactic structure of the input sentence was produced. The semantic interpreter received this structural description and generated a semantic kernel representing the surface content of the sentence. Then the kernel was passed to the state interpreter. The state interpreter modified the contents of the STIs of the Saudi decision module according to a set of interpretation rules which reflect not only the content of the original sentence, but also the context (the current Saudi image of the environment) in which the sentence was generated. This interpretation process resulted in an updated image of the current state of the environment. Once the linguistic processing routines have completed operation, control is passed to the main processing mechanism of the decision module -- a production system representation of Saudi Arabian decision procedures. The next section will consider the content and operation of this processing mechanism in detail.

Section 3: The Processor

The purpose of this section is to describe technical aspects of the processing mechanism used to model the government of Saudi Arabia. Any attempt to model a government using a computer simulation must address two points: (1) what are the structural characteristics of a government; and (2) how is the structure to be implemented as a computer program. The first point deals with the nature of that which is simulated. The second, with its realization as a computer program.

As discussed above, several organizing principles have been used to provide the basis for the answer to the first question: governments are goal seeking systems. But only to state that governments are goal seeking systems allows many different structures to be models of governments. For example, a servo-mechanism can be considered a goal seeking system. But the simple servo-mechanism does not exhibit sufficient complexity in its organization or behavior to allow it to be considered as an appropriate structure for modeling a government. Governments have additional properties which must be represented. The organizing principles further specify characteristics which must be true of the structure if it is to serve as the basis for a model of a government. As was indicated above, some of the organizing principles are that governments are event based; they exhibit redundancy of potential control; they are hierarchically organized. By placing additional constraints on admissible models of governments the class of admissible structures is made smaller.

But even with a characterization of that which is to be simulated, and the organizing principles constraining admissible solutions, there is still the question of implementation. Since the construction of the simulation is an effort at elucidating the internal mechanism by which governments generate behaviors (Cf., Federov, 1972), the manner in which the model is represented as a computer program is consequential. In the area of computer simulations of human problem solving, similar concerns have been expressed. Allen Newell (1973) developed the notion of control structure as a means for addressing this point. The control structure of a model is roughly the system architecture. The control structure specifies how the basic processes of the model are organized into a coherent whole. The control structure is in part determined by the programming language used.

> A language such as FORTRAN (or any other, for that matter) may be seen as a device to evoke a sequence of primitive operations, the exact sequence being conditional upon the data. The primitive operations in FORTRAN are the arithmetic operations, the given functions . . ., the assignment of a value to a variable, the input and output operations, etc. Each of these has a name in the language (+, -, SIN, LOG, etc.). However, just having

> the names is not enough. Specifying the conditional sequence is also required and what does that is called the control structure. In FORTRAN it includes the syntax of algebraic expressions, . . ., the order of statements . . . the syntax of the iteration statement, . . . the format of the conditional and unconditional branch. (Newell, 1973 , 297)

For some purposes, it is acceptable to let the programming language determine in large part the control structure. Often constraints such as minimum execution time, or minimum storage requirements will help determine how the control structure is realized. But if one wishes to make a theoretical statement using the structure of the program itself, those solutions are not acceptable, since such solutions contain implicit but inadmissible theoretical claims. The programming technique (and control structure) that is used for the decision module is called a production system. Since the intent is only to theorize about governments, PL/1 has been used for programming the oil, agriculture, and human resources simulation modules. Newell developed this production system for the simulation of cognitive processes. While the operation of production systems will be discussed in more detail below, several comments are in order. The first is that all operators, other than the basic flow of control in production systems must be explicitly defined. Second, programs structured as production systems do not result in the minimization of program coding time, execution time, or storage requirements. There exist more efficient methods for coding a program to produce similar outputs. But these other ways to program the decision module have the potential for introducing methods and processes that do not reasonably reflect the structure or capability of the processing mechanism of governments. Given the basic flow of control inherent in production systems it was necessary to define only three additional operators, the ** NTC, and NOT operators, discussed below. This method for structuring the decision module has the advantage that the claims about information processing capability of governments are explicit. Any assumptions about the capability of governments to process information had to be explicitly defined. Thus the chance of making unintentional capability claims as a result of the way in which the decision module was programmed have been minimized.

Processing mechanisms written as production systems are formed by a collection of independent rules, called productions. The rules (or productions) are stated in the form of a condition and an action: C → A. The condition refers to the symbol in the short-term image (STI) of the system. The STI represents the system's transient image of the current state of the OE. The actions of the productions consist of transformations on the STI "including the generation, interpretation, and satisfaction of goals, modification of existing elements, and addition of new ones." (Klahr, 1973: 528) A production system obeys simple operating rules:

i. The productions are considered in sequence, starting with the first.
ii. Each condition is compared with the current state of knowledge in the system, as represented by the symbols in STI. If all of the elements in a condition can be matched with elements (in any order) in STI, then the condition is satisfied.
iii. If a condition is not satisfied, the next production rule, the ordered list of production rules, is considered.
iv. If a condition is satisfied, the actions to the right of the arrow are taken. Then the production system is reentered from the top (Step i).
v. When a condition is satisfied, all those STI elements that were matched are moved to the front of STI.
vi. Actions can change the state of goals, replace elements, apply operators, or add elements to STI.
vii. The STI is a stack in which a new element appears at the top pushing all else in the stack down one position. Since STI is limited in size, elements may be lost. (from Klahr, 1973: 528-29)

While a production system may appear to be a simple if not simplistic programming structure, it exhibits several important and powerful characteristics. First, production systems are formally equivalent to state-output or Mealey automata (Cf., Bobrow and Arbib, 1974: 77). A state-output automaton is a structure $\langle Q,X,Y,\delta,\beta \rangle$, where Q is the set of internal states, X is the set of inputs, Y is the set of outputs, δ is a function $\delta: Q \times X \rightarrow Q$, and β is a function $\beta: Q \rightarrow Y$. Thus there is considerable analytic power underlying the simple production system structure. The second advantage that production systems exhibit is their ability to simulate a system in terms of symbol processing mechanisms. By using production systems it is possible to simulate governments as information or symbol processors. The inputs to the system and the outputs generated as well as the internal mechanism can be based upon a non-numerical representation. As a result, many purely mathematical properties such as quadratic utility functions, continuity, or the existence of second derivatives need not be imposed on the mechanism.

An example production system is given in Figure 5 . While it is of little interest in its own right, it does provide a simple and easy to follow example of how production systems operate. This example production system is designed to simulate the hammering of a nail into a piece of wood. The system consists of seven productions. As indicated above, when the production system is entered, control is passed back to the first production.

The three additional operators defined in the present implementation of the production system format are illustrated in productions 1 and 3. In production 1, the condition is "NOT<HAMMER UP>". This condition is satisfied if the symbol "HAMMER UP" is not present in the STI. In the action portion of production 3 the ** and NTC operators are used. The ** (or mask) operator takes the first symbol in the STI, substitutes it for the **, and replaces it as the first symbol in STI. If $$$ were the first symbol in STI, after OLD(**) were executed, the first symbol in STI would be OLD($$$). The primary purpose of this operator is to mask or hide elements in the STI. This prevents the system from recognizing it again unless the condition were explicitly expressed as OLD($$$). The last extension is the notice or NTC operator. It causes the symbol within the angle-brackets to be moved to the front of the STI. Because all production system operations involve the first element in the STI, this operator was included to allow symbols to be moved up to the front of STI.

The behavior of this production system is illustrated in Figure 6. At each step in the process the contents of the STI are listed following the arrow. As can be seen in the figure, the STI is initialized to "HAMMER UP,NIL,NIL". The NIL symbols are simply placeholders. They have no significance for the operation of the system. The question mark in the second line indicates the system has evaluated all of the productions and finding none of them satisfied, calls for an input from the user. The user enters "strike". This causes the fourth production to be satisfied. The action portion of the production causes the symbols STRIKE and HAMMER UP to be masked using the NTC and OLD operators. After striking the nail with the hammer the system asks the user if the nail is flush. But before the system allows the user to answer, it goes through the process of raising the hammer. This is because after the execution of production 4, control is passed to the first production. The condition of the first production is the absence of the symbol "HAMMER UP". Since this symbol has been masked by the previously executed production, the condition is satisfied. Once the symbol "RAISE HAMMER" has been placed in the STI, the productions in the system are satisfied until the hammer is in the up position. At that point, no other productions are satisfied and the system allows user input. If the user reply is "YES" control leaves the system. If the reply is "NO", production 5 is satisfied, causing the process to resume.

While this production system example is extremely simple, it does illustrate how production systems work. But more importantly, it demonstrates how at least some of the organized principles discussed above can be represented in a production system. First, the system is goal seeking. It has the goal of hammering a nail into a piece of wood. Second, it operates on some external environment -- the wood.

Third, the observation and access interface are included in the mechanism. Fourth, it operates on the environment -- hammering the nail, and observes the state of the environment. Fifth, the system is based upon event time (the positions of the hammer and the state of the environment) and not on a continuous clock time. In addition, it illustrates the non-numeric nature of the processing mechanism.

The decision module, or module of the Saudi government, is structured as a large production system. No techniques or operators not discussed in the example were used in the construction of the decision module. One modification was made to the system to allow it to exhibit the properties of hierarchic organization, multiple goal seeking, and redundancy of potential control. Instead of structuring the decision module as a single unified production system, the decision module was structured as a collection of seven interdependent production systems, one for each of the substantive policy areas. These are: military, economic, foreign aid, development, agriculture, oil, human resources, and fiscal affairs. Each area in the Saudi bureaucracy is represented by a production system with a unique STI. When no productions are satisfied in one policy area, control is passed to the next. After all the areas have completed processing, control is passed to the user. Not all of the policy area production systems are entered in a given cycle. For example, the fiscal, oil, agriculture, and human resources sections are executed once a year.

The STIs for each of the seven areas is distinct, but it is possible for one area to write into the STI of another area. However, it is not possible for one area to examine the contents of the STI for another area. This allows each of the STIs to maintain a separate identity, thus allowing bureaucratic flows of information to be represented in the system.

This completes the discussion of the technical aspects of the processing mechanism used to model the government of Saudi Arabia. The following sections will consider the substantive content and behavior of the Saudi Arabian decision module. The remaining sections will consider the substantive content of the processing mechanisms for each of the seven policy domains modeled in the Saudi decision module.

The purpose of this section is to describe the structure, content, and behavior of the processing mechanism used to simulate the government of Saudi Arabia. As was discussed above, the government of Saudi Arabia is viewed as a controller attempting to steer its outer environment to achieve a set of goals. Under this interpretation, the government receives information describing the current state of the environment. The government then emits behaviors designed to cause the current state of the environment to more closely reflect the goals of the government. The processing mechanism used to model this control process is a production system. A production system is a collection of condition - action statements. The conditions refer to the current contents of the short-term image of the current state of the environment. The contents of the STI are called state knowledge elements. The complete set of which can be found in Table 1 . Each element refers to a discrete characteristic of the current environment. The action portion of a production specifies behaviors to be emitted (output sentences), modifications to the STI contents, or both.

The STI may be modified in one of three ways. A new state knowledge element may be introduced into the STI which represents a combination of existing elements. In general, this type of modification of the STI contents reflects a "chunking" or summary of the current contents of the STI. This technique is used to allow the Saudi decision module to maintain a record of interaction sequences, as well as to gather discrete pieces of information together so the simulated government can respond to more than the immediate changes in the environment. This process of regrouping STI elements allows the time basis of governmental behavior to be increased. For example, if this chunking capability were not implemented, the simulated government could generate a response only on the basis of the most recent descriptions of the environment. This consequence is a result of the limited size of the STI. As new elements are introduced into the STI, other elements are deleted. Because there is no facility for reclaiming these deleted elements, the simulated government could not respond to the current description of the environment based upon this lost record of history. The chunking capability allows the simulated government to maintain a record of significant characteristics of the past environment while still operating only on the contents of the STI. These chunks represent the encoding of past experience into the current description of the environment.

It is also possible for additional state knowledge elements to be placed in the STI. A new element will be placed in the STI either if it represents a new occurrence of a characteristic of the environment or if it is not equivantly represented in the STI. For example, if the United States offers to sell arms to Saudi Arabia, a state knowledge element indicating the offer by the United States will be placed in the STI regardless of the status of other offers by the United States. Clearly in the case of arms offers, each interaction must be treated as distinct. On the other hand, there are types of events that need not be kept distinct in the STI. For example, if there is an element in the STI indicating the Saudi government believes a military threat exists to Saudi security, an identical element will not be introduced in the STI even if the conditions which resulted in the entry of the first element are satisfied. This is because generalized security threats are not considered to be cumulative. This does not imply that all actions which might be considered threatening are not kept distinct. Armed attacks on Saudi borders, for example, are considered cumulative.

The third type of modification to the STI is the masking of a state knowledge element. This operation takes place when there is a change in the environment which causes some state knowledge elements to no longer be descriptive of the environment of Saudi Arabia. For example, if a government had previously refused to extend diplomatic recognition to Saudi Arabia, but at a later point in time does recognize the Saudi government, the indication of non-recognition will be masked in the STI. The masking results in the symbol from being recognized as the original symbol. Because elements are moved to the front of the STI if they are part of the condition of a satisfied production, non-referenced elements areeventually deleted from the STI. In this instance, it is important to remember that it is still possible for the STI to contain an element indicating that a government now recognizing Saudi Arabia had previously refused to do so. The effect of the masking operation is to prevent the Saudi simulation from generating behavior predicated upon the current non-recognition of Saudi Arabia by a government, if in fact that government does recognize the Saudis.

These three types of modifications to the STI are not mutually exclusive -- any or all of them may take place. The only restriction is that one of them must take place. If for example, the United States offers to sell arms to Saudi Arabia, a new element (the U.S. has offered arms) will be placed in the STI. If the United States were later to rescind the arms offer, three modifications would be made to the STI: (1) the initial offer would be masked; (2) a new element would be introduced to the effect that the United States has withdrawn support of Saudi Arabia; and (3) a new element would be introduced indicating that the United States had withdrawn the arms offer.

The basic structure of the Saudi Arabian simulation is illustrated in Figure 7. The programmed portion of the system can be divided into four modules: (1) the decision module; (2) the oil module; (3) the agriculture module; and (4) the human resources module.

The decision module is a simulation of the government of Saudi Arabia. The oil, agriculture, and human resources modules are simulations of the physical processes of oil production, crop raising, and manpower, internal to the nation of Saudi Arabia. Each of these three later modules are simulations in their own right programmed in the PL/1 programming language. In this section of the report a brief overview of the simulation will be provided. Succeeding sections will deal with specific aspects in greater detail.

For the purposes of the simulation, these three modules comprise the domestic environment faced by the government of Saudi Arabia. The government of Saudi Arabia is conceptualized as being a goal seeker with respect to these three domestic modules and the user supplied international environment. In its status as a goal seeker, the Saudi decision module has the capability to modify the operations of these other modules. The decision module accomplishes this by passing control information to the modules, e.g., constructing an irrigation system or building elementary schools. Since the decision module is conceptualized as a goal seeking system, the controls passed to the three domestic modules reflect that goal seeking orientation. The decision module (government) selects variables to manipulate in order to "steer" the three modules closer to the goals held by the decision module. At appropriate points in time, the decision module "observes" the current state of these three modules and adjusts its control inputs on the basis of the goals for the three modules and their past performance. The decision module uses its image of the current state of the environment in selecting the controls it applies to the environment. The net effect of this linkage between the four modules is a simulation (programmed in SPITBOL) controlling three other simulations. (As a result of this linkage, the user does not have the capability to directly manipulate the control information passed by the decision module to the three domestic modules. Any influence the user has on the domestic modules is an indirect effect of the impact of user inputs on the decision module.)

The goal seeking orientation of the decision module is reflected in the relationship between the decision module and the international environment. The decision module has goals for the international portion of its environment.

Thus, from the perspective of the decision module, the other national and non-national actors have the same status as the oil, agriculture, and human resources modules in the sense that they are domains to be controlled. Just as the decision module receives information descriptive of the current state of the agriculture module, it also receives information descriptive of the international environment. This descriptive information is incorporated in the image the decision module has of the environment. The user of the simulation is responsible for providing information descriptive of the international environment to the simulation. As a result, the user is not a mere passive manipulator of parameters and variables -- he cannot merely stand outside the system and introduce disturbances; the user is also responsible for closing one of the major information loops in the simulation. The decision module produces responses to the current state of the international environment. The user of the simulation must generate the responses to those Saudi actions. (This is not to say that the user cannot provide external disturbances. Rather, the user cannot just provide such peturbations)

The simulated government of Saudi Arabia is divided into seven semi-independent production systems. Six of the sections are concerned with one specific aspect of the environment: military, economic, foreign aid, development, oil, agriculture, and human resources. The seventh section is the fiscal section. It is concerned with the fiscal affairs of the Saudi government, including review and approval of specific arms purchases as well as the fiscal year budget. Each of the sections has its own STI. It is possible for one section to write in the STI of the other section. But it is not possible for one section to read the STI to another section. Whatever information is passed between the structures comprising the Saudi decision module must be explicitly passed.

In what follows, each of the seven divisions of the Saudi decision module will be discussed in terms of its content and behavior. The productions which serve as the basis for the processing mechanisms representing these sections can be found in Table 3 . The left hand side of the production refers to the state knowledge elements in the appropriate STI. The actions that are executed following the satisfaction of the condition are on the right hand side of the production. The symbols in the productions are state knowledge elements. The statements characterizing the environment which interpret these symbols can be found in Table 1 .

The first set of sections of the Saudi decision module to be discussed are those sections that interact directly with the international environment of Saudi Arabia. These are the sections with which the user of the simulation, in his role as the international environment, comes into direct contact. These sections are: military, economic, foreign aid, and development. These sections differ from the remaining sections in that the user can interact with these sections on continuous basis. The other sections because of their differing time structure, operate only once a year or month. The user is responsible for incrementing time in the simulation. A month may contain an arbitrary number of user inputs.

The primary concern of the military section is the procurement of arms from other governments. This is reflected in the productions themselves (Table 3) as well as the state knowledge elements used by the productions (Table 1). The productions are structured in such a manner as to recognize three types of arms sources: the United States, Western Europe, and the Warsaw Pact states. The simulation prefers to receive arms from the United States and Western Europe, although the United States is the favored arms supplier. The Warsaw Pact governments are considered suppliers of the last resort. If the United States refuses to sell arms to Saudi Arabia, the simulation will ask the United States to reconsider its refusal. If the United States again refuses, it will solicit arms from Western Europe. If Western Europe refuses, the simulation will request arms from Warsaw Pact states only if there is a significant military threat to Saudi security. If at any point in time subsequent to a solicitation of the Warsaw Pact, either the United States or a Western European power agrees to resume arms sales, all contracts with the Warsaw Pact will be cancelled.

The threats to Saudi security that will result in the simulation turning to the Warsaw Pact for arms can be divided into two groups. One group comprises non-specific threats to Saudi security. Examples of this are alliances among Middle Eastern Arab governments which are not allies of Saudi Arabia, or of a direct attack upon Saudi borders. The second group to threats explicitly involve the government of Israel. If during a Middle East conflict, the United States significantly increases Israeli strength, e.g., provides TNC (tactical nuclear weapons), the Saudis will attempt to involve the Soviet Union both in terms of military and political support of the Arab cause. The simulation will also attempt to gain Soviet support if the United States refuses to moderate its provision of military and support to Israel.

When the military section of the Saudi decision module has received an acceptable offer of an arms sale based upon political considerations, it informs the fiscal section of the decision module of the offer and the dollar amount of the proposed transfer. The fiscal section responds with a one month delay. The fiscal section may (1) approve the purchase; (2) deny the purchase for fiscal reasons; or (3) refuse the purchase but suggest that the offering government reschedule the offer to a later point in time. The military section then emits an appropriate output sentence.

At the end of the fiscal year, the military section submits a summary of the contracts signed during the current fiscal year. Depending upon the state of the Saudi revenues, the fiscal section may request the arms budget to be reduced. Depending upon the severity of the revenue shortage, the Saudi government may either cancel the arms contracts, or delay payment for a year. The fiscal section only suggests total dollar amounts to be cut from the arms purchase budget. The military section is responsible for determining where the cuts are to be made. The military section will first attempt to meet the fiscal section's demands by decreasing the arms purchase scheduled from the Warsaw Pact governments. If the suggested cutback cannot be made up from Warsaw Pact contracts, the remainder is equally divided between contracts with Western Europe and the United States. If these cuts are insufficient, purchases from Western European governments are set to zero. If there is still funds remaining to be cut, contracts with the United States are decreased. This process of budget cutbacks by the military section will take place only if the current international environment poses no direct threat to Saudi security. If clear and present dangers are perceived in the environment, the military section will overrule the fiscal section, and refuse to decrease scheduled arms purchases.

The economic section of the Saudi decision module deals only with threats of economic sanctions in light of support for Israel during an Arab-Israeli conflict The section is based upon a series of escalating sanctions. The lowest sanction is a restriction on foreign aid, if such aid is given by the Saudis. The next level is a restriction of credit terms for oil purchases. The third level is a decrease in the supply of oil. The fourth and final level is an oil embargo. The economic section will generate these output sentences if military, political, or economic support is given to Israel. The interaction sequence is (1) a threat is made; (2) additional aid is given to Isarel; (3) the threat is carried out; (4) additional aid is given to Israel; (5) a threat is made. Each additional provision of aid causes the severity of the sanction or threat to be increased. If at any point during the sequence ,a government does not provide additional aid to Israel, the sequence stops at that point. The Saudi decision module will not increase the severity of the sanction unless the other government refuses to head Saudi warnings or reprisals. If the conflict in the Middle East is ended, the Saudi decision module lifts all sanctions. But it maintains a record of the highest sanction invoked against a specific government. If there is a renewed outbreak of conflict in the Middle East, the sequence of threats and sanctions starts from the point that it was broken off. Thus there is a cumulative quality to the behavior of the economic section.

If the economic section imposes oil related sanctions, it informs the fiscal section to expect a temporary decrease in oil related revenues. This is to prevent the fiscal section from overreacting to what may be a short-term revenue decrease.

The foreign aid section of the Saudi decision module has a less developed structure than the military or economic sections. The only case implemented involves Saudi-Iranian relations. In particular, Saudi Arabia will extend economic aid to Iran only if there are sufficient revenues, and if Iran is on friendly terms with Saudi Arabia. If Iran requests economic aid from the Saudis, the simulation will request some display of friendship from Iran before aid will be granted. If such a display is forthcoming, the Saudi decision module will then consider fiscal constraints on aid. If there is sufficient revenues, the aid will be given. However, if short-term investments are not large enough to support aid to Iran, the simulation will deny the Iranian request with the explanation that current reserves do not permit aid to Iran. If Iran does not offer some display of friendship, the aid request will be immediately denied. If a pattern of good relations is established with Iran, the foreign aid section will notify the development section that Iran is an acceptable trading partner. The development section will attempt to establish trade relations with Iran for consumer and capital goods.

Given the restricted scope of the foreign aid section, the fiscal component of the section must also be restricted. The foreign aid section has a default budget of $10,000,000. At the beginning of every fiscal year, the budget is set to this amount Any aid given to Iran is then added to this base figure. If the fiscal section requests a budget decrease, the fiscal section will reduce the base budget. The foreign aid section will accept fiscal section budget decreases up to the point where the budget is equal to $1,000,000. At that point, the foreign aid section will inform the fiscal section that no more budget decreases can be made in the foreign aid budget.

The development section of the Saudi decision module is concerned primarily with trade between Saudi Arabia and Iran. If there is a pattern of friendly relations between Iran and Saudi Arabia, the development section will attempt to establish economic relations with Iran. The Saudi decision module will attempt to import capital and consumer goods from Iran. This search for development assistance will be conditional upon the status of the Saudi revenues. If sufficient revenues are not present, Saudi Arabia will not attempt to import from Iran. If at any time Iran supports insurgent groups operating within Kuwait or the United Arab Emirates, Saudi Arabia will request that Iran discontinue support. If Iran refuses to discontinue its support, the Saudi decision module will cancel all economic agreements with Iran. Saudi Arabia will then turn exclusively to Western sources for development assistance.

The fiscal affairs of the development section are very similar to those of the foreign aid section of the decision module. The yearly development budget is initialized to $7,000,000,000. Any imports of consumer or capital goods are added to the base budget. If the fiscal section requests a decrease in the development budget, the section will decrease the budget until it reaches $100,000,000. At that point, the development section will inform the fiscal section that no more budget decreases can be tolerated.

Section 4:
The Decision Module and its Domestic Environment

This section will consider the decision module and its relationship to the three domestic simulation modules discussed above. Each of the three simulated environments will be discussed as well as the processing mechanism by which the decision module generates controls for these modules, consult PTP working papers 13, 14, 15, 16, 19, 23, 31, 32, 38.

The decision module passes two controls to the oil module: production as a percent (PAPC) of capacity and desired production increase rate (DPIR). PAPC is the daily production of oil expressed as a percent of the total production capacity of the Saudi oil industry. DPIR is the desired percentage increase in the current production capacity. PAPC is used to control the amount of oil actually pumped, while DPIR is used to control the maximum production capacity. The essential core of the oil module consists of multiplying PAPC by the daily production capacity. This results in the daily production of oil. This figure is aggregated into a monthly total production. Auxilliary equations translate DPIR into capital expenditure and after a time delay, increased production capacity. In essence, the revenue generation portion of the oil module consists of multiplying the monthly production in barrels per day by the oil price. The oil module transmits the following performance measures to the decision module: amount invested in increased production capacity, current production capacity, total monthly revenue, and oil reserves. For a full statement of the oil module see PTP Research Report Nos. 15, 23, and 38.

The oil component of the decision module takes these four observations describing the current state of the oil production sector plus the current daily demand for Saudi oil and generates a desired production increase rate (DPIR) and the production figures for the next month (PAPC). The first pieces of information that are considered are the current demand for Saudi oil, the production capacity, and the PAPC. It adjusts PAPC so that it equals the demand for oil. If the demand exceeds the currend production capacity, the decision module sets PAPC equal to one, and increases the desired production capacity increase upward. If on the other hand, the demand is less than the current capacity, the decision module evaluates the current amount of excess capacity. If the excess capacity is too high, the decision module reduces DPIR. Finally, the oil component of the decision module examines the level of proven reserves. If there are insufficient reserves to maintain the current daily production for fifteen years. the decision module determines the production rate that would allow it to maintain the daily production for fifteen years. This last decision overrules all other production decisions. Thus, if reserves are running low, the decision module will ignore the current demand for oil in an attempt to maximize the lifespan of its production capability. In addition, the oil component sends the fiscal component the current month's revenues, the oil related investment for the month, as well as the projection of the revenues for the remains of the fiscal year.

The agriculture component of the decision module passes the following controls to the agriculture module: governmental expenditures for fertilizer, governmental expenditures for farm machinery, governmental investment in irrigation projects, the current price for fertilizer, and the current price for machinery. The agriculture module determines the amount of land available for wheat production, classified into modern and traditional cultivation methods. The levels of fertilizer and mechanization per hectare are then calculated. The amounts of fertilizer and mechanization are then used to determine the yield for modern cultivated land. Land under traditional cultivation methods is assumed to have a constant yield. Finally, the combined yield for the country as a whole is calculated. The agriculture module transmits to the decision module the following information: the total wheat yield given the level of fertilizer application, and the maximum possible yield given the level of machinery usage. Again, for a full discussion of the module, see PTP Research Report 32.

As discussed above, the decision module has three controls that it passes to the agriculture module: irrigation investment, fertilizer purchases, and mechanization purchases. The agriculture component of the decision module makes essentially two decisions. One is the level of irrigation development. The second is the mix of fertilizer and mechanization application. It is assumed that the Saudis will not undertake large investments in irrigation development unless the cost of importing wheat becomes exceedingly large (Cf. CACI report of August, 1975). The agriculture module receives the country demand for wheat from the human resources component of the decision module. If the amount of wheat imported needed to satisfy domestic demand is 15 percent of the Saudi revenues, the irrigation development expenditures are increased drastically. If, on the other hand, the import costs are under 15 percent, the decision module continues its modest $5,000,000 per year investment. The next aspect of the agriculture module the decision module considers is the mix of fertilizer and machinery. The decision module makes a comparison of the two limits on wheat yield. The factor with the lowest limit is increased. In other words, if the limit on yield for fertilizer were lower than the limit for mechanization, the decision module maintains the mechanization expenditure and increases the fertilizer expenditure to the point where it believes the yield limit is at its maximum. If the two constraints are equal, both are increased. The agriculture component then sends back to the sector module the investments in mechanization, fertilizer, and irrigation. In addition, it totals these expenditures and submits them to the fiscal component of the decision module for inclusion in the budget for the next fiscal year.

Since the controls passed to the human resources module reflect the actual structural representation of the human resources simulation more than is the case with either the agriculture or oil modules, the presentation of the module will be somewhat different than the pattern followed in the other two cases. The structure of the human resources simulation will be discussed first. Then attention will be paid to the controls the decision module passes to the simulation. Finally, the operation of the human resources component of the decision module will be discussed.

The human resources simulation has been structured as a flow system. This representation consists of a vector, each element of which represents the number of persons in a particular population category, and a transition matrix. The elements of the transition matrix are transition probabilities. To compute the next year's population characteristics, the vector is multiplied by the matrix. The resulting vector contains the population characteristics for the next year. There are fifteen elements in the data vector. The population categories represented in the vector cover the educational system, and the labor force. Generally speaking the transition constants control the path of people through the Saudi educational system and into the labor force. Further details of the human resources simulation can be found in PTP Research Report No. 31.

The controls the human resources component of the decision module passes to the human resources simulation consist of modifications of the transition constants in the flow matrix. Because of the complexity associated with the modification of the transition matrix, the actual controls will only be broadly characterized here. Details can be found in PTP Research Report No. 31. Essentially, the decision module is concerned with five areas within the human resources module: (1) the number of individuals in the educational system; (2) the size of the petroleum work force; (3) the size of the military; (4) the number of trained civil servants; and (5) the size of the agricultural work force. The controls influencing the number of individuals in the educational system influence the rate at which individuals enter the system. Concern with the number of teachers is reflected by changes in the transition constants leading into teacher training institutions, and their successful movement into the teaching occupation. Controls on the size military, petroleum and civil service workforce change the rate at which individuals enter these areas from the educational system as well as transfers from other occupational categories. Given the skill requirements, part of the change is represented by changing the rate at which individuals already outside of the educational system enter adult education classes. The agriculture workforce is manipulated by influencing the rate at which those employed in traditional farming methods transfer into the modernized agricultural workforce, as well as flows from the educational system.

The human resources module receives these controls as changes in the transition matrix. Thus, the human resources component of the decision module must translate its desired changes in the occupational structure of the Saudi population into changes in the transition constants. These desired changes must in turn be translated into expenditures, reflecting such factors as wage inducements and physical construction.

The controls the decision module elects to apply to the human resources module are a function of the international environment as well as the domestic environment. If there is a hostile international environment, the decision module applies controls designed to increase the size of the trained military force. The levels of the agriculture, education, and petroleum categories are monitored. If these do not maintain a certain rate of increase, controls are applied to increase the rate at which individuals flow into these categories. If the human resources component cannot achieve satisfactory levels of performance after three years, it assumes the civil service workforce is inadequate and attempts to increase the recruitment rate.

The decision module translates these changes in the rate of flow into dollar expenditures. In addition, the module calculates the expenditure necessary to maintain the current numbers of individuals in the military and educational systems. These sums are totaled and sent to the fiscal component of the decision module for inclusion in the next budget.

This completes the discussion of the three domestic simulation modules and their relationship to the decision module. The fiscal component of the decision module will be discussed. It is at this point that the primary interactions between the various components are manifest

Section 5:
The Fiscal Component and the Other Components

At the end of each Saudi fiscal year, control is passed to the fiscal component for a determination of the budget for the next year. Only a portion of the fiscal component operates throughout the year. Its function is to provide revenue forecasts based upon data provided by the oil component, and to make decisions on arms purchases. The revenue forecast is determined by extrapolating the most recent monthly revenue figure through the rest of the fiscal year. This extrapolated figure is then added to the actual revenues from the start of the fiscal year. Thus, the fiscal component does a monthly update of the revenue forecast. The decisions on arms sales are based upon fiscal performance over the last year, in addition to the revenue projections. If based upon the experience of the last fiscal year, there is a high probability of a deficit, the decision module will, depending upon the size of the projected shortfall, either advise refusing the arms offer or decreasing the dollar amount of the purchase.

When the fiscal component enters the budget cycle all of the revenue producing components of the decision module have submitted their proposed expenditures for the next fiscal year. Based upon the state of the international environment, the fiscal component generates one of three budget priority rankings. If the Arab-Israeli conflict has not been permanently resolved, the military and foreign aid budgets are given top priority. The effect of this is that these components will not be asked to decrease their expenditures if there is a need to trim the budget The middle ranked budget items are human resources. agriculture, and development and miscellaneous. The final budget grouping is short-term and long-term investment. If the international environment is uncertain, the decision module will tend to invest its excess revenues in short-term as opposed to long-term sources. If on the other hand, the Arab-Israeli conflict has been resolved with some finality, the fiscal component will be sensitive to the current state of the international economic environment. Under either a stable or unstable economic environment. the first two budget categories are constant. In general, those areas of the Saudi budget concerned with internal development are given top priority. Military expenditures comprise the second priority. During times of economic uncertainty, the decision module will tend to use up excess revenues through short-term investments. During times of economic stability, long-term investments receive a larger proportion of excess revenues.

If after totalling the requests, the fiscal component discovers a deficit situation, it will divide the projected deficit by the number of second priority budget items, and ask each of the affected components to cut their spending by that amount. Each of the revenue consuming components has a minimum budget that it must have in order to maintain its sector. Some of these minimum values reflect the state of the environment, while other reflect committed resources. For example, the military section will reject all budget cuts if the international environment is hostile. On the other hand, the minimum budget for the human resources component is a function of the number of persons in various sectors of the population. Each of the components has a veto power over requests for budget cutbacks. Thus, if the agriculture component is asked to cut its expenditures below its minimal value, the component will set its budget to its minimum value and inform the fiscal component that it cannot decrease its budget any further. After receiving the responses of the various components, the fiscal section has several options. If the new budgets for the components result in a revenue surplus, the extra revenue is allocated to foreign investment. If the new budgets still result in a revenue deficit the fiscal component will, if possible, ask the sectors to cut their expenditures again. If such decreases are no longer possible, the fiscal sector will accept the deficit and redeem some of its investments to cover the projected deficit. Once the fiscal component has achieved an acceptable budget, it informs the various other components that their last budgets were acceptable. The components then allocate their expenditures and the fiscal cycle is complete.

Figure 2

LANGUAGE VOCABULARY

VALID LEXICAL ENTRIES (NOUNS)

ARMED-FORCES

ARMS

ARMS-RESUPPLY

ASSETS

CAPITAL-GOODS

COMTUP

CONSUMER-GOODS

DEMAND

ECONOMIC-AID

FERTILIZER

FRIENDSHIP-TREATY

INFLATION

INTEREST

MECHANIZATION

MILITARY-AGREEMENT

MILITARY-AID

OIL

POLITICAL-AGREEMENT

POLITICAL-SUPPORT

PRICE

RATE

Figure 2 (cont.)

SECURITY-TREATY

TNC

WHEAT

VALID LEXICAL ENTIRES (VERBS AND PREPOSITIONS)

AFFIRM

AGAINST

ALERT

ATTACK

BUY

DISRUPT

FROM

GIVE

IMPOUND

MOBILIZE

PURCHASE

PROVIDE

RAID

RECOGNIZE

SEIZE

SELL

SIGN

TO

WITH

AGAINST

Figure 2 (cont.)

VALID LEXICAL ENTRIES (ACTORS)

SA	(Saudi Arabia)
US	(United States)
IS	(Israel)
USSR	(Russia)
BRITAIN	
EGYPT	
FRANCE	
SWEDEN	
GERMANY	
SYRIA	
IRAN	
KUWAIT	
UAE	(United Emirates)
PLO	
IRAQ	
UAE-INSURGENTS	
KUWAIT-INSURGENTS	

Figure 3

INPUT LANGUAGE GRAMMAR

SENTENCE ::= DECLAR|INTER|STAT

DECLAR ::= AGENT VERB2-PH NOUN-PH|AGENT VERB3-PH NOUN-PH PREP-PH

INTER ::= MOD1 AGENT VERB2 NOUN-PH|MOD1 AGENT VERB3 NOUN-PH PREP-PH

STAT ::= NOUN-PH SVERB VALU UNIT

VERB2-PH ::= MOD VERB2|VERB2

VERB3-PH ::= MOD VERB3|VERB3

MOD ::= MOD1|MOD1 MOD2

MOD1 ::= will

MOD2 ::= not

NOUN-PH ::= NOUN|ACTOR|NOUN WORTH-PH

WORTH-PH ::= worth $ NUMBER

NUMBER ::= program language conventions

AGENT ::= ACTOR|AGENT ACTOR

SVERB ::= is

PREP-PH ::= PREP AGENT

PREP ::= to|from|with|against

VALU ::= NUMBER|$ NUMBER

UNIT ::= per UN

UN ::= ton|hp|barrel

VNOUN-PH ::= VNOUN VTYPE

VTYPE ::= price|demand|rate

Figure 3 (cont.)

The VERB2 and VERB3 members can be found in Figure IV with the indication V2 and V3 following them. The ACTOR set can also be found in the figure.

Figure 4

SYNTACTIC FEATURES

VALID LEXICAL ENTRIES (NOUNS)

ARMED-FORCES/NOUN/-COUNT +ANIMATE/

ARMS/NOUN,WORTH/-ABSTRACT -COUNT/

ARMS-RESUPPLY/NOUN,WORTH/-ABSTRACT -COUNT/

ASSETS/NOUN,WORTH/-ABSTRACT -COUNT/

CAPITAL-GOODS/NOUN,WORTH/-ABSTRACT -COUNT/

COMTUP/NOUN,WORTH/-ABSTRACT -COUNT/ (conventional military technology upgrade)

CONSUMER-GOODS/NOUN,WORTH/-ABSTRACT - COUNT/

DEMAND/NUMBER,TIME(DAY,MONTH,YEAR)/NOUNTYPE/

ECONOMIC-AID/NOUN/+ABSTRACT -COUNT/

FERTILIZER/NOUN,VALUE,UNIT(TONS)/-ABSTRACT -COUNT/

FRIENDSHIP-TREATY/NOUN/+ABSTRACT +COUNT/

INFLATION/NOUN,VALUE,UNIT(YEAR)/+ABSTRACT -COUNT/

INTEREST/NOUN,VALUE,UNIT(MONTH,YEAR.QUARTER)/+ABSTRACT -COUNT/

MECHANIZATION/NOUN,VALUE,UNIT(HP)/-ABSTRACT -COUNT/

MILITARY-AGREEMENT/NOUN/+ABSTRACT +COUNT/

MILITARY-AID/NOUN/+ABSTRACT -COUNT/

MILITARY-SUPPORT/NOUN/+ABSTRACT -COUNT/

OIL/NOUN,VALUE,UNIT(BARRELS)/-ABSTRACT -COUNT/

POLITICAL-AGREEMENT/NOUN/+ABSTRACT +COUNT/

POLITICAL-SUPPORT/NOUN/+ABSTRACT -COUNT/

Figure 4 (cont.)

PRICE/PRICE/NOUNTYPE/

RATE/PERCENT/NOUNTYPE/

SECURITY-TREATY/NOUN/+ABSTRACT +COUNT/

TNC/NOUN,WORTH/-ABSTRACT -COUNT/ (tactical nuclear weapons)

WHEAT/NOUN,VALUE,UNIT(TONS)/-ABSTRACT -COUNT/

VALID LEXICAL ENTRIES (VERBS AND PREPOSITIONS)

AFFIRM/V2/JOINT N(+ABSTRACT +COUNT)/

AFFIRM*/V3/N(+ABSTRACT +COUNT) P(WITH)/

AGAINST/PREP/NONE/

ALERT/V3/N(+ANIMATE) P(AGAINST)/

ATTACK/V2/N(ACTOR)/

BUY/V3/N(-ABSTRACT) P(FROM)/

DISRUPT/V2/N(ACTOR)/

FROM/PREP/NONE/

GIVE/V3/N(+ABSTRACT -COUNT | -ABSTRACT) P(TO)/

IMPOUND/V3/N(-ABSTRACT -COUNT) P(OF)/

MOBILIZE/V3/N(+ANIMATE) P(AGAINST)/

PURCHASE/V3/N(-ABSTRACT) P(FROM)/

PROVIDE/V3/N(-ABSTRACT | +ABSTRACT) P(TO)/

RAID/V2/N(ACTOR)/

RECOGNIZE/V2/N(ACTOR)/

SEIZE/V3/N(-ABSTRACT -COUNT) P(OF)/

SELL/V3/N(-ABSTRACT -COUNT) P(TO)/

Figure 4 (cont.)

SIGN/V2/JOINT N(+ABSTRACT +COUNT)/

SIGN*/V3/N(+ABSTRACT +COUNT) P(WITH)/

TO/PREP/NONE/

WITH/PREP/NONE/

AGAINST/PREP/NONE

Figure 5

```
PD1     C('NOT<HAMMER UP>') A ('RAISE HAMMER')

PD2     C('RAISE HAMMER')  A('OLD(**)', 'HAMMER UP')

PD3     C('HIT', 'HAMMER UP')  A('OLD(**)', 'STRIKE')

PD4     C('STRIKE')  A('OLD(**)',  'NTC<HAMMER UP>', 'OLD(**)')
        PRINTOUT = '***** BANG *****'
        PRINTOUT = '*****IS NAIL FLUSH?*****'

PD5     C('NO')  A('OLD(**)', 'HIT')

PD6     C('YES')  A(END)

PD7     PRINTOUT = '?'
        SYMB = READIN
        PUT(SYMB)

    END
```

Figure 6

```
===>      HAMMER UP, NIL, NIL
?
STRIKE
===>      STRIKE, NIL, NIL
***** BANG *****
***** IS NAIL FLUSH? *****
===>      OLD (HAMMER UP), OLD (STRIKE), NIL
===>      RAISE HAMMER, OLD (HAMMER UP)
===>      HAMMER UP, OLD (RAISE HAMMER), OLD (STRIKE)
?
NO
===>      NO, HAMMER UP, OLD (RAISE HAMMER)
===>      HIT, OLD (NO), HAMMER UP
===>      STRIKE, OLD (HIT), OLD (NO)
***** BANG *****
***** IS NAIL FLUSH? *****
===>      OLD (HAMMER UP), OLD (STRIKE), OLD (HIT)
===>      RAISE HAMMER, OLD (HAMMER UP), OLD (STRIKE)
===>      HAMMER UP, OLD (RAISE HAMMER), OLD (HAMMER UP)
?
YES
===>      YES, HAMMER UP, OLD (RAISE HAMMER)
NORMAL TERMINATION
```

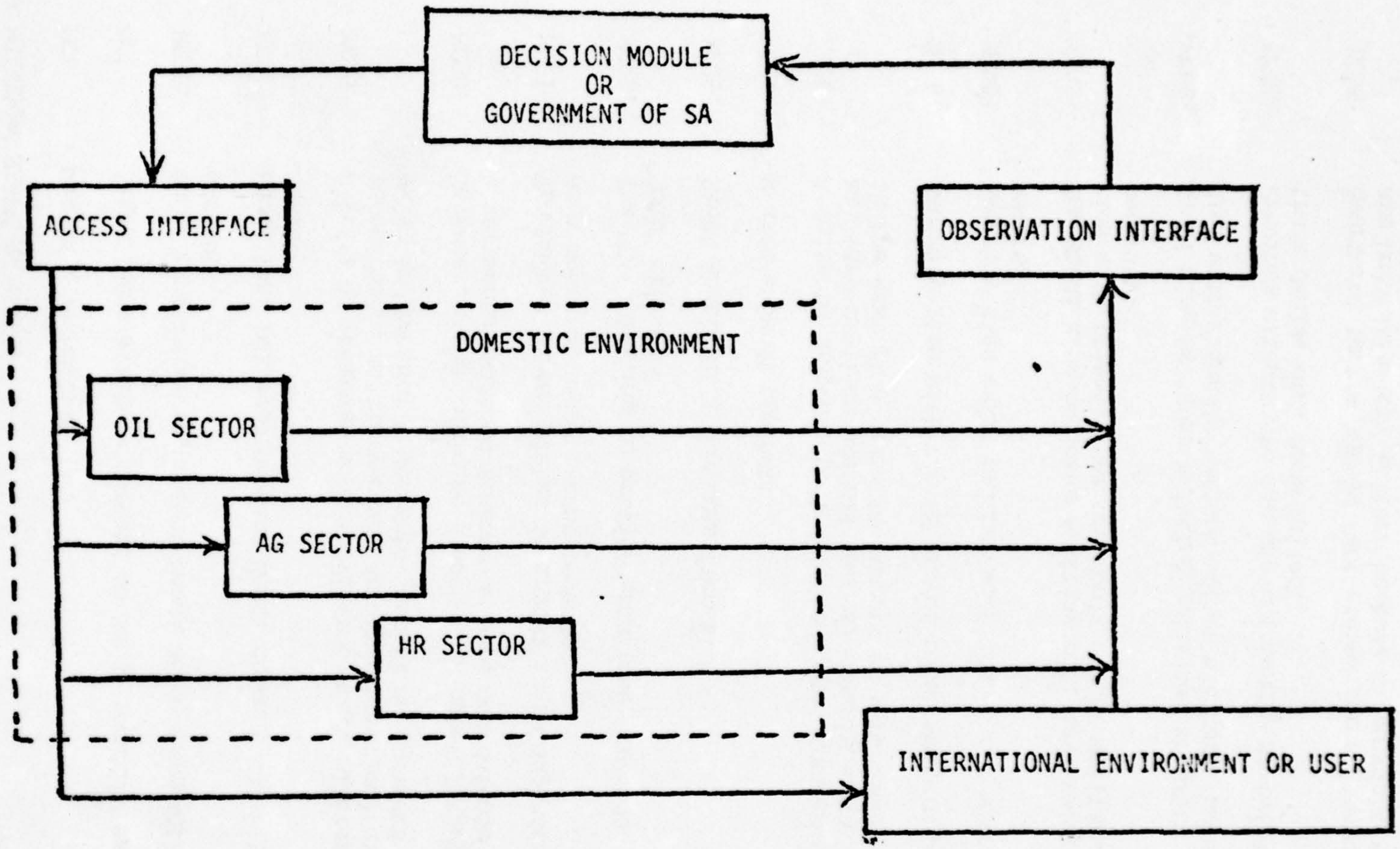

DECISION MODULE
OR
GOVERNMENT OF SA
ACCESS INTERFACE
OBSERVATION INTERFACE
DOMESTIC ENVIRONMENT
OIL SECTOR
AG SECTOR
HR SECTOR
INTERNATIONAL ENVIRONMENT OR USER

Figure 7

Table 1

MILITARY STATE KNOWLEDGE

MC0: Nation x is hostile.

MC5: Significant military threats to Saudi security exist.

MC10: Saudi king believes present Saudi defense capability is not adequate.

MC11: Saudi king believes present Saudi defense capability is adequate.

MC15: A suitable manpower pool (officer corps., military-civilian technicians, military-civilian administration) exists or will exist in the next 5 years to support an expanded defense program.

MC20: Revenues, which could be absorbed in non-military programs or investments exist to finance an expanded defense program.

MC21: The budget bureau wishes to invest in an expanded defense program as a means of using excess revenues.

MC25: The US is willing to provide arms (user provides $ amount)(update "old" c25).

MC26: Saudi Arabia will buy arms from x.

MC28: x aids a Saudi opponent.

MC30: A suitable manpower pool (officers, military-civilian technicians, military-civilian administrators) doesn't exist and won't appear in the next five years to support an expanded defense program.

MC35: Security ties with the US and/or other western powers exist.

MC40: Security ties exist neither with the US nor with other western powers.

MC45: The Saudi king believes existing political security guarantees and ties with friendly nations don't offset military threats to Saudi security.

MC46: Saudi king believes existing political security guarantees and ties with friendly nations offset military threats to Saudi security.

MC50: Previous attempts to placate unfriendly state(s) via negotiations, trade deals, etc. have failed.

MC55: Overtures to the Warsaw Pact states for military/political assistance are unsatisfactory (either because of outright rejections or insufficient assistance).

Table 1 (cont.)

MC60:	Warsaw Pact states are politically unsuitable as sources of assistance (e.g., because they pose either a direct threat or an indirect one via sponsorship of a Saudi regional opponent).
MC65:	The Warsaw Pact states are politically accessible as sources of assistance. (i.e., they pose no security threat, either directly or indirectly via the sponsorship of a Saudi regional opponent).
MC70:	The US is unwilling to provide arms.
MC75:	Britain, France, Sweden, or other western arms source, excluding the US, is available as an arms source (user provides $ amount) (update "old" c75).
MC80:	Britain, France, Sweden, or other western states are not available as arms sources.
MC85:	The Communist bloc is willing to provide arms (user gives $ amount).
MC90:	The arms deal with the Communist bloc is not possible.
MC95:	A long term budget deficit exists. The budget bureau proposes a $x defense cut (user provides $x amount)(update "old" c95).
MC96:	A short term budget deficit exists. The budget bureau proposes an arms delivery delay involving $x ($x provided by budget module).
MC100:	Saudi king believes Saudi national security is not threatened.
MC105:	No budget deficit exists (this doesn't necessarily imply revenues exist to finance an expanded defense program; it only ensures that defense spending won't be cut).
MC110:	A nation important to Saudi national security (other than the US) has withdrawn its support.
MC115:	Revenues do not exist to finance an expanded defense program.
MC125:	(transition term) Interpretation: a significant military threat exists for which present defense capabilities are inadequate. However, a potential manpower pool and revenues exist to support an expanded defense program.
MC130:	(transition term) Interpretation: a significant military threat exists for which present defense capabilities are inadequate. Further, the manpower pool cannot support an expanded defense program. However, security ties with US and/or other western power exist.

Table 1 (cont.)

MC135: US withdraws political and/or military support from Saudi Arabia.

MC140: Overtures to the US to restore suspended military and/or political support fail.

MC145: (transition term) Interpretation: a significant military threat exists for which present defense capabilities are inadequate. Further, the manpower pool cannot support an expanded defense program and no security ties exist with the US or other western powers.

MC150: (transition term) Interpretation: a significant military threat exists for which present (or projected) defense capabilities are inadequate. Further, despite the existence of security ties with the west, these security guarantees don't offset the military threat.

MC155: (transition term) Interpretation: a signifncant military threat exists for which present (or projected) defense capabilities are inadequate. Further, existing security ties with the west don't offset the threat, and the Warsaw Pact states are politically unavailable as sources of assistance. Finally, past efforts to deflect the threat via negotiations have failed.

MC160: (transition term) Interpretation: a significant military threat exists for which present (or projected) defense capabilities are inadequate. Further, existing security ties with the west don't offset the threat, and past efforts to deflect the threat via negotiations have failed. However, the Warsaw Pact states are politically accessible as sources of assistance.

MC165: (transition term) Interpretation: a significant military threat exists for which present (or projected) defense capabilities are inadequate. Both the west and Warsaw Pact states have been approached for military/political aid; but the results are unsatisfactory. Finally, past efforts to deflect the threat via negotiations have failed.

MC170: (transition term) Interpretation: a significant military threat exists for which present defense capabilities are inadequate. However, a potential manpower pool and revenues exists to support an expanded defense program. Unfortunately, the US is unwilling to provide arms.

Table 1 (cont.)

MC175: (transition term) Interpretation: a significant military threat exists for which present defense capabilities are inadequate. However, a potential manpower pool and revenues exist to support an expanded defense program. Unfortunately, the US, Britain, France, Sweden, and other western sources are unavailable as arms sources.

MC180: (transition term) Interpretation: the US withdraws its political and/or military support.

MC185: (transition term) Interpretation: the US withdraws its political and/or military support and the remaining political guarantees enjoyed by the Saudis from other states aren't sufficient to safeguard Saudi security from external threats. Attempts to end suspension of security ties with the US have failed.

MC190: x is currently attacking SA.

MC195: The budget bureau rejects US arms sale price and offers the following counterproposal (user provide counterproposal price in $).

MC200: US guarantees Saudi security.

MC210: SA asks US to resume support.

MC220: Attempt to placate hostile actors.

MC270: No cuts in defense spending are to be made.

MC290: The budget bureau approves the arms sale with the US.

MC291: The budget bureau approves the arms sale with the western arms source (Britain, France, or Sweden).

MC292: The budget bureau approves the arms deal with the Communist bloc.

MC295: US arms purchase not ok'ed.

MC296: Budget bureau rejects western (other than US) arms sale price and offers counterproposal (user provides counterproposal price in $).

MC297: Budget bureau rejects Communist bloc arms sale price and offers the following counterproposal (user gives counteroffer in $).

Table 1 (cont.)

STATE KNOWLEDGE
POLITICAL-MILITARY SECTION

MD1	Arabs initiate conflict with Israel
MD2	Israel initiates conflict with Arabs
MD3	West will not supply Arabs with arms
MD4	SA requests support from US for Arab cause.
MD5	US or Western support is given to Arabs against Israel
MD6	US will not support Arabs.
MD7	Requested that US sign friendship treaty with SA.
MD8	Threaten US with Soviet aid and request Soviet aid.
MD9	Request Soviet political support.
MD10	US gives TNC to Israel.
MD11	IS requests TNC from US.
MD12	IS will not return TNC to US.
MD13	US will continue to sell TNC to IS.
MD14	Threatened US/IS if TNC not removed.
MD15	US refuses to halt TNC sales to IS.
MD16	IS refuses to return TNC to US.
MD17	Econ. Sanctions against West and ask USSR for TNC.
MD18	USSR will sell TNC to SA.
MD19	USSR will not give TNC to SA.
MD20	Request USSR military support.
MD21	US sells COMTUP to IS.
MD22	SA threatens US and asks for aid.
MD23	US will not sell COMTUP to IS.
MD24	IS sends COMTUP back to US.
MD25	US sells COMTUP to IS after threat.
MD26	IS refuses to return COMTUP to US.

ECONOMIC STATE KNOWLEDGE

EC1:	x supports I's position.
EC2:	I is aggressive.
EC3:	x receives aid from SA.
EC4:	Aid cutoff threat to x.
EC5:	x continues to support I after aid cutoff.
EC6:	x pressures I to "cooperate."
EC7:	SA cutoff aid to x.
EC8:	SA threatens credit restrictions for oil purchases.
EC9:	Cash must be paid for on
EC10:	x supports I after credit restriction.
EC11:	I is not aggressive.
EC12:	Threaten supply reduction.
EC13:	x supports I even after supply reduction threat.
EC14:	Supply of oil cut.
EC15:	x supports I even after supply cut.
EC16:	x supports I even after embargo threat.

Table 1 (cont.)

EC17:	Embargo of x.
EC18:	x condemns I behavior.
EC19:	x maintains its neutrality vis-a-vis I.
EC20:	x is an unacceptable place for SA foreign investment for political reasons.
EC21:	SA has liquid assets in x.
EC22:	Threat to take the money out of x.
EC23:	y is an acceptable investment place for political reasons.
EC24:	y is an acceptable investment place for economic reasons.
EC25:	Transfer investments from x to y.
EC27:	I is intransigent - but not violent.
EC28:	Moderate level of aid to Middle East Arabs.
EC29:	High level of aid to Middle East Arabs.
EC30:	International economy is very unstable.
EC31:	Lift embargo for economic reasons.
EC32:	Lift embargo for political reasons.
EC33:	I has changed to coop.
EC34:	US should not be prime arms army source for SA.
EC35:	Embargo threat to x.
EC36:	x continues to support I, even after threat of transfer.
EC37:	x continues to support I even after threat of credit end.

OIL STATE KNOWLEDGE

DEMAND(NUMBER):	daily demand for oil in barrels
PAPC(NUMBER):	production as a per cent of capacity.
COST(NUMBER):	expenditure for current fiscal year (updated monthly)
DPIR(NUMBER):	desired production increased rate.
L.PC(NUMBER):	last month's production capacity.
TOTREV(NUMBER):	total revenue for year (updated monthly).
EXCESS.CK.:	in short term image if program has already checked for excess production capacity.
ONE.CK.:	in short term image if program has checked if Saudi Arabia is pumping at or above capacity.
REV.CK.:	in short term image if revenue projections have been completed.
PSET:	in short term image if simulation has checked whether proven reserve will last 15 years.
PSTOP:	in short term image if reserves will not last 15 years.

Table 1 (cont.)

REV.TOT.: in short term image if current revenues (TOTREV) have been incremented.

DSET: in short term image if desired production rate (DPIR) has been updated.

PADJ: in short term image if production as per cent of capacity (PAPC) has been adjusted according to world demand.

AGRICULTURAL STATE KNOWLEDGE

IRRG: budget for irrigation

MECH: budget for mechanization

FERT: budget for fertilizer

MECH.YLD: maximum yield given specific level of mechanization.

FERT.YLD: maximum yield given specific level of fertilization.

YMECH: level of mechanization.

YFERT: level of fertilization.

GVPMECH: government price for mechanization.

GVPFERT: government price for fertilizer.

IRRW: current irrigated wheatland size.

ATP: available tractor power.

CUT(NUMBER): $ amount budget section wants ag. to cut its budget.

OK: budget module has approved agriculture's budget.

AG.FINAL: agriculture's lowest possible budget.

HUMAN RESOURCES STATE KNOWLEDGE

maintain (#): cost of maintaining current levels in Human Resources.

wheat (#): current domestic demand for wheat.

AG(#): number of people in "self-employed in agriculture" sector.

Table 1 (cont.)

PET(#):	number of people in "petroleum workers" sector.
expand (#):	cost for expanding Human Resources.
milit(#):	cost of increasing the military.
cut(#):	amount budget module wants Human Resources to cut its budget.
O.K.:	budget module O.K. is Human Resources budget.
HRC1(year):	military personnel inadequate.
HRC2(year):	Saudi bureaucracy inadequate.
HRC3(year):	Saudi educational system inadequate.
HRC4(year):	too few petroleum workers.
HRC5(year):	too few agricultural workers.
HRS1:	X(Israel, Iran, Kuwait, Syria, Iraq, . . .) increases military capability and is not an ally of SA.
HRS2:	Allocate appropriate expenditures to induce persons from a) unstructured pool to enter enlisted forces, and b) secondary school to enter officer corps (i.e., in total transition matrix raise (11,1) by .0004, lower (1,1) by .0004, and raise (11,4) by .0048 lowering (7,4) by .0048.
HRS3:	Allocate expenditures appropriate to induce persons from unstructured pool to become petroleum wage earners. (i.e., raise (8,1) by .000171 and lower (1,1) by .000171).
HRS4:	Induce persons in unstructured pool to enter ag land reform (raise (14,1) .0002 and lower (1,1) .0002).
HRS5:	Allocate appropriate expenditures to induce persons from teacher training to enter civil service (i.e., change total transition matrix (10,5) raised by .005 and (5,5) lowered by .005.
HRS6:	Growth rate of Saudi educational system inadequate to meet demands placed on manpower. Allocate appropriate expenditures to boost educational system growth rate. (i.e., raise (2,1) by .002 and lower (1,1) by .002, raise (5,3) by .09, lower (15,5) by .09.
HR.FINAL:	lowest possible budget for Human Resources (put in budget module).

Table 1 (cont.)

FISCAL STATE KNOWLEDGE

B.PROJ(NUMBER): projected revenues for fiscal year.

REV(#): revenues for current fiscal year.

MC295: don't buy arms from U.S.

MC291: buy arms from Western European source.

MC290: buy arms from U.S.

MC296: do not buy arms from western source.

MC292: buy arms from Warsaw state.

MC297: do not buy arms from Warsaw state.

B.C1: Israel is not hostile.

AG(#): agriculture budget.

FA(#): foreign aid.

HR(#): human resources budget.

DM(#): development and miscellaneous budget.

MIL(#): military budget

Group1(#): sum of budgets for priority sectors.

Group2(#): sum of budgets for lower priority sectors.

B.C2: international economy is unstable.

B.C6: budget items > revenues

B.C7: Group1 > revenues

B.C4: (Group1+Group2 > revenues)

B.report: budget is finished.

B.C9: all Group2 members have minimum budget.

Table 1 (cont.)

FOREIGN AID DEVELOPMENT STATE KNOWLEDGE

MD27	Iran requests economic aid.
MD28	Current Saudi - Iranian conflict.
MD29	Aid given to Iran.
MD30	Not enough $ for aid to Iran.
MD31	Request security treaty with Iran.
MD32	Iran signs security treaty with SA.
MD33	Request capital goods from Iran.
MD34(x)	Iran will sell capital goods worth x.
MD35	SA bought capital goods from Iran.
MD36	Request consumer goods from Iran.
MD37(x)	Iran will sell capital goods worth x.
MD38	SA bought consumer-goods from Iran.
MD39(x)	x-insurgents disrupt x.
MD40(x)	Iran supports x-insurgents.
MD41(x)	Iran will not support x-insurgents.
MD42(x)	SA asks Iran not to support x-insurgents.
MD43(x)	No econ. aid to Iran because of support of x-insurgents.
MD44(x)	Iran supports x-insurgents after end of econ. aid.
MD45(x)	Threaten end of all commercial arrangements with Iran.
MD46(x)	Iran supports x-insurgents even after threat of commercial break.
MD47	End all commercial arrangements with Iran.
MD48	Purchase all capital and consumer goods from West.
MD49(x)	Give military aid to x.
MD50(x)	Iran attacks x.
MD51(x)	SA asks for support against MD50(y).
MD52(x)	x gives support to SA for MD51(y).
MD53(x)	x supports MD50(y).
MD54(x)	x does not support SA (MD51(x)).

Table 2

TRANSFER INTERPRETATION RULES

Military

SI1	TRANSFER(AG1,AG2,ARMS), AG2 is in Middle East, AG2 is not an ally of SA = MC5, MC0(AG2).
SI2	TRANSFER(AG1,AG2,ARMS), AG1 is Warsaw, MC0(AG2) = MC60.
SI3	TRANSFER (AG1,AG2,ARMS), AG1 is Warsaw, MC0(AG2), MC85 = MC60, OLD(MC85).
SI11	TRANSFER(AG1,AG2,ARMS), MC190(AG2) = MC5.
SI12	TRANSFER(AG1,AG2,ARMS), AG2 is on hostile list = MC28(AG1).
SI13	TRANSFER(AG1,SA ARMS), MC26(AG1) = OLD(MC26(AG1)).
SI14	TRANSFER(AG1,SA,ARMS)/NEG, AG1 is in West Europe = AG1 will not sell arms list. If Britain, France, and Sweden all on list = MC80.
SI15	TRANSFER(US,SA,ARMS)/NEG, MC210 = OLD(MC210), MC140.
SI16	TRANSFER(US,SA,ARMS)/NEG, MC210, MC26(US) = OLD(MC210), MC140, OLD(MC26(US)).
SI17	TRANSFER(US,SA,ARMS)/NEG, MC70, MC135, NOT(MC140), MC25 = OLD(MC25).
SI18	TRANSFER(AG1,SA,ARMS)/NEG, MC75(AG1) = OLD(MC75(AG1)).
SI19	TRANSFER(AG1,SA,ARMS)/NEG, AG1 is ally of SA, AG1 is not US = MC110.
SI20	TRANSFER(AG1,SA,ARMS)/NEG, AG1 is Warsaw member, MC175 = MC55.
SI22	TRANSFER(US,SA,ARMS)/FUT = MC25.
SI23	TRANSFER(US,SA,ARMS)/FUT, MC140 = OLD(MC140).
SI24	TRANSFER(US,SA,ARMS)/FUT, MC70 = OLD(MC70).
SI25	TRANSFER(US,SA,ARMS)/FUT, MC180 = OLD(MC180).
SI26	TRANSFER(US,SA,ARMS)/FUT, MC135 = OLD(MC135).
SI27	TRANSFER(AG1,SA,ARMS)/FUT, AG1 = Warsaw member, MC85.

Table 2 (cont.)

SI28	TRANSFER(AG1,SA,ARMS)/FUT, AG1 is Western Europe, MC80 = OLD(MC80), MC75.
SI29	TRANSFER(AG1,SA,ARMS)/FUT, AG1 is Western Europe = MC75.
SI30	TRANSFER(AG1,SA,ARMS)/FUT, AG1 is an ally of SA, MC190 = MC46.

Economic

SI4	TRANSFER(AG1,IS,ARMS), EC4(AG1) = OLD(EC4(AG1)), EC5(AG1).
SI5	TRANSFER(AG1,IS,ARMS), EC8(AG1) = EC37(AG1).
SI6	TRANSFER(AG1,IS,ARMS), EC9(AG1) = EC10(AG1).
SI7	TRANSFER(AG1,IS,ARMS), EC12(AG1) = EC13(AG1).
SI8	TRANSFER(AG1,IS,ARMS), EC14(AG1) = EC15(AG1).
SI9	TRANSFER(AG1,IS,ARMS), EC35(AG1) = EC16(AG1).
SI10	TRANSFER(AG1,IS,ARMS), NOT(EC17(AG1)), NOT(EC5(AG1)), NOT(EC10 (AG1)), NOT(EC13(AG1)), NOT(EC15(AG1)), NOT(EC16(AG1)), NOT(EC16(AG1)) = EC1(AG1).
SI21	TRANSFER(AG1,IS,ARMS)/NEG = EC10(AG1).
IMD9	TRANSFER(X,Y,ARMS-RESUPPLY), X is west or US, Y is an Arab attacking IS, MD4 = MD5.
IMD12	TRANSFER(X,Y,TNC), X is west or US, Y is Arab attacking IS, MD4 = MD5.
IMD13	TRANSFER(X,Y,COMTUP), X is west or US, Y is Arab attacking IS, MD4 = MD5.
IMD20	TRANSFER(US,IS,ARMS-RESUPPLY)/NEG = MD5.
IMD21	TRANSFER(US,IS,TNC)/NEG = MD5.
IMD22	TRANSFER(US,IS,COMTUP)/NEG = MD5.
IMD25	TRANSFER(US,IS,ARMS-RESUPPLY), MC0(IS) = MD6.
IMD26	TRANSFER(US,IS,COMTUP), MC0(IS) = MD6.

Table 2 (cont.)

IMD27	TRANSFER(US,IS,TNC), MCO(IS) = MD6.
IMD28	TRANSFER(US,IS,TNC) = MD10.
IMD29	TRANSFER(US,IS,TNC)/INT(IS) = MD11.
IMD30	TRANSFER(IS,US,TNC) = MD12.
IMD31	TRANSFER(US,IS,TNC)/NEG = MD13.
IMD32	TRANSFER(US,IS,TNC), MD14 = MD15.
IMD33	TRANSFER(IS,US,TNC)/NEG, MD14 = MD16.
IMD34	TRANSFER(USSR,SA,TNC) = MD18.
IMD35	TRANSFER(USSR,SA,TNC)/NEG = MD19.
IMD36	TRANSFER(US,IS,COMTUP) = MD21.
IMD37	TRANSFER(US,IS,COMTUP)/NEG, MD21 = MD23.
IMD38	TRANSFER(IS,US,COMTUP), MD21 = MD24.
IMD39	TRANSFER(US,IS,COMTUP), MD21 = MD25.
IMD40	TRANSFER(IS,US,COMTUP)/NEG, MD21 = MD26.

<u>Development</u>

IMD43	TRANSFER(IRAN,SA,CAPITAL-GOODS), MD33 = MD34.
IMD44	TRANSFER(IRAN,SA,CAPITAL-GOODS)/NEG = MD28.
IMD45	TRANSFER(IRAN,SA,CONSUMER-GOODS), MD36 = MD37(x).
IMD48	TRANSFER(IRAN,UAE-INSURGENTS,ARMS) = MD40(UAE).
IMD49	TRANSFER(IRAN,KUWAIT-INSURGENTS,ARMS) = MD40(KUWAIT)
IMD53	TRANSFER(IRAN,X-INSURGENTS,ARMS), MD43(x) = MD44(x).
IMD56	TRANSFER(IRAN,X-INSURGENTS,ARMS), MD45(x) = MD46(x).
IMD63	TRANSFER(X,Y-INSURGENTS,ARMS), MD50(y) = MD53(x).

Table 2 (cont.)

SUPPORT INTERPRETATION RULES

Military

If the type of support is military, then treat the kernel as a TRANSFER kernel.

SI31 SUPPORT(US,SA,any)/NEG = MC135.

IMD15 SUPPORT(X,Y,POLITICAL), X Is West or US, Y is an Arab attacking IS, MD4 = MD5.

IMD17 SUPPORT(US,Y,POLITICAL)/NEG, Y is an Arab attacking IS, MD4 = MD6.

IMD19 SUPPORT(US,IS,POLITICAL)/NEG = MD5.

IMD24 SUPPORT(US,IS,POLITICAL), MC0(IS) = MD6.

Economic

SI32 SUPPORT(AG1,IS,any), EC4(AG1) = OLD(EC4(AG1)), EC5(AG1).

SI33 SUPPORT(AG1,IS,any), EC8(AG1) = OLD(EC8(AG1)), EC37(AG1).

SI34 SUPPORT(AG1,IS,any), EC9(AG1) = OLD(EC9(AG1)), EC10(AG1).

SI35 SUPPORT(AG1,IS,any), EC12(AG1) = OLD(EC12(AG1)), EC13(AG1).

SI36 SUPPORT(AG1,IS,any), EC14(AG1) = OLD(EC14(AG1)), EC15(AG1).

SI37 SUPPORT(AG1,IS,any), EC35(AG1) = OLD(EC35(AG1)), EC16(AG1).

SI38 SUPPORT(AG1,IS,any), NOT(EC17(AG1)), NOT(EC5(AG1)), NOT(EC10(AG1)), NOT(EC13(AG1), NOT(EC15(AG1)), NOT(EC36(AG1)), NOT(EC37(AG1)), NOT(EC16(AG1)) = EC1(AG1).

Foreign Aid and Development

IMD41 SUPPORT(SA,IRAN,ECONOMIC)/INT(IRAN) = MD27.

IMD50 SUPPORT(IRAN,X-INSURGENTS,POLITICAL) = MD40(x) (x = UAE or KUWAIT).

IMD51 SUPPORT(IRAN,X-INSURGENTS,MILITARY) = MD40(x).

IMD54 SUPPORT(IRAN,X-INSURGENTS,MILITARY), MD43(x) = MD44(xx).

IMD55 SUPPORT(IRAN,X-INSURGENTS,POLITICAL), MD43(x) = MD44(x).

Table 2 (cont.)

IMD57	SUPPORT(IRAN,X-INSURGENTS,MILITARY), MD45(x) = MD46(x).
IMD58	SUPPORT(IRAN,X-INSURGENTS,POLITICAL), MD45(x) = MD46(x).
IMD62	SUPPORT(X,SA,MILITARY), MD51('ANY') = MD52(x).
IMD64	SUPPORT(X,Y-INSURGENTS,MILITARY), MD50(y) = MD53(x).
IMD65	SUPPORT(X,Y-INSURGENTS,POLITICAL), MD50(y) = MD53(x).
IMD66	SUPPORT(X,IRAN,MILITARY), MD50('ANY') = MD53(x).
IMD67	SUPPORT(X,IRAN,POLITICAL), MD50('ANY') = MD53(x).
IMD68	SUPPORT(X,SA,MILITARY)/NEG, MD50('ANY') = MD54(x).

FORCE-DISPLAY INTERPRETATION RULES

Military

SI39	FORCE-DISPLAY(AG1,AG2), AG1 is in the Middle East, AG1 is not an ally of SA = MC5, MC0, AG1 is placed on HOSTILE list.
IMD2	FORCE-DISPLAY(IS,X),NOT(MD1), X is an Arab = MD2.
IMD4	FORCE-DISPLAY(X,IS),NOT(MD2),X is an Arab = MD1.
IMD11	FORCE-DISPLAY(X,IS), X is an Arab = Put X on Arabs attacking IS list.

Fiscal

SI40	FORCE-DISPLAY(IS,AG1), BC1 = OLD(BC1).

ATTACK INTERPRETATION RULES

Military

SI41	ATTACK(AG1,SA) = MC190(AG1), MC5, MC0, AG1 is placed on HOSTILE list.
SI42	ATTACK(AG1,SA), MC190(AG1) = MC45.
SI43	ATTACK(IS,AG2), AG2 is an ally = EC2.

Table 2 (cont.)

SI44	ATTACK(AG1,AG2), AG1 is an ally, MC190(AG2) = OLD(MC190(AG2)), MC46.
SI45	ATTACK(AG1,SA)/NEG, MC190(AG1) = OLD(MC190(AG1)), MC0, MC11.
SI46	ATTACK(AG1,SA)/NEG, MC45, MC200, MC201 = OLD(MC45), OLD(MC200), OLD(MC210).
IMD3	ATTACK(X,IS),NOT(MD2), X is an Arab = MD1.
IMD5	ATTACK(IS,X)/NEG, X is an Arab = ODD(MD2).
IMD7	ATTACK(X,IS)NEG, X is an Arab, MD1 = OLD(MD1).
IMD10	ATTACK(X,IS), X is an Arab = Put X on list of Arabs attacking IS.

Fiscal

SI47	ATTACK(IS,AG2), BC1 = OLD(BC1).
SI48	ATTACK(IS,AG2), EC2 = OLD(EC2), EC27.

Foreign Aid and Development

IMD46	ATTACK(UAE-INSURGENTS,UAE) = MD39(KUWAIT).
IMD47	ATTACK(KUWAIT-INSURGENTS,KUWAIT) = MD39(KUWAIT).
IMD52	ATTACK(X-INSURGENTS,X)/NEG, MD39(x) = OLD(MD39(x)).
IMD60	ATTACK(IRAN,UAE) = MD50(UAE).
IMD61	ATTACK(IRAN,KUWAIT) = MD50(KUWAIT).

RECOGNIZE INTERPRETATION RULES

Military

SI49	RECOGNIZE(AG1,SA) = take AG1 off HOSTILE list. If HOSTILE list is empty, and MC0, then OLD(MC0).
SI50	RECOGNIZE(AG1,SA), MC60 = OLD(MC60).
SI51	RECOGNIZE(AG1,SA)/NEG = MC0, place AG1 on HOSTILE list.

Table 2 (cont.)

SI52 RECOGNIZE(AG1,SA), AG1 is Warsaw Pact state = MC60.

Fiscal

SI53 RECOGNIZE(IS,PLO) = BC1.

SI54 RECOGNIZE(IS,PLO)/NEG, BC1 = OLD(BC1).

ALIGN INTERPRETATION RULES
(note: AG1 may be a collection of actors.)

Military

SI55 ALIGN(AG1,any), AG1 contains a Middle Eastern nation, SA is not in AG1, US not in AG1 = MC5.

SI56 ALIGN(AG1,any), SA in AG1, AG1 contains a Western government = MC35.

SI57 ALIGN(AG1,any), SA in AG1, US in AG1 = MC200.

SI58 ALIGN(AG1,any), SA in AG1, US in AG1, NOT(MC190), MC201 = OLD(MC201), MC100, OLD(MC200).

SI59 ALIGN(AG1,MILITARY,POLITICAL,orSECURITY)/NEG, SA in AG1, AG1 contains a Western government, take Western government(s) off Western Treaty list. If WESTERN TREATY list is empty, MC35 = OLD(MC35).

SI60 ALIGN(AG1,FRIENDSHIP), AG1 contains all Middle Eastern governments = MC201.

SI61 ALIGN(AG1,FRIENDSHIP), AG1 contains all Middle Eastern governments, NOT(MC190), MC100, MC200 = OLD(MC100), MC200).

SI62 ALIGN(AG1,FRIENDSHIP)/NEG, SA is in AG1 = take each element of AG1 of TREATY LIST.

IMD6 ALIGN((IS,X)NEG, X is an Arab, MD1 = OLD(MD1).

IMD8 ALIGN((X,IS),PEACE), X is an Arab, MD1 = OLD(MD1).

Table 2 (cont.)

Economic

SI63 ALIGN(AG1,any), IS is in AG1, for any AG in AG1 EC4(AG) = OLD(EC4(AG)), EC5(AG).

SI64 ALIGN(AG1,any), IS is in AG1, for any AG in AG1 EC9(AG) = OLD(EC9(AG)), EC10(AG).

SI65 ALIGN(AG1,any)), IS is in AG1, for any AG in AG1 EC12(AG) = OLD(EC12(AG)), EC13(AG).

SI66 ALIGN(AG1,any), IS is in AG1, for any AG in AG1 EC8(AG) = OLD(EC8(AG)), EC37(AG).

SI67 ALIGN(AG1,any), IS is in AG1, for any AG in AG1 EC14(AG) = OLD(EC14(AG)), EC15(AG).

SI68 ALIGN(AG1,any), IS is in AG1, for any AG in AG1 EC35(AG) = OLD(EC35(AG)), EC16(AG).

SI69 ALIGN(AG1,any), IS is in AG1, for any AG in AG1 NOT(EC17(AG)), NOT(EC5(AG)), NOT(EC10(AG)), NOT(EC15(AG)), NOT(EC16(AG)), NOT(EC36(AG)), NOT(EC37(AG)) = EC1(AG).

Foreign Aid and Development

IMD42 ALIGN((SA,IRAN),SECURITY), MD31 = MD32.

RATE AND LEVEL INTERPRETATION RULES

Oil

SI70 RATE(OIL,#) = Enter # in STI as oil demand.

SI71 LEVEL(OIL,$) = Enter $ in STI as oil price.

Agriculture

SI72 LEVEL(FERTILIZER,$) = Enter $ in STI as price of fertilizer.

SI73 LEVEL(MECHANIZATION,$) = Enter $ in STI as price of mechanization.

SI74 LEVEL(WHEAT,$) = Enter $ in STI as price of wheat.

Table 2 (cont.)

Fiscal

SI75	RATE(INTEREST,#) = Enter # in STI as interest rate.

Table 3

POLITICAL MILITARY SECTION

If M.S210 then OLD(**)
Printout = ===> is the U.S. willing to consider restoring support to Saudi Arabia?

If M.S165(AGNT) then OLD(**)
Printout = ===> Saudi Arabia will not buy arms from AGNT at this time.

If M.S95(AGNT) then OLD(**),M.C26(AGNT).
Printout = ===> Saudi Arabia will purchase arms from AGNT.

If M.S105 then OLD(**),
Printout = ===> In light of the current situation, Saudi Arabia asks for western support.

If M.S100 then OLD(**)
Printout = ===> Saudi Arabia calls on the peoples of the Arab world to unite.

If M.S110 then OLD(**)
Printout = ===> Saudi Arabia affirms its ties with the US and the west and asks for their support.

If M.S115 then OLD(**) and for each HOSTILE AGENT
Printout = ===> if AGNT is willing to cooperate with Saudi Arabia, we are willing to negotiate.

If M.S90 then OLD(**)
Printout = ===> is the US willing to provide arms to Saudi Arabia?

If M.S135 then OLD(**)
Printout = ===> is the USSR willing to provide arms to Saudi Arabia?

If M.S130 then OLD(**)
Printout = ===> are Britain, Sweden, or France willing to provide arms to Saudi Arabia

If M.S120 then OLD(**)
Printout = ===> Is the USSR willing to guarantee Saudi security?

If M.S170(AGNT) then OLD(**)
Printout = ===> Saudi Arabia attacks AGNT.

If M.S166(AGNT) then OLD(**)
Printout = Because of uncertainty with respect to revenues, AGNT is requested to approach us at a later time.

If M.S301(AGNT),(VALU) then OLD(**)
Printout = Because of severe budget constraints, Saudi Arabia must cancel arms contracts worth VALU with AGNT.

Table 3 (cont.)

If M.C302(AGNT),(VALU) then OLD(**)
Printout = Because of short-term budget problems, Saudi Arabia must delay for a year, contracts worth VALUE with the AGNT

If M.C25, not (M.C115) then OLD(**) and M.C25 (to budget sti)

If M.C75(AGNT),not (M.C115) then OLD(**) and M.C75(AGNT) (to budget sti)

If M.C25,not (M.C115),M.C5,not (M.C26(US)) then OLD(**) and M.C25 (to budget sti)

If M.C25,M.C115 then OLD(**),M.S165(US).

If M.C25,not (M.C5),not (M.C10) then OLD(**),M.S165(US).

If M.C25,M.C100 then OLD(**),M.S165(US)

If M.C75(AGNT),M.C5, not (M.C115),not (M.C26(AGNT)),M.C70, then NTC(M.C75(AGNT)), OLD(**), NTC(M.C75(AGNT)) OLD(**), and M.C75(AGNT) (to budget sti)

If M.C75(AGNT),M.C5,not(M.C115),not(M.C26(AGNT)),M.C140 then NTC(M.C75(AGNT)), OLD(**), and M.C75(AGNT) (to budget sti)

If M.C75(AGNT),M.C115 then OLD(**),M.S165(AGNT)

If M.C75(AGNT),not (M.C5),not (M.C10) then OLD(**),M.S165(AGNT)

If M.C75(AGNT),M.C100 then OLD(**),M.S165(AGNT)

If M.C75(AGNT),M.C25 then OLD(**),M.S165(AGNT)

If M.C80,M.C5,M.C10, not(M.C115),M.C85(AGNT),M.C45,not(M.C26(AGNT)),M.C140 then NTC(M.C85(AGNT)),OLD(**) then M.C85(AGNT) (to budget sti)
current sti = milit. sti

If M.C85(AGNT),M.C11 then OLD(**),M.S165(AGNT).

If M.C85(AGNT),M.C115 then OLD(**),M.S165(AGNT)

IF M.C85(AGNT),M.C46 then OLD(**),M.S165(AGNT)

If M.C85(AGNT),M.C100 then OLD(**),M.S165(AGNT)

If M.C85(AGNT),M.C75(STR) then OLD(**),M.S165(AGNT)

If M.C0,M.C5,M.C10,not(M.C35),M.C115 then EXIT,M.S100,M.S105

If M.C0,M.C5,M.C10,M.C115,M.C35,not(EXIT) then EXIT1,M.S100,M.S110

If M.C45,M.C140,not(EXIT2) then M.S115,EXIT2.

Table 3 (cont.)

If M.C135,not(M.C180) then M.S105,M.S100,M.C180

If NOT(EXIT8),M.C110,not(M.C115),not(EXIT3),not(M.C190(US)) then OLD(**),M.S90,EXIT8

If M.C95,M.C5,not(M.C35),not(EXIT4) then EXIT4,M.S100,M.S105

If M.C95,M.C5,M.C35,not(EXIT5) then EXIT5,M.S100,M.S110

If M.C175,M.C90,not(EXIT6) then EXIT6,M.S100,M.S105

If M.S85(AGNT),M.C175 then OLD(**),M.S165(AGNT)

If M.C170,M.C80,not(M.C175) then M.C175,M.S135

If M.C75(AGNT),M.C170 then OLD(**),M.C75(AGNT) (to budget sti)

If M.C125,M.C70,not(EXIT$) then EXIT$,M.C170,M.S130

If M.C25,M.C125,not(EXIT7),not(M.C26(US)) then OLD(**),EXIT7,M.C25 (to budget sti)

If M.C0, M.C5,M.C10,not(M.C115),not(M.C125),not(EXIT8),not(M.C190(US)),not(EXIT3)
then M.S90,M.C125,EXIT8.

If M.C190(STR.AGNT),not(EXIT9) then EXIT9,M.S170(AGNT)

IF M.C70,not(M.C140) then OLD(**),M.S210,M.C210

If M.C140,M.C110,not(OLD(M.S210)) then M.S210,M.C210

If M.C290 then OLD(**),M.S95(US)

If M.C295 then OLD(**),M.S166(US)

If M.C291(STR.AGNT) then OLD(**),M.S95(AGNT)

If M.C296(AGNT) then OLD(**),M.S166(AGNT)

If M.C292(AGNT) then OLD(**),M.S95(AGNT)

If M.C95(X) then if X is less than or equal to purchases from Warsaw states, then Warsaw purchases are reduced by X and M.S302 ((Warsaw)$); otherwise Warsaw purchases are set to zero and M.S302((Warsaw)$). The remaining funds to be cut are equally divided between Western Europe and the U.S. If purchases from the U.S. are greater than or equal to amount to be cut, then U.S. purchases are reduced by that amount and M.S.302 ((US)$) ; otherwise U.S. purchases are reduced to zero and M.S302((US)$). If purchases from Western Europe are greater than the amount to be cut, Western Europe purchases are reduced by that amount and M.S((West Europe)$); otherwise Western Europe purchases are set to zero and M.S302((Western Europe)$).

Table 3 (cont.)

If M.C96, then repeat the above procedure, substituting M.S301((AGENT($) for M.S302((AGENT)$) throughout.

WORLD MODELS

POLITICAL-MILITARY SECTION

WMD1	MD2, M.C175, MD8 = MD4, MD.S1
WMD2	MD5 = MD.S2, MD7.
WMD3	MD6 = MD8, MD.S3, MD.S4.
WMD4	MD8, M.C85(AGNT) = M.C85(AGNT) TO BUDGET STI.
WMD5	MD10, NOT(MD1), NOT(MD2) = MD14, MD.S6.
WMD6	MD10, NOT(MD1), NOT(MD2) = MD14, MD.S6.
WMD7	MD11, NOT(MD1), NOT(MD2) = MD.S7.
WMD8	MD15, MD16 = (E.C13(US), E.C2 TO ECON. STI).
WMD9	MD17, MD18 = (M.C85 TO BUDGET STI), MD.S9, (SET US ARMS PURCHASES TO ZERO), (CUT SOVIET ARMS OFFER BY 1/2 BEFORE SUBMITTING TO FISCAL SECTION)
WMD10	MD15, MD16, MD1 = (E.C13(US), E.C2 TO ECON. STI), MD20, MD.S10
WMD11	MD15, MD16, MD2 = (E.C13(US), E.C2 TO ECON. STI), MD20, MD.S10.
WMD12	MD21, MD1 = MD22, MD.S11.
WMD13	MD21, MD23, MD24 = OLD(MD21), OLD(MD22), OLD(MD23).
WMD14	MD25, MD26 = MD27, MD.S12.
WMD15	MD21, MD2 = MD.S5, MD9.

MD.S1 Will the US give political support to the Arabs to restore peace in the Middle East?

MD.S2 Will the US sign a friendship treaty with SA?

MD.S3 Since the US has refused to provide arms to the Arabs, or to act to restrain Israeli aggression, Soviet assistance will be sought.

MD.S4 Will the USSR sell arms to SA?

MD.S5 Will the USSR provide political support to the Arabs to restrain IS?

MD.S6 SA demands all TNC's be returned to the US and the US halt and desist in any more sales of TNC's. If the US refuses, economic sanctions will be imposed and Soviet support sought.

MD.S7 SA looks with alarm at Israel's request for TNC and asks the US to refuse.

MD.S8 Will the USSR sell TNC to SA?

MD.S9 SA cancels all defense contracts with the US.

MD.S10 SA requests military support from the USSR on behalf of the Arabs.

Table 3 (cont.)

MD.S11 SA demands that all COMTUP's be returned to the US and that all future sales be halted unless the US is willing to sell COMTUP's to SA.

MD.S12 Will the USSR provide political support to bring peace to the Middle East?

ECONOMIC SECTION

If E.S1(AGNT) then OLD(**)
Printout = Unless AGNT withdraws support from Israel, Saudi Arabia will deny foreign aid to AGNT.

If E.S2(AGNT) then OLD(**)
Printout = Because AGNT has continued to support Israeli aggression in spite of our warnings, all aid has been halted.

If E.S3(AGNT) then OLD(**)
Printout = As a result of AGNT's action, Saudi Arabia will restore suspended aid.

If E.S4(AGNT) then OLD(**)
Printout = Unless AGNT's support of Israel stops immediately, Saudi Arabia will restrict credit terms for oil purchases.

If E.S5(AGNT) then OLD(**)
Printout = As a result of continued support of Israel, AGNT must now pay cash for oil.

If E.S6(AGNT) then OLD(**)
Printout = Oil supply to AGNT will be halved in face of continued support for Israel.

If E.S7(AGNT) then OLD(**)
Printout = The supply of oil to AGNT has been halved.

If E.S8(AGNT) then OLD(**)
Printout = If AGNT continues to ignore repeated Saudi warnings, all oil will be cut off.

If E.S9(AGNT) then OLD(**)
Printout = No Saudi oil will be shipped to AGNT

If E.S10(AGNT) then OLD(**)
Printout = Saudi aid to AGNT will be halted unless AGNT renounces Israel.

If E.S13(AGNT) then OLD(**)
Printout = Saudi Arabia lifts the embargo against AGNT.

Table 3 (cont.)

If E.S14 then OLD(**)
Printout = Saudi Arabia lifts all oil related restrictions.

If E.C1(AGNT),E.C2,E.C3(AGNT) then OLD(**),E.S1(AGNT),E.C4(AGNT)

If E.C5(AGNT),E.C2,E.C4(AGNT) then OLD(**),E.S2(AGNT),E.C7(AGNT)

If E.C4(AGNT),E.C2,E.C18(AGNT) then OLD(**)

If E.C7(AGNT),E.C18(AGNT) then OLD(**),E.S3(AGNT),E.C3(AGNT)

If E.C1(AGNT),E.C2,not(E.C3(AGNT)) then OLD(**),E.S4(AGNT),E.C8(AGNT)

If E.C37(AGNT),E.C2 then OLD(**),E.C9(AGNT),E.S5(AGNT) and
if not(TEMP.FLUX) then TEMP.FLUX(to budget sti)

If E.C10(AGNT),E.C2 then OLD(**),E.C12(AGNT),E.S6(AGNT)

If E.C13(AGNT),E.C2 then OLD(**),E.S7(AGNT),E.C14(AGNT) and
if not(TEMP.FLUX) then TEMP.FLUX(to budget sti)

If E.C15(STR.AGNT),E.C2 then OLD(**),E.S8(AGNT),E.C35(AGNT)

If E.C16(AGNT),E.C2 then OLD(**),E.S9(AGNT),E.C17(AGNT), and
if not(TEMP.FLUX) then TEMP.FLUX(to budget sti)

If E.C3(AGNT),E.C2,not(E.C18(AGNT)) then E.C3(AGNT),E.S10(AGNT)

If E.C4(AGNT),E.C2,E.C18(AGNT) then OLD(**),E.C3(AGNT),E.S3(AGNT)

If E.C17(AGNT),E.C30 then OLD(**),E.S13(AGNT)

If E.C17(AGNT),E.C18(AGNT) then OLD(**),E.S13(AGNT), and
if not(TEMP.FLUX) then TEMP.FLUX(to budget sti)

If E.C17(AGNT),E.C27 then OLD(**),E.S13(AGNT)

If E.C27 then OLD(**),E.S14, and if TEMP.FLUX (in budget sti) then OLD(**)

OIL SECTION

Oil 2 = if this month's L.PC has not replaced last month's L.PC then do so.

and

if the production capacity is less than the PC of two months ago then DPIR is equal to L.PC of last month minus PC (production capacity).

Table 3 (cont.)

Oil 3 = if haven't checked to see if current proven reserves will last 15 years at current production then do so.

and

if reserves will not last 15 years then decrease production os that reserves will last 15 years. Put PSTOP in short term image.

Oil 4 = check to see if current production is equal to demand. If PSTOP is in short term image then do not modify production, otherwise modify balance production with demand.

Oil 5 = if not rev.ck then update budget projection. (current receipt and monthly production times months in fiscal year)

Oil 6 = if not one.ck then, if PAPC greater than 1.0 then PAPC = 1.0 and DPIR is set so that current demand will be met in 3 months.

Oil 6.3 = if not excess ck. and if current capacity exceeds demand by 60 percent then DPIR = 0.

AGRICULTURE SECTION

unnumbered production:
if cost of importing enough wheat to meet demands is more than 10 percent of fiscal year revenues then increase production of wheat (i.e., increase production into short term image). Note demand for wheat from Human Resources.

AG.1 = if YMECH = YFERT then recompute FERT and MECH by:
MECH = GVPMECH*((1.3*IRRW)-(.093*ATP))
FERT = GVPFERT* .046*IRRW

AG.2 = if YMECH > YFERT then recompute FERT by:
FERT = GVPFERT*.046*IRRW

AG.3 = if YFERT > YMECH then recompute MECH by:
MECH = GVPMECH*((1.3*IRRW)-1.093*ATP))

AG.5 = if INC.PROD in short term image
set IRRG to 20,000,000 o/w
set IRRG to 5,000,000

AG.6 = if cut(#) then if not INC.PROD then
IRRG=IRRG-cut(#)

AG.7 = if not o.k. then agriculture budget is
IRGG+FERT+MECH

AG. 7.1 = if IRGG = 0 then ag.final in short term image.

Table 3 (cont.)

HUMAN RESOURCES SECTION

I. DEFINITIONS

A. Control Statements Passed to Human Resources

1. educal = persons in primary education system
2. selfag = persons self employed in agriculture
3. petrol = persons earning wages in petroleum industry
4. milit 1 = persons serving as enlisted soldiers
5. milit 2 = persons serving as officers
6. civil = persons who are civil servants

HR2
if self-ag is less than 90 percent last year's self-ag then HR.C5(YEAR)

HR3
if pet is less than 90 percent last year's pet then HR.C4(YEAR)

HRM4
If HR.C5(YEAR),HR.C5(YEAR-1),not(HR.C2(YEAR))then HR.C2(YEAR)

HRM5
If HR.C4(YEAR),HR.C4(YEAR-1),not(HR.C2(YEAR))thenHR.C2(YEAR)

HRM6
If HR.C1(YEAR),HR.C1(YEAR-1),not(HR.C2(YEAR))thenHR.C2(YEAR)

HRM7
If HR.C2(YEAR),HR.C2(YEAR-1),HR.C2(YEAR-2),not(HR.C3(YEAR))then HR.C3(YEAR)

HRM8
If HR.C5(YEAR),not(HR.S4)thenHR.S4

HRM9
If HR.C4(YEAR),not(HR.S3)then HR.S3

HRM10
If HR.C3(YEAR),not(HR.S6)then HR.S6

HRM11
If HR.C2(YEAR),not(HR.S5)then HR.S5

HRM12
If HR.C1(YEAR),not(HR.S2)then HR.S2

HRM13
If HR.S2 then OLD(**),MILIT 1 = 0.0004,MILIT2 = 0.0048

Table 3 (cont.)

HRM14
If HR.S3 then OLD(**),PETROL = 0.000171

HRM15
If HR.S4 then OLD(**),SELFAG = 0.0002

HRM16
If HR.S5 then OLD(**),CIVIL = 0.005

HRM17
If HR.S6 then OLD(**),EDUCA1 = 0.002

HRM18
If MILIT(SIR) then OLD(**),VALI = MILIT1*HR.A1 + MILIT2*HR.A4 * 21000
MILIT(VAL1)

HR19
if cut(#) then if cut is greater than expand(#) then expand (o). o/w divide cut equally between civil educa 1.

HR21
if not o.k. then HR budget equal to expand(#) + *maintain*(#) + *milit*(#). put HR(#) in budget module. And if expand(o) then put HR final in budget module.

BUDGET SECTION

BME1 = if B.PROJ + last year's revenue balance is < last year's revenue then MC115.

BME1.1 = if B.PROJ + last year's revenue balance is > last year's revenue and MC115 then mask MC115.

BME2.0 = if MC25 and if B.PROJ + last year's revenue balance is > last year's revenue then MC290.

BME2.1 = if MC25 and if B.PROJ + last year's revenue balance is < last year's revenue then MC295.

BME3.0 = if MC75 and if B.PROJ + last year's revenue balance is > last year's revenue MC291.

BME3.1 = if MC75 and if B.PROJ + last year's revenue balance is < last year's revenue MC296.

BME4.0 = if MC85 and if B.PROJ + last year's revenue balance > last year's revenue MC292.

BME4.1 = if MC85 and if B.PROJ + last year's revenue balance is < last year's revenue MC297.

Table 3 (cont.)

BME5.0 = if month = BUD.TIME then go to BM otherwise read an input sentence.

BM1.0 = if not BC1 then Group1 = MIL.BUD + FOREIGN AID BUD. and Group2 = Human Resources Budget + Development and miscellaneous budget + Agriculture Budget.

BM2.0 = if 3C2 then Group1 = Human Resources + Development and Miscellaneous + Agriculture and Group2 = Military and Foreign Aid.

BM3.0 = if not BC2 then Group2 = Military and Group1 Human Resources, Foreign Aid, Development, Agriculture, Miscellaneous.

BM7.0 = if not BC9 and if Group1 + Group2 is > revenues then BC6
 and if Group1 > revenues BC7
 and if Group1 $\leq$ revenues BC8

BM7.1 = if not BC9 and if Group1 + Group2 $\leq$ revenues then BC4

BM8.0 = if B.REPORT printout budget.

BM9.0 = if BC4 and not BC1 then B.REPORT and 10 percent surplus revenues into long term investment and 90 percent in short term investment.

BM10.0 = if BC4 and not BC2 then B.REPORT and 40 percent surplus revenues into long term investment and 60 percent in short term investment.

BM11.0 = if BC4 and BC2 then B.REPORT and 10 percent surplus revenues into long term investment and 90 percent in short term investment.

BM16.0 = if BC7 then program error, run terminates program interrupt at . . .

BM17.0 = if BC8 and not BC1 and not BC9 and AG.FINAL, HR.FINAL, and DM.FINAL then BC9.

BM17.1 = if BC8 and not BC1 and not BC9 and not AG.FINAL, not HR.FINAL, or not BM.final then decrease non-final budgets to balance total budget.

BM18. = if BC8, BC2, not BC9, and MIL.FINAL, and FA.FINAL then BC9.

BM18.1 = if BC8, BC2, not BC9, and not MIL.FINAL or not FA.FINAL then decrease non-final budget to balance total budget. (IF TEMP.FLUX then MC96 otherwise MC95).

BM19.0 = if BC8, not BC2, and not BC9 and MIL.FINAL then BC9.

BM19.1 = if BC8, not BC2, and not BC9 and TEMP.FLUX then MC96.

BM19.2 = if BC8, not BC2, and not BC9 and not TEMP.FLUX then MC95.

Table 3 (cont.)

BM20.0 = BC9 then reduce short and long term investments to cover deficit and B.REPORT.

DEVELOPMENT AND FOREIGN AID SECTIONS

The development budget is initially set to $7,000,000,000 and lowest possible budget is $100,000,000. Otherwise all budget cuts by fiscal module are accepted.

The foreign aid budget is initialized at $10,000,000 and lowest value is $1,000,000. Otherwise all fiscal module cuts are accepted.

FA AND DM SECTIONS

WMD16	MD27, NOT(MD28), AND SHORT TERM INVESTMENTS GE11,000,000,000 = MD.S13(x) (x = 1/50 OF SHORT-TERM INVEST.), (X IS PUT IN FA BUDGET), MD29.
WMD17	MD27, NOT(MD28), (SHORT-TERM LE 11,000,000,000) = MD.S14, MD30.
WMD18	MD27, MD 28 = MD.S15, MD31.
WMD19	MD31, MD32 = MD.S16(x), MD33, (x = 1/50 OF SHORT-TERM INVEST.).
WMD20	MD34(x) = MD.S17(x), MD35, (x TO DM BUDGET).
WMD21	MD35 = MD.S18(x) (x = 1/100 OF SHORT-TERM), MD36(x).
WMD22	MD37(x) = MD38, MD.S19(x) (x TO DM BUDGET).
WMD23	MD38, MD28 = OLD(MD28).
WMD24	NOT(MD28), NOT(MD35) = MD.S16(x), MD33, (x = 1/50 SHORT-TERM), ONLY EXECUTE ONCE PER YEAR.
WMD25	MD39(x), NOT(MD40(x)) = MD42(x), MD.S20(x).
WMD26	MD42(x), MD40(x), MD39(x) = MD43(x), MD.S21(x), MD28.
WMD27	MD40(x), MD39(x) = MD42(x), MD28, MD.S22(x), OLD(MD40(x)), (MAKE CHANGES IN FA BUDGET).
WMD28	MD44(x), MD39(x) = MD45(x), MD.S23(x), MD.S20(x).
WMD29	MD46(x), MD39(x) = MD47, MD.S24, MD48, MD49, MD.S25(MAKE CHANGES IN FA BUDGET).
WMD30	MD50(x) = MD51(x), MD.S26.

Table 3 (cont.)

FA AND DM

MD.S13(x)	In the spirit of developing the Middle East, SA gives Iran $X.
MD.S14	Despite its concern with the development of the Middle East, current fiscal conditions prevent any expenditures of economic aid to Iran.
MD.S15	Despite its concern for the development of the Middle East, recent events show Iran to be undependable and therefore unsuitable for economic aid. Will Iran sign a security treaty with SA?
MD.S16(x)	Will Iran sell capital-goods worth $X to SA?
MD.S17(x)	SA will buy capital goods worth $X from Iran.
MD.S18(x)	Will Iran sell consumer goods worth $X to SA?
MD.S19(x)	SA will buy consumer goods worth $X from Iran.
MD.S20(x)	Iran should not support X-insurgents. Is Iran going to support them?
MD.S21(x)	Because of Iranian support of X-insurgents, SA will give no further economic aid to Iran.
MD.S22(x)	Economic aid to Iran will be cut if it continues to support X-insurgents.
MD.S23(x)	If Iran continues to support X-insurgents, all commercial arrangements will be voided.
MD.S24	All commercial arrangements with Iran have been voided. SA will purchase all capital and consumer goods from Western sources.
MD.S25(x)	SA gives military aid to X.
MD.S26	Will Egypt, Syria, or the US give military support to SA?

Part IV: Conclusion

Chapter of this report contains an illustrative run of the simulation, an overview of the issues involved in validating the simulation and a summary discussion of the relevance of the project simulation to policy planning.

Chapter 7

The last chapters have treated the simulation of Saudi Arabian decision-making from a fairly abstract perspective. At this point it would be useful to illustrate the capabilities of the simulation through a description of an actual run. Recall that the user interacts with the simulation via a computer terminal. At the same time, the simulation produces a copy of simulation output on a line printer. This provides the user with a permanent record of the inputs to the simulation by the user as well as of simulation responses. The following six pages are a sample hard copy record of an actual simulation run.

An aspect of the simulation not reflected in the output is the scenario capability. A scenario is a collection of input sentences stored as a member of a partitioned dataset. A collection of these scenarios forms a scenario library. It is possible for a user to enter the name of a member of the scenario library as input to the simulation. Overhead software, not part of the simulation per se, retrieves scenario from the library, and introduces the sentences in it as input to the simulation. As a result, the hardcopy of the output does not reflect the use of a scenario. With this scenario capability, it is possible to provide a set of constant initial conditions for a simulation run. After the scenario has been exhausted, the user can introduce non-scenario input sentences. In this way, it is possible to investigate the responses by the simulation given a uniform partial history. A second use of the scenario capability is to link mini-scenarios into a larger scenario. For example, scenarios can be written for an Arab instigated Middle East war, and Israeli instigated war, Western support of the Arabs during a war, Western support of the Israelis during a war, or Western neutrality. By combining these mini-scenarios it is possible to create six different conflict scenarios. Thus the scenario capability makes it possible to confront the simulation with different situations in a systematic manner.

With this background, we now turn to an example simulation run. The input sentences and responses are based upon scenarios provided by W. Phillips and D. McCormick, of the University of Maryland. The example starts in June of 1977. The oil module is executed once each month. As can be seen from the output, 232,909,744 bbl of oil was produced during that month. The monthly revenue was $1,969,543,231. The decision module controls the oil module by manipulating the daily production level and investments to increase producing capacity.

After the oil module has executed, the decision module waits for user input. This is indicated by "$$$ ENTER INPUT SENTENCE $$$" in the Figure. In this case the user entered the sentence "WILL SA GIVE ECONOMIC-AID TO IRAN." In the simulation, SA stands for Saudi

```
PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH= 6        YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS   232,909,744 BBL.
AVG DAILY PRODUCTION WAS  7,763,658 BBL, 0.6700 OF CURRENT CAPACITY OF
11,586,000 BBL PER DAY.          CAPACITY INCREASED BY      95,000 BBL PER DAY.
CURRENT PROVED RESERVES 108,382,846,976 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY       95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=   1,314,156,618            INDEPENDENT SALE REVENUE=       67,107,108
SELLBACK REVENUE=     588,279,504            TOTAL NONTAX REVENUE=      655,386,613
TOTAL OIL REVENUE=   1,969,543,231

                              END OF OIL MODULE

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> WILL SA GIVE ECONOMIC-AID TO IRAN?
===> DESPITE ITS CONCERN FOR THE
DEVELOPMENT OF THE MIDDLE EAST.RECENT EVENTS
SHOW IRAN TO BE UNDEPENDABLE AND THEREFORE
UNSUITABLE FOR ECONOMIC AID. WILL IRAN SIGN
A SECURITY TREATY WITH SA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
----------------------------END OF MONTH-----------------------------
                     YEAR= 1977 , MONTH= 7


PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH=  7       YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS    240,657,227 BBL.
AVG DAILY PRODUCTION WAS  7,763,136 BBL, 0.6645 OF CURRENT CAPACITY OF
11,681,000 BBL PER DAY.          CAPACITY INCREASED BY      95,000 BBL PER DAY.
CURRENT PROVED RESERVES 108,726,976,512 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY       95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=   1,357,870,577            INDEPENDENT SALE REVENUE=       69,339,351
SELLBACK REVENUE=     607,846,515            TOTAL NONTAX REVENUE=      677,185,866
TOTAL OIL REVENUE=   2,035,056,444

                              END OF OIL MODULE
```

FIGURE 3
SAMPLE SIMULATION RUN

SAUDI ARABIA : HUMAN RESOURCES
A ONE-YEAR PROJECTION

PERSONS IN UNSTRUCTURED POOL	5,881,137
PERSONS IN ELEMENTARY ED	333,670
PERSONS IN INTERMEDIATE ED	70,024
PERSONS IN SECONDARY ED	16,148
PERSONS IN TEACHER TRAINING	14,859
PERSONS IN TECH & ADULT ED	50,497
PERSONS IN UNIVERSITIES	23,942
PETROLEUM WAGE EARNERS	49,288
NON-PETROLEUM WAGE EARNERS	11,623
CIVILIAN GOVT EMPLOYEES	122,444
MILITARY GOVT EMPLOYEES	83,074
NON-INDUSTRIAL WAGE EARNERS	113,943
SELF-EMPLOYED NON-AG	14,985
SELF-EMPLOYED AG	981,564
PERSONS MOVED THROUGH SYSTEM	160,666

END OF HUMAN RESOURCES MODULE

```
PTP AGRICULTURE SECTOR MODULE: DEVELOPMENTAL VERSION 2.3

***  YEAR = 1977  **************************************************

OUTPUT FROM RESOURCE ALLOCATION COMPONENT:

    CULTIVABLE LAND IS   809,000 HECTARES.
    TOTAL RAINFED LAND IS   120,000 HECTARES.  .399 OF THIS LAND IS
    ALLOCATED TO WHEAT PRODUCTION, BUT HALF THE LAND ALLOCATED IS
    IN FALLOW EACH YEAR; HENCE RAINFED LAND DEVOTED TO WHEAT
    THIS YEAR IS     23,999 HECTARES.
    A NEW IRRIGATION DEVELOPMENT PROJECT IS BEGUN:
        IT WILL COST $     5,000,000, OR $ 130.000 PER CUBIC METER/YR.
        IT WILL REQUIRE  5 YEARS TO COMPLETE.
        IT WILL PROVIDE        38,461 CUBIC METERS OF WATER PER YEAR.
    THIS YEAR'S COST OF IRRIGATION DEVELOPMENT PROJECTS IN PROGRESS
    IS $  3,000,000.
    NEW IRRIGATION WATER AVAILABLE THIS YEAR IS            000 CUBIC
    METERS PER YEAR.  ASSUMING A NEED OF  11,000 CUBIC METERS
    PER HECTARE PER YEAR, NEW IRRIGATED LAND IS          0 HECTARES.
    MODERN IRRIGATED LAND IS           0 HECTARES.
    TOTAL MODERN IRRIG CROPPED WHEATLAND IS   179,999 HECTARES.
    TOTAL CROPPED WHEATLAND IS   203,999 HECTARES.
    PHYSICAL LAND:
        TOTAL UNDER CULTIVATION IS   570,000 HECTARES.
        ALLOC TO WHEAT IS   203,999 HECTARES.
        IRRIGATED TOTAL IS   450,000 HECTARES.

OUTPUT FROM MODERNIZATION COMPONENT:

    GOVT ALLOCATION FOR FERT FOR WHEAT THIS YR IS $      38,915.
        AMOUNT PURCHASED IS  82,799 METRIC TONS.
        AT $  0.46 PER METRIC TON.
    FERTILIZER APPLICATION RATE IS  459 KG PER HECTARE.
    GOVT ALLOCATION FOR TRACTORS IS $     821,925.
        AMOUNT PURCHASED IS          6,849 HP.
        AT $ 120 PER HP.
    AVAILABLE TRACTOR POWER IS      234,814 HP.
    POWER UTILIZATION LEVEL IS  1.30 HP PER HECTARE.
    YIELD:
        LIMIT FROM FERT APP RATE IS 6799 KG PER HECTARE.
        LIMIT FROM MECH LEVEL IS 6825 KG PER HECTARE.
        RESULTING YIELD FOR IRRIG LAND IS 6799 KG PER HECTARE.
        ASSUMED YIELD FOR RAINFED LAND IS  900 KG PER HECTARE.
        OVERALL WEIGHTED AVERAGE YIELD IS 6105 KG PER HECTARE.

OUTPUT FROM PRODUCTION COMPONENT:

    TOTAL COUNTRY WHEAT YIELD IS       1,245,597 METRIC TONS.
```

```
............................... BUDGET MODULE .........................

BUDGET FOR 1978
MILITARY: $7,000,000
FOREIGN AID: $10,000,000
HUMAN RESOURCES(TOTAL): $2,816,298,000
        SUB-TOTALS FOR HUMAN RESOURCES
           EXPANSION: $0
           MAINTENANCE: $2,816,298,000
           MILITARY: $0
AGRICULTURE: $6,913,675
DEV. AND MISC: $7,000,000,000
TOTAL EXP: $9,840,211,456
SHORT-TERM INV. $49,131,310,337
LONG-TERM INV. $5,459,035,928
INCOME: $64,430,557,924
TOTAL SHORT-TERM INV.: $83,237,075,455
TOTAL LONG-TERM INV.: $9,261,577,672

.......................................................................

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IRAN WILL SIGN SECURITY-TREATY WITH SA.
===> WILL IRAN SELL CAPITAL GOODS WORTH  $1,664,741,471 TO SA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IS MOBILIZES ARMED-FORCES AGAINST EGYPT;

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IS MOBILIZES ARMED-FORCES AGAINST SYRIA.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
-------------------------------END OF MONTH-------------------------------
                         YEAR= 1977 , MONTH= 8



PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH=  8        YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS   240,641,307 BBL.
AVG DAILY PRODUCTION WAS  7,762,622 BBL, 0.6591 OF CURRENT CAPACITY OF
11,776,000 BBL PER DAY.         CAPACITY INCREASED BY     95,000 BBL PER DAY.
CURRENT PROVED RESERVES 109,071,040,512 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY      95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=   1,357,780,752          INDEPENDENT SALE REVENUE=        69,334,764
SELLBACK REVENUE=     607,804,875          TOTAL NONTAX REVENUE=      677,139,639
TOTAL OIL REVENUE=   2,034,920,391


                              END OF OIL MODULE
$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IS ATTACKS EGYPT.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> SYRIA ATTACKS IS.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EGYPT ATTACKS IS.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IS ATTACKS SYRIA.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> WILL SA GIVE ECONOMIC-AID TO IRAN?
===> IN THE SPIRIT OF DEVELOPING THE MIDDLE EAST, SA GIVES IRAN $1,664,741,471.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
-------------------------------END OF MONTH-------------------------------
                         YEAR= 1977 , MONTH= 9
```

```
MONTH=  9          YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS    232,863,524 BBL.
AVG DAILY PRODUCTION WAS  7,762,117 BBL, 0.6538 OF CURRENT CAPACITY OF
11,871,000 BBL PER DAY.        CAPACITY INCREASED BY      95,000 BBL PER DAY.
CURRENT PROVED RESERVES 109,404,028,928 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY      95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=    1,313,695,834          INDEPENDENT SALE REVENUE=      67,093,791
SELLBACK REVENUE=     588,158,613          TOTAL NONTAX REVENUE=     655,252,404
TOTAL OIL REVENUE=   1,969,148,239

                          END OF OIL MODULE

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IRAN WILL SELL CAPITAL-GOODS WORTH $700,000,000 TO SA.
===> IS THE US WILLING TO PROVIDE ARMS TO SAUDI ARABIA?
===> SA WILL BUY CAPITAL GOODS WORTH $700,000,000 FROM IRAN
===> WILL IRAN SELL CONSUMER GOODS WORTH $832,370,890 TO SA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> US WILL GIVE ARMS TO IS.
===> UNLESS US'S SUPPORT OF IS STOPS IMMEDIATELY,
SAUDI ARABIA WILL RESTRICT CREDIT TERMS
FOR OIL PURCHASES.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> FRANCE WILL GIVE ARMS TO IS.
===> UNLESS FRANCE'S SUPPORT OF IS STOPS IMMEDIATELY,
SAUDI ARABIA WILL RESTRICT CREDIT TERMS
FOR OIL PURCHASES.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> FRANCE WILL NOT GIVE ARMS TO SA.
===> IS THE US WILLING TO PROVIDE ARMS TO SAUDI ARABIA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> SWEDEN WILL NOT SELL ARMS TO SA.
===> IS THE US WILLING TO PROVIDE ARMS TO SAUDI ARABIA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> BRITAIN WILL NOT GIVE ARMS TO SA.
===> IS THE US WILLING TO PROVIDE ARMS TO SAUDI ARABIA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
------------------------------END OF MONTH------------------------------
                         YEAR= 1977 , MONTH= 10

PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH= 10          YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS    240,610,228 BBL.
AVG DAILY PRODUCTION WAS  7,761,620 BBL, 0.6486 OF CURRENT CAPACITY OF
11,966,000 BBL PER DAY.        CAPACITY INCREASED BY      95,000 BBL PER DAY.
CURRENT PROVED RESERVES 109,748,092,928 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY      95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=    1,357,605,389          INDEPENDENT SALE REVENUE=      69,325,809
SELLBACK REVENUE=     607,723,581          TOTAL NONTAX REVENUE=     677,049,391
TOTAL OIL REVENUE=   2,034,654,780

                          END OF OIL MODULE

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> US WILL NOT SELL ARMS TO SA.
===> IN LIGHT OF THE CURRENT SITUATION, SAUDI ARABIA
ASKS FOR WESTERN SUPPORT.
===> SAUDI ARABIA CALLS ON THE PEOPLES OF THE ARAB WORLD TO UNITE.
===> IS THE US WILLING TO PROVIDE ARMS TO SAUDI ARABIA?
===> ARE BRITIAN, SWEDEN, OR FRANCE WILLING TO PROVIDE ARMS TO SAUDI ARABIA?
===> IS THE USSR WILLING TO PROVIDE ARMS TO SAUDI ARABIA.
===> IS THE U.S. WILLING TO CONSIDER RESTORING SUPPORT TO SAUDI ARABIA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> BRITAIN WILL GIVE POLITICAL-SUPPORT TO IS.
===> UNLESS BRITAIN'S SUPPORT OF IS STOPS IMMEDIATELY,
SAUDI ARABIA WILL RESTRICT CREDIT TERMS
FOR OIL PURCHASES.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
------------------------------END OF MONTH------------------------------
                         YEAR= 1977 , MONTH= 11
```

```
PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH= 11          YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS    232,833,927 BBL.
AVG DAILY PRODUCTION WAS  7,761,130 BBL, 0.6434 OF CURRENT CAPACITY OF
12,061,000 BBL PER DAY.         CAPACITY INCREASED BY      95,000 BBL PER DAY.
CURRENT PROVED RESERVES 110,081,015,808 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY      95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=   1,313,728,838          INDEPENDENT SALE REVENUE=       67,085,263
SELLBACK REVENUE=    588,081,198           TOTAL NONTAX REVENUE=     655,166,462
TOTAL OIL REVENUE=   1,968,895,300


                               END OF OIL MODULE

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IRAN WILL SELL CONSUMER-GOODS WORTH $300,000,000 TO SA.
===> SA WILL BUY CONSUMER GOODS WORTH $300,000,000 FROM IRAN

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> USSR WILL SELL ARMS WORTH $5,000,000 TO SA;

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> UAE-INSURGENTS DISRUPS UAE.
*** ERROR *** UNRECOGNIZABLE WORD==> DISRUP

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> UAE-INSURGENTS DISRUPTS UAE.
===> IN LIGHT OF THE CURRENT SITUATION, SAUDI ARABIA
ASKS FOR WESTERN SUPPORT.
===> SAUDI ARABIA CALLS ON THE PEOPLES OF THE ARAB WORLD TO UNITE.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
------------------------------END OF MONTH------------------------------
                        YEAR= 1977 , MONTH= 12



PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH= 12          YEAR= 1977          ****************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS    240,580,150 BBL.
AVG DAILY PRODUCTION WAS  7,760,650 BBL, 0.6384 OF CURRENT CAPACITY OF
12,156,000 BBL PER DAY.         CAPACITY INCREASED BY      95,000 BBL PER DAY.
CURRENT PROVED RESERVES 110,425,014,272 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCRFASE CAPACITY BY      95,000
BBL PER DAY  3 MONTHS FROM NOW.

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=   1,357,435,680          INDEPENDENT SALE REVENUE=       69,317,143
SELLBACK REVENUE=    607,644,910           TOTAL NONTAX REVENUE=     676,962,053
TOTAL OIL REVENUE=   2,034,397,734


                               END OF OIL MODULE
===> SAUDI ARABIA WILL PURCHASE ARMS FROM USSR.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IRAN GIVES POLITICAL-SUPPORT TO UAE-INSURGENTS.
===> ECONOMIC AID TO IRAN WILL BE CUT
OFF IF IRAN CONTINUES SUPPORT OF UAE INSURGENTS

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> US WILL SELL ARMS WORTH $8,000,000 TO SA.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
------------------------------END OF MONTH------------------------------
                        YEAR= 1978 , MONTH= 1
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```
PTP OIL MODULE: DEVELOPMENTAL VERSION OF AUGUST 21, 1975.

MONTH=  1          YEAR= 1978              ******************************************

$$$ PRODUCTION STATISTICS $$$
MONTHLY PRODUCTION WAS   240,565,450 BBL.
AVG DAILY PRODUCTION WAS  7,760,175 BBL, 0.6334 OF CURRENT CAPACITY OF
12,251,000 BBL PER DAY.         CAPACITY INCREASED BY       95,000 BBL PER DAY.
CURRENT PROVED RESERVES 110,769,012,736 BBL.
   28,500,000 DOLLARS INVESTED THIS MONTH TO INCREASE CAPACITY BY       95,000
BBL PER DAY  3 MONTHS FROM NOW.
PROVED RESERVES MULTIPLIER IS  1.4299

$$$ REVENUE STATISTICS $$$
POSTED PRICE=  12.500          SELLBACK PRICE=  11.624 OR      0.9299 OF POSTED
 PRICE.
TAX REVENUE=    1,357,352,736          INDEPENDENT SALE REVENUE=         69,312,908
SELLBACK REVENUE=     607,606,459          TOTAL NONTAX REVENUE=        676,919,367
TOTAL OIL REVENUE=    2,034,272,104


                              END OF OIL MODULE
===> SAUDI ARABIA WILL PURCHASE ARMS FROM US.
===> IS THE US WILLING TO PROVIDE ARMS TO SAUDI ARABIA?

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IS WILL NOT ATTACK EGYPT;

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> IS WILL NOT ATTACK SYRIA.
===> SAUDI ARABIA LIFTS ALL OIL RELATED RESTRICTIONS.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EGYPT WILL NOT ATTACK IS.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> SYRIA WILL NOT ATTACK IS.

$$$ ENTER INPUT SENTENCE $$$
### INPUT ECHO ###=> EOM
------------------------------END OF MONTH-------------------------------
                        YEAR= 1978 , MONTH= 2
```

Arabia, US for the United States, and IS for Israel. Given the structure of the language, the simulation interprets Iran to be the author of the sentence. The simulation responds by citing past difficulties between Iran and Saudi Arabia, and asks for some sign of cooperation from Iran. The next input is the symbol "EOM," (indicating "end of month"). This symbol is used to increment the month. Unless the user enters EOM, the simulation clock will never be incremented. The EOM causes the month to be incremented, and the execution of the oil module.

According to the fiscal cycle of Saudi Arabia, July of 1977 is the end of the fiscal year. At the end of each fiscal year, the human resources and agriculture modules are executed, and a budget prepared. The decision module controls the human resources module by modifying the rates of transition among the occupation categories. The decision module controls the agriculture module by manipulating expenditures for irrigation development, fertilizer purchase, and mechanized farm machinery purchases.

The next section of the figure is the Saudi budget for 1978. After the budget has been settled, the simulation waits for user input. At this time the user enters a response to the Saudi request for a security-treaty. As a result, the Saudi decision module requests that Iran sell capital goods to Saudi Arabia. The next inputs are from the scenario library. This scenario is of an Israeli instigated Middle East war. The EOM in the scenario library causes the month to be incremented during the outbreak of hostilities. After the scenario has been entered, Iran again requests economic aid. The simulation responds affirmatively, and the user increments the month.

The next input is an offer by Iran to sell capital-goods to Saudi Arabia in response to the previous request of the Saudis. The simulation produces outputs requesting military aid from the United States, the acceptance of the Iranian offer, and a request for consumer goods from Iran. It must be emphasized that the simulation was not responding to the Iranian sale of capital goods with a request for U.S. assistance. The simulation was responding to the MIddle East war.

At this point, the scenario library was re-entered, and a scenario of Western support for the Israelis selected. The simulation responds with oil related sanctions against supporters of Israel, and an almost constant request for support from the United States. After the end of the month, the United States responds by refusing support to Saudi Arabia. The simulation responds with calls for support and asks the U.S. to reconsider its refusal.

After the execution of oil module for November of 1977, the Iranians offer to sell consumer goods to Saudi Arabia in response to the earlier request. In addition, the Soviet Union responds to the Saudi call for support with an arms offer. The next sentence illustrates the response of the simulation to errors in the input sentence. In particular, "disrupts" is mispelled "disrups". The simulation responds that "disrup" is an unrecognizable word and prompts for user input. The corrected sentence is re-entered. This sentence indicates that domestic insurgents in the UAE are active. The simulation responds with calls for unity and support.

After the execution of the oil module, the simulation responds favorable to the Soviet arms offer. The next sentence indicates Iranian support for the insurgents operating in the UAE. Saudi Arabia responds by threatening Iran with a cutoff of economic aid if this support continues. The simulation then receives an arms offer from the United States, presumably an attempt to counter Soviet influence.

In January of 1978, Saudi Arabia accepts the U.S. arms offer and requests continued support. At this point, the scenario library is re-entered, and the end of war scenario is given to the simulation. The simulation responds by lifting all oil related sanctions.

It must be emphasized that the responses produced by the decision module are sensitive to the order of the input sentences. Thus different responses would have been forthcoming had the sample input sentences been entered in a different order. For example, it will be noted that when Western support was given to Israel during the war, the United States was the last government to deny aid to Saudi Arabia. Had the United States responded sooner, the simulation would have immediately threatened the United States with Soviet support if U.S. was not given to the Arabs.

While this sample of the simulation behavior illustrates only a few of the input sentences and simulation response, it does provide a flavor of the capabilities and operation of the simulation. In particular, the example illustrates the interpretative aspect of the simulations' perception of the environment as well as the tendency of the simulation to respond to other than the immediate input sentences.

The utility of the simulation will, of course, depend to a large extent upon its "validity." Moreover, since the approach was specifically adopted out of a desire to model the complexity of Saudi decision-making, the validity of the simulation is difficult to assess. Nonetheless, it seems clear (at least in a "lessons learned" sense) that large scale social simulation efforts must be continually concerned with validity issues (e.g., see Brewer, 1974). The discussion of validation problems provided in Hermann (1967) is a very useful summary of the issues involved. Rather than repeat his points, this discussion will focus on problems specific to the "production system" approach described above and to the concern for doing mechanism elucidating experiments. If the research questions necessitated (and at some point they will) extremal experiments, then it would be critical to consider the problem of construct validity much more than has been done thus far. Ideally, each variable in the simulation would have several converging measures or indices. If observed values of a particular measure of the same variable, confidence is increased that the variable is being measured in a valid manner. For example, if the output of the agriculture module is operationalized as (1) reported number of bushels of wheat per acre, and as (2) reported number of bushels of corn per acre, the output construct is validated if both measures increase concordantly. If they do not, the definitions are not converging and therefore one or the other or both are not valid.

A second criterion important for evaluating simulations used in extremal experiments is the "precise" correspondence between the hypothesized relations among the variables in the simulation and those in the system being simulated. If the agriculture module hypothesizes that agricultural output will increase when the number of tractors is increased, then once both variables are defined, the correlated increases must be demonstrated to occur. Both construct validity and "hypothesis validity" are critically important to establish prior to doing extremal experiments since such experiments assume that both the variables are being measured "well" <u>and</u> that the functional form relating the variables is known (see Federov, 1972, p. 6). However, the simulation reported on here is viewed more as aiding in elucidating more macro-level or global attributes and behaviors. As a result, there are several validity issues which must be resolved prior to extensive consideration of construct and hypothesis validity questions.

It was argued earlier that it was necessary to model the internal structure of the government. Thus (using the language of Zeigler, 1970) the desire is not only to establish an input-output morphism between the production systems and the Saudi government but also to preserve certain internal processing relations intervening between inputs and outputs. Measures must therefore be established for bureaucratic variables as well as for external environment variables. For example, bureaucracies in the Middle East vary in their sophistication, and level of trained personnel. Thus their information processing capabilities also vary.

Moreover since the simulation hopefully will be developed from its present primitive state to a more "sophisticated" form, there is no point in applying very strict operational tests to the relations when fairly crude observations are sufficient to suggest needed restructuring. For example, the agricultural process model completely ignores the role of labor.

That is, yield is independent of the number of farmers. Nonetheless, it seems reasonable to require that the simulations be continually monitored in order to ensure a satisfactory final product. Fitting the evaluational criteria to the purpose of the simulation at various stages in its development is consistent with such monitoring. For example, thorough defining of converging measures of variables and statistical comparison of postulated with observed relationships among values on the variables is appropriate for evaluation of portions of the agriculture, human resources and oil production modules. That there is a positive correlation between number of tractors purchased and number of bushels of wheat produced is already directly testable. But for the decision module, and for other aspects of the external environment module, and for other aspects of the external environment modules, these procedures would be premature. There are at least two important reasons for this claim. First, for examining the output behavior of the decision module, a sophisticated description of the environment upon which it must act is required. Such a description is not yet available. Second, for evaluation of relationships the exact functional form relating variables must be specified.

Clearly, however, aspects of the module are amenable to other forms of evaluation even at its early stage of development. Townsend (1972) in comparing psychological information-processing models, suggests that the limits of what responses the models can produce is an important place to start in evaluating the models. This can be done at the simulation level only or at both a theoretical and an empirical level. For example, in the agriculture decision module, the amount of fertilization and number of tractors are constrained so that if one increases the other must also increase or remain stable. Whether such a constraint holds empirically is a question that can be investigated.

A second aspect of the simulation which can be evaluated is the degree to which it includes variables which are clearly relevant to the operations it is carrying out. Especially at an early stage of development such questions are crucial to ask of the simulation. For example, the oil production module takes only two inputs, budget for exploration and production. Perhaps skilled labor is also important for determining final production level.

One valuable source of information about what variables ought to be included has proven to be policy planners in the State and Defense Departments. These people are actively involved in monitoring the processes being simulated and, as a result, have formed "mental images" of these processes. Initial interviews were conducted to introduce ourselves and our goals to policy planners and to elicit from them their idea of key variables and the relationships between these variables. The overall intent of the interviews was to identify images in the areas of system identification, controls, and outputs. Interviews were performed in the Department of Defense's International Security Affairs and the State Department's Intelligence Research Groups. Subsequently, interviews have been held in the Defense Department's Policy Analysis and Evaluation Agency.

Initial interviews coupled with a preliminary analysis of relevant academic literature in the areas of oil production, agricultural economics and human resource economics produced initial flow diagrams. These flow diagrams were used to generate responses, in terms of agreement or disagreement with the relationships demarcated, from the interviewees. Several of those interviewed responded with helpful suggestions. Unfortunately most of those interviewed (not surprisingly) found the flow diagrams difficult to work with or were reluctant to comment until they could assess what the relationships led to in terms of specific output.

The above considerations, then, are central to evaluational monitoring of the Saudi Arabian simulation. The decision module poses special problems. The difficulty in evaluating the module concerns possibilities for defining appropriate measures for the variables contained in the module. Two possibilities which may yield a considerable payoff will be discussed.

A first possibility lies in taking an event data approach to defining variables. As described by Burgess and Lawton (1972) this approach defines categories of communications (the "events") and then treats them quantitatively. For example, common event categories for action include diplomatic protest, give warning, protest, and break diplomatic relations. The event data analysis is potentially advantageous to simulations such as the one described here because it does allow quantification of aggregate behaviors. Existent event data are, unfortunately, not directly usable in the Saudi Arabia simulation because, first, no one has collected data on all or even many of the events directly relevant to the simulation. Secondly, it is hypothesized in the simulation that information is processed in a culturally dependent way. This means that the access interface of the module itself must determine the coding strategy for identifying and categorizing events. Finally, much of the event data analyses currently available use categories which are too gross for what is needed in the decision module. A minimal unit of analysis appears to be the bureaucracy. Once the level of analysis in events data is established, and the events categorized, it is impossible to regain a finer-grained level of information. In spite of these problems, the events data approach seems a potentially fruitful one to try, in that it does allow the abstracting of behavioral occurrences into a usable quantitative form.

A second possibility for measuring variables in the decision module hinges on the module's observation interface with the external environment. The interface operates on the external environment, e.g., the two constraints and their qualitative measurement discussed above, producing a filtered "picture" for the decision module. This process can be indexed by comparing, for example, New York Times descriptions of events to reported perceptions of those same events by Saudi officials and in Saudi technical reports. Once the events data analysis has allowed categorization of Times descriptions, they can be compared to event data analyses of reported perceptions inside Saudi Arabia.

Before event data descriptions can be usefully employed, the language processing capabilities of the simulation discussed above must be implemented. Once the basic language has been specified, the resultant taxonomy of events will allow event descriptions to be coded into the language of the simulation for comparison. In addition, the outputs from the decision module (sentences in the language) can be coded according to existing event data coding schemes. Thus while current event data collection efforts are not directly relevant, the simulation outputs can be made comparable to existing data collections.

In addition to the general problems of validity, there are three questions that pertain to validity that can be asked of the structure of the decision module for the Saudi Ministry of Agriculture. The first is: Does the production system faithfully reflect the manner in which the Saudi's process information about the environment? This question has several implications. It is the case that the Saudi's make the sorts of distinctions about the information they received that the model assumes that they do? In the production system, an explicit scale is used to represent knowledge about the environment. Additionally, the production system invokes an explicit model of how the environment will respond to various decision module outputs, e.g., levels of the various budgets. The second question is: Are the descriptions of the environment in the decision module consistent with those that the Saudi's use to describe the environment? For example in the decision module, the two variables upon which the description of the environment are based are the fertilizer and mechanization constraints. The third question is: Are the information capabilities assumed for the decision model consistent with the capabilities of the Saudi's? In other words, do the Saudi's have the capability to determine the fertilizer and mechanization constraints. Given that the Saudi's do not currently have the bureaucratic ability to determine the population, it may not be reasonable to assume that the bureaucracy has the capability to perceive these two constraints.

Apart from the validity issues, the general question of the policy relevance of simulations of the type described in this report remains to be discussed. It appears that the simulation discussed in this report facilitates policy planning in several important ways.

First the production system format, condition--action statements, provides a natural representation of "if-then" beliefs about the world that policy makers might have. The condition portions of the productions refer to states or descriptions of the environment, while the actions refer, for the most part, to governmental behavior. In addition, the symbolic basis of the productions requires no knowledge of statistics or mathematics.

Second, within the social sciences, very few models maintain an explicit control perspective. However, to the extent policy makers are primarily interested in how various policies might be used to produce intended effects in the environment, a control perspective is required. The simulation, described above presents the policy maker with a simulated world, much like the world he sees himself facing.

Often, computer simulations present the policy maker with a set of numerical parameters to manipulate. The structures of such simulations require the user/policy maker to provide interpretations of the numerical parameters and to relate the parameters to the actions of governments. The Project simulation, however, presents the policy maker with a simulation that can be communicated within a language very close to English. In proposing proper or acceptable inputs to the ismulation, the user need not learn any special computer language or esoteric set of rules for entering information into the simulation. Instead, the user may rely upon his existing facility with English to construct inputs to the simulation. As a reuslt, a natural interaction pattern is established, with the user and the simulation communicating with English-like sentences.

A final sense in which the Project simulation increases the access and utility of computer simulations to the policy maker is in its linguistic representation of governmental action. The user needs no special instruction to interpret the output of the simulation. Moreover, governmental action is frequently described in linguistic and symbolic terms. In the simulation, this linguistic character is preserved. It would be expected that the linguistic capabilities of the simulation would lower the costs involved in learning to interact with and use it.

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THE PROJECT FOR THEORETICAL POLITICS SIMULATION

USER'S MANUAL

RELEASE 1.0, JUNE 21, 1976

WRITTEN BY FRANK E. MILLER

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1. EXECUTING THE PTP SIMULATION

The following steps are required to execute the PTP simulation:

1. You must be logged on ts0032. To logon ts0032 type:

   logon ts0032/XXXXXX id(XXXXXXXXXX) f(ad23) p(ptpuser)

2. Enter: ex system(ptpinit)

   This entry will initialize the simulation data files to the 1974 values.

3. Enter: sub system(spitcom)

   This entry will submit the simulation as a batch job.

4. Enter: ptpcom

   This entry will allow you to establish communication with the batch job. You have ten minutes from the time the submitted job begins executing to enter this instruction. The batch job is execution class B, so if there is a large B queue, the delay may be considerable.

PTPCOM will notify you when communication has been established. The first thing you should see after communication has been established is SPITBOL system output. After this has been displayed, the oil module will execute. After the oil module output has been displayed, the simulation will prompt for input by displaying the following: $$$ ENTER INPUT SENTENCE $$$. At that point there are two types of information that can be entered: control information and input sentences. The user should refer to section 2 concerning the valid grammatical constructs of input sentences before attempting any input of this nature to the simulation. In addition, the user should thoroughly examine section 3 describing control information that is either required or optional, to see what he must supply to the simulation as required input.

The aforementioned procedure for executing the simulation (logging on) is not unique. An alternate method for step 4 of the logon procedure will allow the "scenario" processing feature of the simulation to be executed. Processing of this nature is described in section 3 under the subsection on input scenarios.

In the event that the user feels he will require more than the "average" amount of processing time (approximately a two to five year run of the PTP simulation), an alternate method for step 3 of the logon procedure has been provided. To execute this procedure, step 3 of the previously given logon procedure should be modified so that the user will instead enter the following information:

sub system(spitcom2)

This essentially changes the batch processing Job Control Information which is given as input to the computer. This particular batch job is execution class C, and may require even more time than the class B job to get in the execution phase. This modification to the logon procedure provides more CPU time on the computer to the end user. Thus, this will increase the simulation run time, as well as the cost, greatly, and therefore should be used with much discretion.

In addition to the terminal printout generated by the simulation at a particular TSO terminal, hardcopy (paper output) will also be generated. Hardcopy output may be picked up at Baker Systems Engineering Building on the fifth floor. The user should refer to section 3 on Control Information for various methods of generating output (i.e., various features of output of the simulation may be suppressed or generated as desired by the user).

2. INPUT SENTENCES

There are two major classifications of input to the PTP simulation. Those are: control information and input sentences. This section will only describe those inputs of sentential form. The user should refer to section 3 for control information. Input sentences themselves are further classified into two major categories: agentive sentences and stative sentences.

2.1 Agentive Sentences

2.1.1 Verb Types

Agentive sentences express an action on the part of some agent or agents. There are two existing types of agentive sentences which are recognizable by the simulation: verb2 and verb3 sentences.

A verb2 sentence requires two elements other than the verb within the sentence, hence, its name (e.g., IS attacks SA). This example has an agent (IS), a verb (attacks), and a second agent (SA). Although a verb2 or verb3 sentence in which the subject agent is the same as the object agent is lexically valid, and will be parsed as such, it makes no sense contextually for an agent to perform an action upon itself, and it will therefore generate an error message to that effect (see section 5 on error messages). Some lexically valid examples of verb2 sentences may appear as follows:

US recognizes PLO.

IS will attack EGYPT.

IRAN will not raid SYRIA.

A verb3 sentence requires three elements other than the verb (e.g., US will not sell arms to SA). This sentence has an agent (US), a verb (will not sell; tense will be discussed later), a noun (arms), and another agent (SA). Since the simulation language follows the same basic constructs of the English language, it is evident that verb3 phrases will require the use of a preposition. This is because sentences using verb3 verbs describe the action of some agent with reference to another agent. The required prepositions for this type of verb are found within the attribute list of verb3 verbs (see section 4) as follows:

BUY/V3/N(-ABSTRACT] + ABSTRACT) P(TO)/

The prepositions of the system: to, from, with; follow the corresponding verbs as they would in English. The following are lexically valid examples of verb3 agentive sentences:

US affirms security-treaty with IS.

Syria, Kuwait, Egypt sign peace-treaty.

France will give arms to Iran.

2.1.2 Sentence Tense and Forms

Due to the structure of the language recognizer of this simulation, the PTP language is a Context-Sensitive Language. Languages of this form are, by nature, restrictive in form. Therefore, for this simulated natural language to be parsed and interpreted correctly, the forms of the sentences given should be adhered to. As has been mentioned previously, the structure of the simulation language is very similar to English, although many of the special items such as articles (a, an, the), conjunctions (and, or), and adjectives have been omitted. Implementation of such features would have required more time and effort than was available and they were not essential to the operation of the PTP simulation. Since adjectives have been intentionally left out, the use of hyphenated words is provided to the user (see section 4 in the Table of Valid Lexical Entries). Although the input sentences may sound somewhat stilted to the user because of the lack of some English word-types, their meaning will be correctly interpreted by the simulation, provided they are listed correctly upon input into the simulation.

With respect to English grammar construction, various sentence types have been built into the simulation language. For verb2 and verb3 agentive sentences only, there are two verb tenses: present and future. In addition, the future tense may be either positive or negative (the latter is signified by the word 'not' in front of the verb). In accordance with grammar, the endings of verbs change appropriately with tense, and, the word 'will' preceeding the selected verb is used to signify the future tense (Note: this is the only word which can be used to show future tense).

Another form of the agentive sentence is the interrogative sentence. The agentive interrogative sentence is not to be confused with stative interrogative sentence (described in subsection 2.2.4). The agentive question is meant to represent one country posing a question to another. It may not be used as a query to the system. An example of this would be:

WILL US GIVE ARMS TO IS?

Since this is not to be interpreted as a query to the system, the user should not expect an immediate response from the system. One restriction imposed is that the question be in the future tense (i.e., the word 'will' must be used). In addition, all questions must naturally end with a question mark. It should be noted, in accordance with the above description of agentive interrogative sentences, that in the above example, the simulation assumes that 'IS' is the speaker (i.e., Israel is asking the U.S.).

Using a simple verb3 sentence as an example, the following shows the four major sentential forms outlined above:

US sells arms to SA.

US will sell arms to SA.

US will not sell arms to SA.

Will SA buy arms from US?

The second sentence of the above example is not wholly correct and represents a special case within the simulation. With the verb3 verbs 'buy' and 'sell,' a special clause may appear at the end of the sentence. This is the "worth" clause, consisting of the word 'worth' followed by an integer dollar amount. Failure to enter an integer dollar amount may cause system failure. An example of this is:

US sells arms to IS worth $1,500,000.

It should be noted that when the verb 'sell' is used in the future - positive tense and the second agent is Saudi Arabia (i.e., the action is directed towards Saudi Arabia), it is mandatory to include a worth clause. This is to insure proper recording within Saudi Arabia's budget (primarily used with military transfers).

Another sentential form is provided in the simulation language by the use of "joint" verbs. There are only two verbs (verb3) within this class of verbs: sign, affirm. To model a multi-lateral action, multiple agents may be used with a joint verb (e.g., US, IS, SA sign security-treaty). Bi-lateral actions may be represented by single agents and the preposition 'with' (e.g., US affirms peace-treaty with IS) or, as a multi-lateral (e.g., US IS affirm peace-treaty). Although one can express a bilateral action as a multi-lateral action, a multi-lateral can not be represented in the same form as a bilateral (e.g., US, IS sign military-agreement with SA; this statement is incorrect).

2.2 Stative Sentences

2.2.1 Description

A stative sentence consists of a state description of the environment of Saudi Arabia. Stative sentences are, therefore, the means by which the user may change the simulation parameters (i.e., the perception of the simulation concerning the affairs of Saudi Arabia. Note: these are not the Control Information to be mentioned in Section 3). If left unchanged by the user, these environmental parameters of the simulation will be set to default values (precomputed values based on 1974 statistics).

2.2.2 Types of Stative Sentences

There are two major types of stative sentences which can be interpreted by the simulation semantically: "level-types" and "rate-types." The first of these types may be described, generally, as prices or demands. The second type of stative sentence actually involves the setting of various rates (e.g., interest-rate, inflation-rate). Examples of the aforementioned stative sentences are given as follows:

Example Number	Stative Sentence
(1)	Oil price is $11.20 per barrel.
(2)	Wheat price is $72.20 per ton.
(3)	Fertilizer price is $.46 per ton.
(4)	Mechanization price is $120 per hp.
(5)	Oil demand is 7,700,000 barrels.
(6)	Interest-rate is 7%.

When assigning a price to a given noun, the price is assigned as per unit noun. The noun (e.g., oil, wheat, fertilizer) must first be a "value" noun before it may appear in an assignment statement of any nature. The simulation will parse the statement to check for this fact, and, if the assignment is a price stative assignment, it will check the stative sentence for valid units. Failure to enter the correct units for a given noun in this type of assignment (only required in a "price" assignment) will generate an error message to the user from the simulation (see section 5 on Error Messages). One can see from the above examples that the price assigned must be followed by the word 'per' and the unit for that noun. Value nouns appear in the table of valid lexical entries as follows:

OIL/NOUN,VALUE,UNIT(BARRELS)/-ABSTRACT -COUNT/

In a price assignment, a dollar amount preceeded by a dollar sign must be present. Generally, the first five of the above examples are the only way to enter these particular assignments, with variation permitted in the price assigned, only. When an assigned value is large enough, commas may be inserted as desired since they will be ignored by the simulation (to be described below).

2.2.3 Interpretation of Stative Sentences

The meanings of the first four stative sentence examples should be reasonably self-explanatory. The fifth example, however, shows no unit such as 'per unit time' (as it is not required in "demand" assignments). This is because the unit of time is understood (by the simulation) to be the unit used here(i.e., it defaults to a unit of time and cannot be changed). The unit of time used for such "demand" stative sentences is assumed to be daily.

The user should be aware that the simulation is very sensitive to changes in oil demand as presented in an assignment statement. In addition, there is no conception of seasonal fluctuation in oil demand. For this reason, average demand should be used in these assignments. To accurately simulate oil demand, this average demand assigned should reflect average demand as mediated by OPEC's informal allocation rules. The rate of Saudi Arabia's oil production yielded by the simulation will change one month after the oil demand has been assigned a value, at which time a value (more or less) equal to the assigned demand will be produced. Care should be used in assigning a value to oil demand, in that, if the demand is set too low, it may not be enough to support the Saudi system and may generate an appropriate error message. The same situation exists for price changes of oil (delay, etc.). The simulation simply accepts the price given from the stative sentence by the user and starts charging that amount. Thus, the user is responsible for accounting for OPEC changes. This responsibility is not assumed by the simulation.

The sixth example of stative sentence is a "rate-type" of sentence. For example, 'interest-rate' is meant to reflect the average interest paid to the Saudis on both its long and short term investments. Because of the lack of adjectives (mentioned before), the string 'interest-rate' must include the hyphen (the same is true for 'inflation-rate,' the only other "rate-type" noun which may be assigned a value from a stative input sentence). There are two equivalent variations permitted in entering the interest-rate (and inflation-rate):

e.g., Interest-rate is 7%.

Interest-rate is .07.

The unit of time assumed for these assignments ('interest'/'inflation') is 'per year' and may not be changed.

The stative sentences shown in the previous sections may be entered at any time during a run of the simulation. They may be readily interspersed with the aforementioned "agentive" sentences. Again, the user is cautioned to beware of the values he uses in these assignment statements. The examples which were shown before gave the actual default values taken on by the associated variables to which they were assigned, a fact the user might be able to incorporate into his own particular execution of the simulation. Also, these values may be used to give the user an idea of the type of value required for a given variable should he wish to change it. The user should also remember that there is a delay in response to some of the input stative sentences, but that it (any changes made) should have to be put into effect by the time a month has been processed on the simulation. Again recall that unless these variables are changed (those shown in the examples), they will remain "in effect" throughout the execution of the simulation.

2.2.4 Stative Queries

Unlike the agentive question, the stative question is a direct query of the system. An immediate response should be expected by the user. The stative query is provided so that the user may inquire about the current values of stative variables (e.g., 'OIL PRICE,' 'INFLATION RATE'). It should be noted that only those variables which may be manipulated by the user can be queried. These variables consist of all the 'PRICE' information, 'OIL DEMAND', and 'INTEREST RATE.' An example of the stative query is as follows:

'WHAT IS OIL PRICE?'

Note that the article 'the' is not included because it is not recognized by the system. If the query cannot be handled, a message to this effect will be printed. Again, the question mark is required as an end symbol to this kind of query.

2.3 Sentence End Symbols and Delimiters

The grammar of the simulation can be viewed as a natural language, as was mentioned previously. By this analysis, there is an alphabet associated with the grammar permitted by the simulation. This alphabet consists of the twenty-six letters of the English alphabet, the ten arabic numerals, blank, hyphen, the special characters '$' and '%', commas, and valid sentence end symbols. Any characters other than the above will not be recognized by the simulation and will generate an 'unrecognizable word' message. The use of numeric quantities, hyphens, and the special characters '$' and '%', is given in subsections 2.1 and 2.2.

2.3.1 Positional Delimiters

A positional delimiter is defined here as those symbols which may be given by the user within input sentences to separate words or phrases. The symbols of this class are the blank and the comma. Both of these symbols may be written as frequently as desired by the user. However, like any higher level programming language, there must be rules to govern the use of these characters. Their allowable appearances within input sentences is described below.

Commas may appear absolutely anywhere in an input sentence. This is because the simulation grammar will completely ignore them. However, when parsing input sentences the grammar will replace all commas with null strings, an action which may produce erroneous results to the sentence. An example of this may be shown as follows:

Input Sentence:

US,IS SIGN FRIENDSHIP-TREATY.

Sentence After Commas Are Removed:

USIS SIGN FRIENDSHIP-TREATY.

The string 'USIS' will not be recognized by the simulation as a valid actor, and will produce a message to this effect. Therefore, each comma which delimits words must be followed or preceeded by at least one blank. The exception to this is shown in section 2.2, within stative sentence assignments. That is the case in which commas are used to keep track of positions within numeric strings (e.g., $7,700,000). In these cases, placing blanks before or after commas in numeric strings will yield unrecognizable numbers. Hence, blanks should be omitted surrounding commas in numeric strings.

Blanks, on the other hand, may only appear between words (here a numeric string or dollar amount string is considered a word). In addition, as many blanks as desired by the user may be put in input sentences, as long as at least one blank appears between two words.

2.3.2 Sentence End Symbols

Depending on the type of input being done, the input string may or may not require an end symbol. Both sentences and control information may be entered into the system. Control information does not require any end symbols. Input sentences, on the other hand, do require end symbols. The valid sentence end symbols are the period(.), the semi-colon(;), and the question mark(?). If a sentence is entered without any end symbol, an error message will be produced. NOTE: If parts of a sentence (i.e., object-agent, prepositional phrases if required, etc.) are missing, the simulation will trigger a 'missing end symbol' message here also.

Each of the sentence end symbols has a special significance. A period at the end of a given user input sentence will inform the simulation that "normal" processing of the sentence is to take place. This implies that the sentence is to be parsed by the simulation grammar, interpreted semantically, and run through the set of simulation productions.

A semi-colon used as an end symbol causes the sentence to be parsed and interpreted but not run through the simulation productions. With this end symbol, the user may simulate parallel actions taking place. That is, the interpreted meaning of all input sentences with semi-colons will be perceived by the system, but, the system will not proceed with any operation on these inputs until the next sentence with a period or a question mark is entered, at which time all of the interpreted sentences will effectively be operated on. Therefore, the semi-colon signals the simulation that batched input is to occur.

A question mark informs the simulation that the associated sentence is a question. Questions are described in detail in subsections 2.1.2 and 2.2.4. Since it is mandatory that each query must end with this end symbol, no other end symbols may be used to replace it. Thus, batched input is not possible with queries.

2.4 Simulation Agents

The construction of agentive input sentences (described in subsection 2.1) requires that verb2 sentences have at least one agent, the principal "do-er" of the action given in the sentence, while verb3 sentences must have at least two agents, the principal "do-er" of the action and the "receiver" of the action. There are exceptions to these rules. Some verb2 sentences may have a second agent, the "receiver," while some verb3 sentences may have more than two agents (see subsection 2.1.2 concerning "joint" verbs). All of the agents mentioned above must come from the list of valid actors (agents) of the simulation. In addition, when writing these agents within input sentences, the user must be certain to use the correct character string representation of the agent's name (i.e., neither 'United States', 'Saudi Arabia', nor 'Soviet Union' will be recognized by the simulation). If a character string representation of an agent is used which is not in the table of valid simulation actors an 'UNRECOGNIZABLE WORD' message will be produced. The user should refer to section 4 (PERMITTED VOCABULARY) for the correct character string representation of the allowed agents within the simulation.

2.4.1 Execution Time Agents

When the simulation first begins execution, certain knowledge, which may be viewed as the "perception" of "state knowledge" of Saudi Arabia, it is initialized by the system. Some of this knowledge pertains to the relation of Saudi Arabia with the other agents of the system. The following categorical relationships are set up:

ALLIES (of Saudi Arabia): US, France, Britain, Sweden, Egypt, and Syria.

The following geographical relations are set up:

MIDEAST: Israel, Egypt, Syria, Iran, United Arab Emirates, Iraq, Kuwait, PLO.

WEST: US, France, Britain, Sweden

WARSAW: USSR

Note that not all of the simulation actors are used here (see section 4).

2.5 Default Simulation Values

It is most reasonable to assume that there are many variable parameters controlling the operation of the PTP simulation. Some of these parameters may be changed by the user (see subsection 2.2 concerning stative sentences). Other variables can be only changed by the simulation itself. Still another kind of these variables may not change during the course of the simulation at all. The following is a compiled list of some of those variables of the simulation and the initial values given to them by the simulation. The user should refer to subsection 2.2 under "Stative Sentences" in conjunction with section 4 (PERMITTED VOCABULARY) to see which of these parameters may be changed. These variables are as follows:

State Variable	User Controlled	Initial Value
Oil Demand	Yes	7,700,000 barrels/day
PAPC*	No	.8149
DPIR*	No	95,000 barrels/day
Oil Posted Price	Yes	$11.651 per barrel
Wheat Price	Yes	$72.20 per bushel
Fertilizer Price	Yes	$0.47 per ton

State Variable	User Controlled	Initial Value
Fertilizer Demand	No	15,000 tons
Mechanization Price	Yes	$120 per horsepower
Mechanization Demand	No	5,000 horsepower
Irrigation Allocation	No	$500,000
Long-Term Investments	No	$53,328,766.00
Short-Term Investments	No	$362,857,252.00
Foreign Aid Budget	No	$10,000,000
Military and Defense Budget	No	$7,000,000,000
Month	Yes (by EOM)	8
Year	Yes (by EOM)	1974
OPTIONS IN EFFECT**		'OILPRINT'

*Refer to Project for Theoretical Politics Working Papers #15, 23 for description.

**Refer to section 3 on Control Information (LISTOP command).

3. CONTROL INFORMATION

The execution of the simulation is dependent upon a batch processing link with time sharing. Thus, breaking this link will cause the simulation to cease operation. At the time when the user receives the 'COMMUNICATION HAS BEEN ESTABLISHED' message, the aforementioned link is built and the simulation enters the PTPCOM mode. This mode of operation is restricted to simulation operation only. That is, the user is no longer in control of any system time sharing features and cannot access them. He may, at this time, only enter input and receive output from the simulation. The user should be aware of this restricted operation.

3.1 Required Control Information

3.1.1 Ending the Simulation

To terminate the simulation, the user must enter the character string '/*' (without quotes). This method of termination may be used whenever the simulation prompts the user for input. Special cases exist when "scenarios" are being processed (to be described in a later section). The user may enter this even when he is not prompted, if it can be entered between output from the simulation, but this is generally not suggested. Entering symbols (or sentences) when not prompted for them by the simulation has the effect of "staggering" the input. Generally, if more than two lines of input are staggered at the terminal, the simulation will have an Abnormal Termination (ABEND).

The effect of entering '/*' (without quotes) is to break the batch-time sharing communications link, and, to return the user to normal time sharing processing. The user, at this time, may now use all of the time sharing features available to him at the beginning of the session. It should be noted that the communication link is not known to be broken until a 'READY' message is received at the terminal from the system. If, at any time during the execution of the simulation, this 'READY' message is received, the user should recognize that the link is broken, and, if desired, repeat the entire process of re-submitting the simulation as a batch job (refer to section 1). Since wait-time in the job queue is usually long, one can see why it is undesirable to have a restart the simulation in this manner.

3.1.2 Abnormal Job Termination (ABEND)

There are several things which may cause the simulation to ABEND. One of these situations, "staggering input", is described in subsection 3.1.1. Another cause for abnormal termination is the over-running of the time parameter (of the

SPITBOL decision module). If the user has entered the simulation by way of SPITCOM, and receives an ABEND, he may be attempting to process too many years of the simulation or he may be simply processing too long. This situation may be corrected by using SPITCOM2 as described in section 1.

An ABEND may also be caused by the SPITBOL decision module if too many statements are executed during a particular run of the simulation. The current allowed limit is 268,435,456 statements, and should be sufficient for normal processing. Note here that this statement limit refers only to the number of SPITBOL statements executed, not the number of input sentences passed to the simulation. Any error messages received from the SPITBOL decision module concerning the statement-limit should be reported to the authors. Pressing the attention key on the terminal will cause the PTPCOM mode to terminate, thus breaking the communication between the batch job and the time sharing terminal session. This will also cause the batch program to ABEND. Abnormal terminations of the previously described form should be avoided if at all possible. The user should note that if he has overrun the time parameter, the simulation may cease operation at any point. If this occurs in a sector module (PL/I), the data returned to the SPITBOL decision module would be erroneous, and, an error message would be printed such as '***ERROR***ILLEGAL DATATYPE'. STI errors may also occur if the time parameter is exceeded. Again, the solution here is to use the SPITCOM2 submittal method (refer to section 1) instead of SPITCOM. This is not actually an error in the simulation system. If the problem is not rectified, report the situation to the authors.

3.1.3 End of Month (EOM)

The character string 'eom' (entered without quotes) signals the simulation that the current month has ended. This symbol is necessary to simulate time sequence actions within the simulation. The effect of this instruction is to increment the month by one, and execute the oil module. Note that the month will not increment without the entry of eom. The actions of some sentences require more than one month to be completed. Thus, the user should enter eoms to observe all of the results of given input.

To receive any output from the oil, agriculture, human resources, or budget modules, it is the user's responsibility to enter eoms. All of these modules, except for the oil module, process and print at the end of the Saudi fiscal year (the oil module prints monthly, see above). In order to simulate a Saudi fiscal year, 12 or 13 eoms must be entered. Because of the nature of the calendar used by the Saudis, the beginning of the fiscal year changes. Every fourth year is a thirteen month year. The simulation knows this and behaves accordingly. After the appropriate number of eoms have been entered, the simulation will initiate the execution of the agriculture, human resources, and budget modules, in addition to the output from the oil module for that month.

There is virtually no limit to the number of statements (input sentences) which may be entered between entering eoms. For accurate modeling, however, it is desirable to control the amount of user input at these times. It is not necessary to enter any other input eom's. This may be used to observe the time-wise production of Saudi Arabia with no interaction. However, it should be remembered that it is the user's responsibility to signal the end of a month to the simulation.

3.2 Optional Control Information

3.2.1 Short Term Image (STI) and Productions

All optional control information for the simulation mentioned in this section refers to output listing control of the decision module.* One of these

*For discussion of the decision module, see PTP Working Paper #13.

structures within the decision module, the short term image, whose printing is controlled by the parameter 'PRINT' (to be described later), should be described here for clarity to the user. The short term image is actually a SPITBOL data structure representing the memory of Saudi Arabia. A piece of state knowledge, existing in the character representation form of a production (e.g., 'M.C110'), resides as one element in the short term image. The simulation keeps track of the head of each STI, and, therefore has recollection about what is most recently learned or known by Saudi Arabia. The head of the STI is linked (in a list-like fashion) to each following element in the STI. Thus, the simulation is able to manipulate the entire STI, knowing which element is which. A listing of the STI would show several separate and distinct elements.

Productions are statements which test the contents of the STI or change the contents of the STI (Condition and Action, respectively). It is the changing of the STI which simulates the knowledge which is currently known by the Saudis. For the contents of the STI to make any sense, however, the user must have a list of various productions used by the simulation and their corresponding codes. The production systems are the means by which the decision module actually makes logical choices of action. In addition the SPITBOL decision module keeps track of the location of the productions being executed at a given time, and, the type (Condition (c), or Action (a)) of the production.

There are several STI in the simulation described as follows:

STI Name	Number of Elements	Type
DM.STI	5	Development or Misc.
AG.STI	15	Agriculture
HR.STI	15	Human Resources

STI Name	Number of Elements	Type
FA.STI	5	Foreign Aid
BUD.STI	20	Budget
MILIT.STI	25	Military and Defense
ECON.STI	25	Political/Economic

The user may not directly manipulate these STI, but, may observe the contents of them at any time during the execution of the simulation. Methods for doing this are described in the following sections (see 'PRINT').

3.2.3 Optional Simulation Control Inputs

Simulation control symbols, in the same manner as the required control inputs, may be entered as input to the simulation. These control statements may be entered any time the simulation prompts the user for input. The user should note that the spellings of the control statements must be correct for the simulation to interpret them correctly. In addition, these symbols must not be entered with any sentence end symbols. The actions (i.e., system responses), which these statements control, will come into effect immediately after entering them. The optional simulation control parameters are as follows (when entered they must not have quotes around them):

'PRINT'/'NOPRINT' - The 'PRINT' parameter to the simulation, if entered, will cause each change in the short term images (see subsection 3.2.1) to be displayed. This will generate output each time a production executes in which a reference to any STI is made. Each element of the current STI, at the time of the execution of a given production, will be printed according to its position within the STI. The production elements within the STI are in coded form and will make little sense to the user unless he has a listing of the simulation productions and their corresponding codes. It is for this reason, and the fact that this option produces large amounts of output, that its use is suggested to be limited. This option may be "turned off" by its default value, the 'NOPRINT' parameter.

'ECHO'/'NOECHO' - The 'ECHO' command signals to the simulation that each input, following this command, is to be printed at the terminal <u>and on hardcopy</u>. It should be noted by the user that user input (including control information) will not appear on hardcopy if this parameter is not "turned off." After a run of the simulation, any hardcopy (paper output) from the simulation may be picked up on the fifth floor of the Baker Systems Engineering building under TS0032. The default value for this parameter is 'NOECHO'.

'KERNEL'/'NOKERNEL' - This parameter prints the semantic kernel (interpretation) of the current input sentence generated by the simulation grammar. For this parameter to be used effectively, the user must know the general form of the semantic kernel. A semantic kernel has the following form for the <u>agentive</u> input sentences:

Kernel-type(Agent1,(Agent2),(Object))/Tense,Sign/Dec[Int] (Agent1)/

Agent1, agent2, object of sentence, tense of sentence, and sign (positive or negative) are described in subsection 2.1. DEC refers to whether the sentence is <u>declarative</u>, and, INT refers to whether the sentence is <u>interrogative</u>. Note that only one of the pair [DEC,INT] will appear in the kernel. The agent of this clause is the primary agent of the sentence. The form of the semantic kernel for the stative sentence is as follows:

Kernel-type(Noun assigned the value,Value assigned)

The possible values for Kernel-type reflect the nature of the input sentence. These possible values within the realm of the simulation are as follows:

Values of Kernel-type	Sentence Type
'RATE'	Stative
'LEVEL'	Stative
'TRANSFER'	Agentive
'ALIGN'	Agentive
'SUPPORT'	Agentive
'FORCE-DISPLAY'	Agentive
'ATTACK'	Agentive
'RECOGNIZE'	Agentive

This parameter has a default value of 'NOKERNEL', and may be turned off by the same. This parameter may be of interest if the user desires to observe the internal workings of the simulation grammar.

'COND'/'NOCOND' - This parameter may be given by the user to print the conditions (c) and the actions (a) of any productions executed. In addition, the <u>location</u> of said condition or action is printed. This location is the location within the SPITBOL decision module source code. Once this keyword has been activated, the parameters of each 'TRUE' (satisfied) condition and the associated action statement parameters will be printed (see subsection 3.2.1 for description of productions). This parameter is in effect until it is turned off by the associated 'NOCOND' parameter. The possible production locations within the decision module when the 'COND' parameter is "turned on" are given as follows:

Section Within Decision Module

Initialization

Interpretation

Military

Economic

Oil

Agriculture

Human Resources

Budget

Foreign Aid

Development and Miscellaneous

A sample output from the PTP simulation using this parameter may appear as follows (e.g., in this example it is given that the satisfied condition statement was in the 'INTERPRETATION' section of the decision module):

C -- INTERPRETATION == NOT(E.C37(US))

A -- INTERPRETATION == E.C1(US)

It should be noted again by the user that a knowledge of possible simulation productions as outlined in subjection 3.2.1 would be helpful here.

'OILPRINT'/'NOOILPRINT' - The 'OILPRINT' keyword permits the user to suppress the output from the PTP oil module, which currently prints on a monthly basis. All monthly output from this module (this does not apply to the hardcopy output - paper output, it is still generated, while the terminal printout is not) except that which occurs in the last month of the Saudi year (month = 7, or, every 4th year, month = 8) will be suppressed. Like the other parameters, this option may be turned on or off at the desire of the user, but, as mentioned prior, the last month of the Saudi year will print automatically. It should be noted by the user that he will still receive the output of the end of month message and the output displaying the current month and year. This parameter will suppress a considerable amount of output from the simulation. The default value for this parameter is 'OILPRINT.'

'LISTOP'- The 'LISTOP' keyword may be used to print which of the previously mentioned optional simulation parameters are in effect at a given time. If they are in effect, the keyword name for a given parameter will be given (e.g., 'COND'), if not, the second negated form of the keyword for a given parameter is given (e.g., 'NOPRINT'). Thus one of the two values of each parameter pair (e.g., 'ECHO'/'NOECHO') will be printed by this command.

All of the simulation optional parameters are recanted in the following table along with their default simulation values. Note that these values will not change unless changed by the user. The optional parameters are again as follows:

Optional PTP Simulation Parameters

Keyword of Parameter Pair	Default Value
ECHO/NOECHO	NOECHO
KERNEL/NOKERNEL	NOKERNEL
COND/NOCOND	NOCOND
PRINT/NOPRINT	NOPRINT
OILPRINT/NOOILPRINT	OILPRINT
LISTOP	[does not apply]

3.3 Scenario Processing

3.3.1 Definition

A scenario is a preplanned organization of input sentences prescribed by the user to model a predetermined set of events. A scenario may consist of any of the allowed user inputs of normal processing (see section 2, subsections 3.1, 3.2). Within the bounds of the PTP simulation, a scenario may only exist as a member dataset of a "partitioned dataset." Users should refer to other computer manuals for a definition of partitioned datasets. In addition to this requirement, all scenarios which are to be processed within one run of the simulation must be members of the same partitioned dataset. That is, the user may only specify one partitioned dataset as the "scenario library" for a given run, and, the system automatically searches this library for the given scenarios requested. Other scenarios libraries (other partitioned datasets) may of course be kept, but will not be searched by the PTP simulation.

3.3.2 Specifying Scenario Libraries

For the user to inform the simulation that scenarios will be read during execution, the user must enter the execution mode PTPCOM. This mode is entered as follows:

ptpcom-mode lib(fully qualified partitioned dataset name)

where:

ptpcom-mode is: PTPCOM

lib(XXXXXX) is: the scenario library name to be searched.

An example of this is as follows:

ptpcom2 lib(ts0538.lib.data)

It is not necessary to specify the fully qualified name if the user is logged on TS0032. Nor is there any big difference in using TTY compatible characters of lower case characters. In the example above, the simulation would note that 'TS0538.LIB.DATA' is the scenario library and would search there for specific scenarios requested during the course of the simulation. Other user requirements for scenario processing exist only after execution has begun and are listed below.

3.3.3 Specifying Scenario Members

As is mentioned in subsection 3.3.1, an individual scenario exists as a member dataset of the scenario library dataset. Providing that the correct execution modes were specified, the user may request the processing of individual scenarios any time after he is first prompted for input by the simulation (i.e., $$$ ENTER INPUT SENTENCE $$$). Thus, once execution has begun, a user may input a scenario request in place of an input sentence, at any time. This request must appear as follows:

=member name

where 'member-name' is the partitioned dataset member of the library which is scenario desired. For example, if a scenario library, TS0538.LIB.DATA, contained three scenarios as member datasets, CRISIS, IG238, WEATHER; the user could request them in this fashion:

$$$ ENTER INPUT SENTENCE $$$	(simulation input prompt)
.	
=CRISIS .	(user response)
.	
=IG238 .	"
.	
=WEATHER .	"

The scenarios will begin processing immediately after the reference has been made. In PTPCOM2 and PTPCOM3 this processing cannot be halted until all of the sentences in the scenario have been read and the simulation prompts the user for input. It should be noted that the simulation will print out the user prompt after each scenario sentence but will immediately read the next scenario sentence onto the input stack. Thus, the user should wait until he is certain that the last sentence has been read before further entering any input. The execution mode PTPCOM4 allows the interrupting of scenarios (see below), but, if the interrupt key is hit in PTPCOM2 or PTPCOM3 (or PTPCOM), the simulation will most likely terminate or a terminal "lockout" condition may occur.

In addition to making scenario requests as user input, the user may place such a request directly in a scenario (as one of the input sentences). This can be done in such a way as to build a large scenario out of several existing smaller ones. However, the user should confirm the existence of his scenario datasets before attempting to reference them within the simulation, since, once the simulation has started, it is not possible to "list" the contents of a dataset. The user should also take care not to devise a circular reference which would result in an infinite loop. This may be seen in the following example:

=IG1 (within member IG2)

=IG2 (within member IG1)

The system is not equipped to recognize such a condition and it will clearly result in much grief if it is permitted by the user to exist in his scenarios.

It is suggested that the first statement in user scenarios is 'ECHO' (see subsection 3.2.2). Otherwise, the sentences coming from the scenario will not be displayed at the terminal or on hardcopy. Thus, if the user does not know his scenario, verbatim, he will not know of its contents (other than output sentences generated by the simulation) without this command. These scenarios may also contain any other valid input sentences including control information and scenario references and may therefore represent a wide variety of modeling. Since the scenarios require no user intervention during their execution, the processing time is greatly optimized as well as the throughput volume of the simulation. This processing method is then suggested as a viable alternative, in lengthy simulation sessions, to continuous user input.

3.3.4 PTPCOM, Interrupt-handling Execution Mode

Using PTPCOM enables the user to interrupt the execution of the scenario during its processing. It should be noted that input from the scenario is placed on a stack once it is read from the dataset but before processing. Thus, to interrupt the scenario, the user must press the attention key once and wait until the rest of the stack has completed processing. This may take some time, but will readily be recognized as the simulation will print a message:

ATTN INTERRUPT ==])

Pressing the attention key repeatedly (rapidly) may result in control being returned to the terminal monitor program (i.e., a READY message). It should be noted also that this attention exit is not available until the batch/time-sharing interface link is built (see first paragraph of major section 3).

The user may also build the attention into a scenario by placing the string '=*' (without quotes) as an input sentence in a scenario. This will cause a simulated attention interrupt. The user may then enter the optional interrupt commands (as with regular interrupts) as described below. It should also be noted here that these are not legitimate terminal commands but, rather, special PTP system commands which are designed for use on the PTP simulation and are only valid in such a system environment.

Once an attention interrupt has been acknowledged (attention message printed), the user may do one of the following:

a.) Send statements directly to the simulation.

b.) Delete the rest of the scenario (see below).

c.) Resume the scenario (press carriage return).

d.) Terminate PTPCOM -mode (enter '/*', without quotes)

e.) Send a new scenario and then resume the old scenario (enter: =new-member)

The string '=/*' (without quotes) may be used to delete the scenario stack once an interrupt has been acknowledged. The user may then enter input sentences as normal. This string may also appear directly in a scenario, although there is no apparent reason to do so. There is a great deal of flexibility associated with scenario processing, and, if used effectively, it could be an imaginative modeling tool.

4. PERMITTED VOCABULARY

The following section lists all of the permitted vocabulary of the PTP simulation. Words, such as 'WILL' (used in questions and to designate verb tense) and 'IS' (verb form used in noun value assignments, not Israel), are not shown. All words may be entered in the same manner as shown (words are shown before the first slash of each lexical entry) with some exceptions. The verbs with asterisks ('SIGN', 'AFFIRM') should be entered without asterisks and are the regular forms of said verbs, as opposed to the other form, the "joint" form (described in subsection 2.1.2). This non-joint form requires the use of the preposition 'WITH'. Other exceptions are two actors ('UAE-INSURGENTS', 'KUWAIT-INSURGENTS') which appear as plural forms but should be regarded as singular. Thus, like other actors, these require verbs in the first person singular form, although such a form will sound odd (e.g., 'UAE-INSURGENTS RAIDS SA').

4.1 Attribute Groups

Each noun entry is listed with specific simulation attribute groups. Each verb entry is listed with the verb type, the attributes of associated nouns, and required prepositions (only in 'verb3' type verbs). In addition to nouns and verbs, actors and prepositions are listed (which have no attributes). The user can then design lexically valid sentences by matching verb and noun attributes.

The first set of noun attributes (which appear between first and second slash) describe the wordtype ('NOUN'), whether it may be used to assign a 'WORTH' clause ('WORTH'; see subsection 2.1.2), whether it may be assigned a value ('VALUE'; see subsection 2.2.2), and if used in a value assignment, what type of units (e.g., 'PER TON') must be specified ('UNIT(. . .unit. . .)'). The second set of noun attributes (appearing between the second third slash) reflects the nature of the noun in question, such as whether it is an abstract noun (e.g., 'MILITARY-AID') signified by '+ABSTRACT', or non-abstract signified by '-ABSTRACT', and whether the noun can be given in countable units ('+COUNT') or not ('-COUNT'). Some of these attributes are optional, which can be readily seen, but, the last two of these attributes mentioned will usually appear.

Verb attributes are somewhat more simple. First, the type of the verb, as described in subsection 2.1.1, is listed. This section is followed by a general attributes section (between the second and third slash). The attributes of nouns which may be used as objects of these verbs are listed (e.g., 'N(. . .attributes. . .)'). These attributes must be present in the noun entries. An error message will be produced for verb and noun attributes which do not match (within a given input sentence). Also, the noun attributes of the object of a 'verb2' verb are only that the noun be an actor (see subsection 2.1.1). In the case of 'verb3' verbs, a preposition is required between the object of the sentence and the second actor, and, is listed in the second attribute section (e.g., 'P(. . .required preposition. . .)').

Other words ('DEMAND', 'RATE', 'PRICE') may only be used in value assignments and therefore have no attributes (see subsection 2.2.2). Any word that is given in an input sentence and is not either assumed by the simulation (described above) or appearing in the table of permitted vocabulary, is marked as an unrecognizable word by the simulation grammar.

With the grammatical structure of the PTP simulation, some of the inputs may sound rather strange. In actuality, they are not exactly like the English language, but are rather close copies. Again, the structure of a 'natural' language would be too ambiguous for use on the computer. Thus a language more closely representing a compiler-type language was created. The structure of sentences, in accordance with standard English grammar, requires that the endings of verbs should change, depending upon the tense of the input sentence. This and other requirements is the attempted simulation of the English language.

4.2 Valid Lexical Entries (NOUNS)

ARMED-FORCED/NOUN/-COUNT +ANIMATE/

ARMS/NOUN,WORTH/-ABSTRACT -COUNT/

ARMS-RESUPPLY/NOUN,WORTH/-ABSTRACT -COUNT/

ASSETS/NOUN,WORTH/-ABSTRACT -COUNT/

CAPITAL-GOODS/NOUN,WORTH/-ABSTRACT -COUNT/

COMTUP/NOUN,WORTH/-ABSTRACT -COUNT/

CONSUMER-GOODS/NOUN,WORTH/-ABSTRACT -COUNT/

DEMAND/NUMBER,TIME(DAY,MONTH,YEAR)/NOUNTYPE/

ECONOMIC-AID/NOUN/+ABSTRACT -COUNT/

FERTILIZER/NOUN,VALUE,UNIT(TONS)/-ABSTRACT -COUNT/

FRIENDSHIP-TREATY/NOUN/+ABSTRACT +COUNT/

INFLATION/NOUN,VALUE,UNIT(YEAR)/+ABSTRACT -COUNT/

INTEREST/NOUN,VALUE,UNIT(MONTH,YEAR,QUARTER)/+ABSTRACT -COUNT/

MECHANIZATION/NOUN,VALUE,UNIT(HP)/-ABSTRACT -COUNT/

MILITARY-AGREEMENT/NOUN/+ABSTRACT +COUNT/

MILITARY-AID/NOUN/+ABSTRACT -COUNT/

MILITARY-SUPPORT/NOUN/+ABSTRACT -COUNT/

OIL/NOUN,VALUE,UNIT(BARRELS)/-ABSTRACT -COUNT/

POLITICAL-AGREEMENT/NOUN/+ABSTRACT +COUNT/

POLITICAL-SUPPORT/NOUN/+ABSTRACT -COUNT/

PRICE/PRICE/NOUNTYPE/

RATE/PERCENT/NOUNTYPE/

SECURITY-TREATY/NOUN/+ABSTRACT +COUNT/

TNC/NOUN,WORTH/-ABSTRACT -COUNT/

WHEAT/NOUN,VALUE,UNIT(TONS)/-ABSTRACT -COUNT/

4.3 Valid Lexical Entries (VERBS and PREPOSITIONS)

AFFIRM/V2/JOINT N(+ABSTRACT +COUNT)/

AFFIRM*/V3/N(+ABSTRACT +COUNT) P(WITH)/

AGAINST/PREP/NONE/

ALERT/V3/N(+ANIMATE) P(AGAINST)/

ATTACK/V2/N(ACTOR)/

BUY/V3/N(-ABSTRACT) P(FROM)/

DISRUPT/V2/N(ACTOR)/

FROM/PREP/NONE/

GIVE/V3/N(+ABSTRACT -COUNT | -ABSTRACT) P(TO)/

IMPOUNT/V3/N(-ABSTRACT -COUNT) P(OF)/

MOBILIZE/V3/N(+ANIMATE) P(AGAINST)/

PURCHASE/V3/N(-ABSTRACT) P(FROM)/

PROVIDE/V3/N(-ABSTRACT | +ABSTRACT) P(TO)/

RAID/V2/N(ACTOR)/

RECOGNIZE/V2/N(ACTOR)/

SEIZE/V3/N(-ABSTRACT -COUNT) P(OF)/

SELL/V3/N(-ABSTRACT) P(TO)/

SIGN/V2/JOINT N(+ABSTRACT +COUNT)/

SIGN*/V3/N(+ABSTRACT +COUNT) P(WITH)/

TO/PREP/NONE/

WITH/PREP/NONE/

4.4 Valid Lexical Entries (ACTORS)

SA	(Saudi Arabia)
US	(United States)
IS	(Israel)
USSR	(Russia)
BRITAIN	
EGYPT	
FRANCE	
SWEDEN	
GERMANY	
SYRIA	
IRAN	
KUWAIT	

UAE (United Arab Emirates)

PLO

IRAQ

UAE-INSURGENTS

KUWAIT-INSURGENTS

5. ERROR MESSAGES FOR THE PTP SIMULATION

Messages Generated by Grammar

mssg. '***ERROR***' word 'IS NOT A VALUE NOUN'

descr. The given word is not one of those which can be used in making an assignment. Words which may be assigned values appear as follows in the table of valid lexical entries: e.g., OIL/NOUN,VALUE,...
↑

mssg. '***ERROR***' word 'IS NOT A VALID QUALIFIER'

descr. The given word is not one of those valid qualifiers which may be used in assignment statements following the primary noun (oil,fertilizer,etc.). Valid qualifiers are: price, rate, demand.

mssg. '***ERROR*** SENTENCE DOES NOT HAVE A VALID END SYMBOL'

descr. This message is generated if the input sentence does not end in one of the valid end symbols ('.' or ';' or '?'). It may also occur if a partial sentence is entered, or, if more sentence parts were expected (prepositional phrase missing, etc.)

mssg. '***ERROR*** WRONG UNITS SPECIFIED FOR THIS NOUN'

descr. Incorrect units were used in an assignment statement. Correct units appear in the table of VALID LEXICAL ENTRIES (see section 4) in the following manner: e.g., OIL/NOUN,VALUE,UNIT(BARRELS)/...
↑

mssg. '***ERROR*** A JOINT VERB REQUIRES 2 ACTORS'

descr. When using this multilateral form of a joint verb, 2 or more actors were not entered simultaneously as the subject of the sentence.

mssg. '***ERROR*** NON-MATCHING VERB/NOUN ATTRIBUTES'

descr. The attributes of the verb and noun as given in the table of VALID LEXICAL ENTRIES are not matching.

mssg. '***ERROR***' object 'CANNOT BE ASSIGNED VALUE'

descr. The given object of the entered sentence cannot be assigned a value in a "worth" clause. Those words which can be assigned values appear as follows in the table of VALID LEXICAL ENTRIES: e.g., ARMS/NOUN,WORTH/...
↑

mssg. '***ERROR*** MISSING DOLLAR VALUE FOR WORTH CLAUSE'

descr. The word "worth" was not followed by a dollar amount in a "worth" clause.

mssg. '***ERROR*** INCORRECT PREPOSITION →' word

descr. The given word is not the preposition required by the given verb. The required preposition may be found in the table of VALID LEXICAL ENTRIES as follows: e.g., SELL/V3/N(-ABSTRACT) P(TO)/
↑

mssg. '***ERROR***' wordtype 'EXPECTED,'
'CHECK →' word 'OR WORD THAT FOLLOWS'
'***ERROR*** ILLEGAL SENTENCE'

descr. An improper positioning of a word in a sentence not in accordance with the grammatical construction described in section 2 of this manual will generate this message. The given wordtype (e.g., noun, verb, etc.) was next expected by the system.

mssg. '***ERROR*** UNRECOGNIZABLE WORD →' word

descr. The given word is not in the table of VALID LEXICAL ENTRIES.

mssg. '***ERROR*** MULTIPLE AGENT NOT PERMITTED WITH THIS VERB'

descr. The user has attempted to use more than one agent with a non-joint verb.

mssg. '***ERROR*** INVALID USAGE OF' word

descr. The given word is improperly positioned in the sentence. This is a general diagnostic message.

mssg. '***ERROR*** QUERY CANNOT BE SERVICED BY INTERPRETER'

descr. The stative variable queried either cannot be manipulated by the user or is not a stative variable.

Messages Generated by Semantic Interpreter

mssg. '***SEMANTIC ERROR*** AGENT1 IS THE SAME AS AGENT2'

descr. The subject and object agents are identical.

mssg. '***SEVER INTERPRETER ERROR***'

descr. Report this to authors along with the given run of the simulation.

Messages Generated by Production Systems

mssg. '***KERNEL CANNOT BE INTERPRETED***'

descr. The system cannot operate on this semantic kernel.

mssg. '***I/O ERROR***', '***STI ERROR***'

descr. Internal errors, report to authors.

6. PROGRAM DESCRIPTION

The PTP simulation consists of approximately four or five major modules. The whole of the simulation is governed by an assembler language monitor module. This monitor is the substance of the PTPCOM mode (see section 3). The other major modules and their respective programming languages are as follows (refer also to figure 6.1):

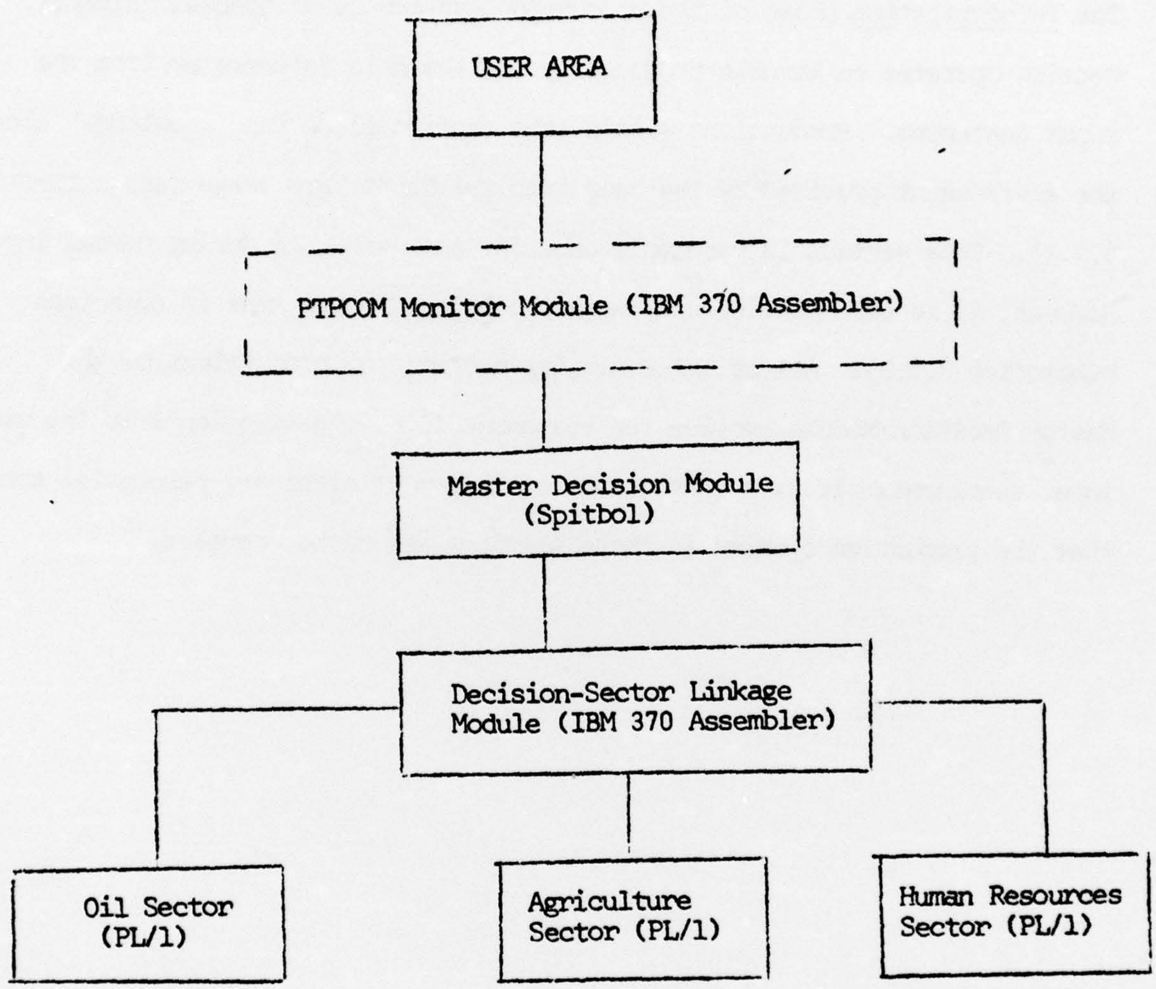
Module	Programming Language
Master Decision Module	Spitbol
Oil Sector Module	PL/1
Agriculture Sector Module	PL/1
Human Resources Sector Module	PL/1
Decision-Sector Linkage Module	IBM 370 Assembler

The actual code involved in these modules is beyond the scope of this manual.

The Master Decision Module is divided logically into several sections. The first section contains only Spitbol production system functions. This is followed by the simulation grammar (lexical parser and semantic interpreter). Execution of the grammar is sequential. That is, once an input sentence has been introduced to the grammar, it is first parsed by the lexical portion of the grammar, and then interpreted by the semantic portion of the grammar. The final section (the bulk of the decision module) is the set of simulation productions.

The production system is further divided into the nine subsections described in subsection 3.2.1 of this manual (concerning the 'COND' parameter). The Interpretation phase of the production systems is of special interest. This section operates on kernels produced by the semantic interpreter from the input sentences. Productions within this section place the "knowledge" about the environment provided by the user into the Short Term Image (see subsection 3.2.1). This section is used only once for each sentence during normal input. However, it is used continuously when the batched input mode is used (see subsection 2.3.2). All of the remaining sections of productions of the Master Decision Module provide the responses (i.e., "perception") to the user input sentences. It is a consequence of this most elaborate perception scheme that the production systems in these sections are rather complex.

Figure 6.1


USER AREA
PTPCOM Monitor Module (IBM 370 Assembler)
Master Decision Module (Spitbol)
Decision-Sector Linkage Module (IBM 370 Assembler)
Oil Sector (PL/1)
Agriculture Sector (PL/1)
Human Resources Sector (PL/1)