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Theory of the Decision/Problem State

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TABLE OF CONTENTS

THEORY OF THE DECISION-PROBLEM STATE

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SUMMARY

In this paper the concern was focused on how to resolve a sequence or series of related problems or decisions to attain a major outcome. A theory of the decision-problem state was introduced and elaborated. Starting with the basic model of a decision-problem condition, an attempt was made to explain how a major decision problem may consist of subsets of decision-problem conditions composing different condition sequences. In addition, the basic classical decision-tree model was modified to allow for the introduction of a series of characteristics that may be encountered in an analysis of a decision-problem state. The resulting hierarchical model reflects the unique attributes of the decision-problem state. The basic model of a decision-problem condition was used as a base to evolve a more complex model that is more representative of the decision-problem state and may be used to initiate research on decision-problem states.

INTRODUCTION

Individuals are required to make decisions and solve problems in order to obtain their desired outcomes. Frequently, an outcome is associated with a series or sequence of decision-problem conditions. To gain the outcome, the individual must correctly resolve the conditions encountered. Edwards (1962) formally labeled the condition "dynamic decision theory." Edwards was concerned with the effect of the dynamic environment of the decision sequence. In this paper, the focus is on how to perceive and manage a decision-problem sequence to obtain a successful outcome. The process of making the selection or applying the solution is not easily identified. Research has been accomplished in the area of problem solving, decisionmaking, judgment and creativity, all of which touch upon this process. The daily requirement that everyone make many resolutions would lead us to believe that the process is a well-known, easily attained technique; however, this is not the case. As was discussed in another paper (Dieterly, 1980a), there is a basic condition model that may be used in both problem solving and decisionmaking studies. A classification scheme was developed to indicate the varieties of decision-problem conditions that may exist and to represent a decision-problem task.

In another paper (Dieterly, 1980b), a model of the clarification process was presented in an attempt to provide a structure to analyze how to resolve a single desicion-problem condition. The basic condition model, which allows for the classification of decision-problem conditions, and the clarification model, which outlines the approach to use and suggests the possible method employed by individuals in processing information, provide the background for examining single decision-problem conditions and establishing a resolution. In this paper the major emphasis is on a set of decision-problem conditions that is to be completed prior to obtaining a final goal.

This report represents the work accomplished by the AFHRL Technology Office, located at NASA-Ames Research Center. The effort was accomplished in support of a NASA project in the area of resource management. The material presented was developed by the AFHRL Technology Office and provided to the Man Vehicle Systems Research Division of the Life Sciences Directorate as a possible source of background for one of the phases of their project.

DECISION-PROBLEM STATE

To make a decision or to solve a problem is a single action taken with an objective, or end state, in mind. As has been shown (Dieterly, 1980a), a basic model of the problem-decision condition consists of an initial state, a transition, and an end state. The selection of the transition indicates the resolution. Generally, the making of a decision-solution involves a choice of action, implementing the action, an expected outcome, and the high probability of another decision-problem condition. To look at the making of a major decision or the solving of a major problem, the individual is actually confronted with a series of minor decisions or problems, each of which affects the final outcome. In solving major problems or making major decisions, the individual must usually solve a series of minor problems, or make a series of minor decisions, each of which is dependent on the final resolution. Therefore, most major decisions or problems consist of a set of decision-problem conditions that are arrayed in some form of a sequence.

The term decision-problem condition sequence is a little cumbersome so a new term will be introduced. For the purposes of clarity, the term decision-problem state will be used whenever the situation of concern can be decomposed into a set of two or more decision-problem conditions. For example, when someone wishes to decide to go away on vacation, a series of decision-problem conditions must be resolved. The series may consist of the following three decision-problem conditions: (1) Is there enough money? (2) Is free time available? and (3) Is there a place to visit? The decision-problem state consists of four resolutions, three of which affect the final resolution.

A decision-problem state is a series of related decision-problem conditions that must be resolved in order to resolve the total state. The rest of this paper will describe some of the characteristics of a decision-problem state. The decision-tree concept will be modified to accommodate the characteristics identified to provide a method for decomposing a decision-problem state.

PRESCRIPTIVE VS NORMATIVE APPROACH

Previous and current research in the area of decisionmaking and problem solving falls roughly into two categories. Each category may be considered representative of a separate approach to the area. The one approach is to determine how people go about making decisions and arriving at solutions. The second approach determines how decisions should be made and how solutions should be arrived at. Both of the approaches have in the past and are currently generating a vast amount of activity and interest. An acceptable way to attempt to sort out the research is by classifying them as prescriptive or normative. Prescriptive research attempts to provide a method or approach that should be used in decisionmaking and problem solving. Normative research attempts to determine how decisions are made and problems solved under normal conditions. In one case, a way is provided to teach or train decisionmaking; in the other case, a model develops that captures the methods that appear to be used.

Historically, however, the approach to decisionmaking has been different from that to problem solving. Concern with decisionmaking was derived from a practical applied context relating to making decisions the effects of which are significant. The research covers a range of topics, such as analysis of major decisions of the past, how to make decisions in groups, and how people make decisions.

The normative approach focuses on understanding the basic dynamics of decisionmaking and problem solving and is firmly anchored in the early psychological studies of problem solving (Kohler, 1925; Thorndike, 1911). The prescriptive approach grew out of an industrial-educational emphasis on making administrative decisions. This approach, however, can actually be traced further back into time when logic was applied to problems by early philosophers. Much of the current research draws upon the concept of a logical approach to making a selection. The type of selection in terms of magnitude also plays a major role in the name associated with research accomplished. Scientists dealing with multimillion dollar conditions are generally making a decision, where problem solving falls into much simpler scenarios, like a student connecting nine dots with three straight lines.

For example, a decision to develop a new mode of ground transportation may be studied under the title of creativity, creativity in the sense that the choice is expected to be more innovative. If the concern is with a simple problem of deciding if a tone has sounded, the research will be called detection theory. It is difficult, therefore, to attempt to lay out a possible theory that may encompass such a diverse set of areas of research. In this paper such an attempt will be made. The objective is to establish a general model of the decision-problem sequence and set of concepts which may be used as a basis for accomplishing comprehensive research in the area of decisionmaking or problem solving.

Descriptive research applies to how people apparently make decisions while prescriptive research establishes a technique to be used. In either case, there exists more discursive material than actual research studies. Few attempts have been made to analyze the validity of an established technique, nor are there any apparent attempts to explain the process in detail. Therefore, an attempt will be made to theoretically fill in some of these gaps so that research may be attempted. The basic model of decision-problem condition sequence will be presented to accomplish this. A prescriptive base was selected. Although a requirement exists to perform basic research on prescriptive techniques, the objective of this paper is to provide a method that can be used now. The method will look at the decision-problem solving condition sequence and analyze it. We may be crossing the river on a shaking log, but at least we are crossing it.

CLASSIC DECISION TREE

To study the decision-problem state, a systematic method for its decomposition into decision-problem conditions is necessary. The decision-problem sequence, which begins with a major initial state and ends at the major end state through the transition of a sequence of decision-problem conditions, is more complex than a single decision-problem condition. Indeed, some authors recognized this aspect when they developed a suboptimizing technique to reduce a decision into a set of smaller decisions (Mayer, 1977). The decision-tree model, which has gained considerable application in the past 20 years, is an appropriate technique for studying the decision-problem state (Brown, Kahr, and Peterson, 1974; Masse, 1964). However, the classic decision tree does not allow for the flexibility or variability demanded of a model of the decision-problem state.

Therefore, beginning with a classic decision tree, modifications will be made until what is obtained is a hierarchical model of a decision-problem state. Figure 1 indicates the classic decision-tree concept frequently used in decision-making analysis. This type of model indicates a series of three decision levels, each of which fixes the decision maker onto a limited path. The path selected over the levels of decision-problem conditions determines which of the eight end states is obtained. In more complex presentations,

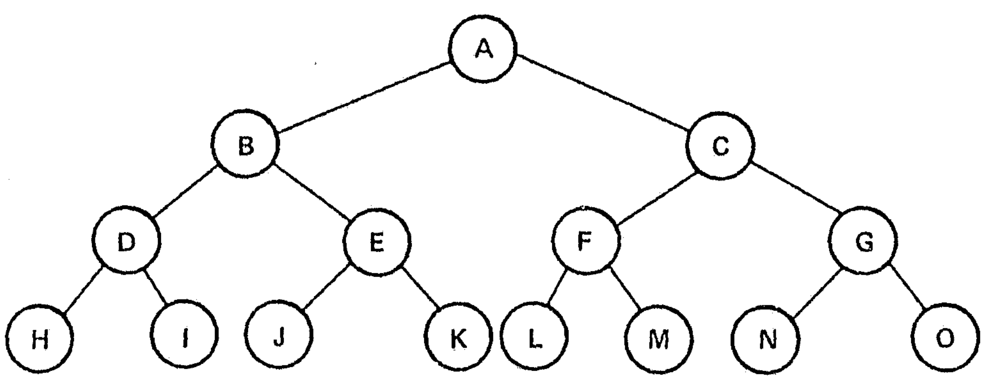

Figure 1.- Classic decision tree.

probabilities may be assigned to each decision-problem choice so that a final probability may be established relative to the end state obtained. In any event, the tree unfolds from the initial decision-problem condition through the series considered, to arrive at a set of final end states. Frequently, a decision-tree technique is applied where the criticality of importance of the end states is immaterial. The major interest is explorative, merely to trace out and identify all the possible conditions, options, and end states. This method is also of great advantage in establishing possible future actions or conditions. This application requires the ability to determine the possible conditions that may be encountered. For example, the design of a war game situation leads itself to a decision tree since the decision conditions are established in advance. The critical aspect is in ascribing different values to the outcomes to select the one of highest value. For simplicity, all the decision-problem conditions will be limited to two options, although in general any number of options may exist.

In the decision-tree technique, the decisions are dependent and sequential; that is, a decision must be made at level one before a level-two decision can be considered. Therefore, level-two and level-three choices are dependent on level-one and level-two choices. Only the first decision-problem condition is independent of later or subsequent choices. These two characteristics, sequential decision strings and dependency, are not particularly emphasized in most studies, but the use of a decision-tree model introduces these constraints whether or not they actually exist in the problem-decision state. Therefore, the classic model of the decision tree technique subdivides a major decision-problem state into a set of decision-problem conditions, strings, or paths, and dependent decision-problem conditions.

FINAL CONDITION FIXITY

In order to apply the decision-tree approach, several modifications will be made to the tree model to adapt it to the type of decision-problem states normally encountered. Generally, most decision-problem states culminate in one of two outcomes: success or failure. Although the outcomes differ in many respects, the final selection criterion is a value judgment that distributes the outcomes into these two subsets. If the final decision-problem outcome may be considered as either a positive or negative outcome, then the decision tree model is constrained. It is constrained by dichotomizing the available final outcomes as either successful or unsuccessful (Fig. 2).

This means that we have a series of decision-problem conditions that provides a set of paths that culminate in either one of two end states. This limits the decision-tree model to two discrete sets of outcomes. Therefore, several decision-problem strings could result in a successful outcome or in an unsuccessful outcome. Generally then, there is established a final end state that either is obtained or not. Frequently, when the end state cannot be stated quantitatively, the question of obtaining it or not becomes arbitrary and is seldom clarified. The actual evaluation of a decision-problem state is seldom systematically planned. Once the resolutions have been made the expected outcome is assumed to occur.

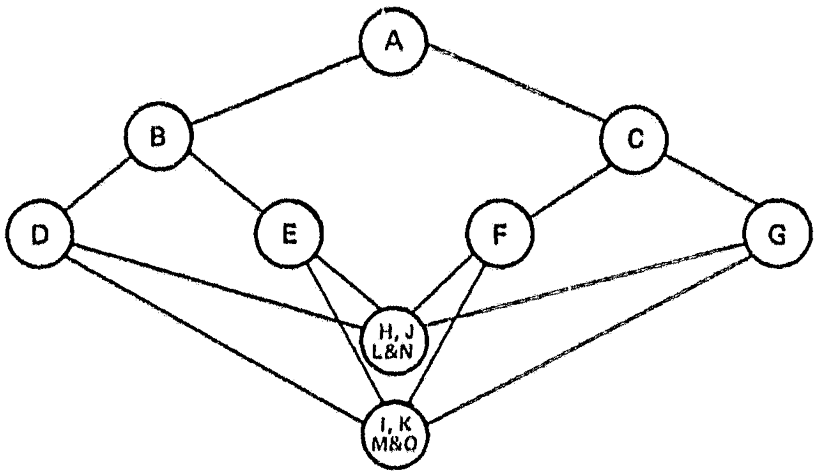

Figure 2.- Grouped outcome sets.

CRITICAL DECISION-PROBLEM CONDITION

In the model shown, two modifications have actually taken place. First, the set of eight end states is grouped into four successful and four unsuccessful, thus allowing for any of four decision-problem strings to obtain success. The grouping is based on an assumption that all final end states are not of equal value. Some end states may be more valuable than others so that the resolver may opt for the most valuable rather than accepting a reasonable lesser value. The definition of value is established and the end states grouped. In addition, by making this assumption, the third-level decision-problem condition becomes critical for all four decision-problem strings. It is at the third level that the choice determines success or nonsuccess; therefore, the resolution at this level is defined as a critical choice. In any decision-problem state there may exist one or more levels of choice that are critical, in that once the choice is made all later choices will not preclude success or nonsuccess. A critical decision-problem condition may occur across a given level or, more likely, only within one or more decision-problem strings.

UNEQUAL DECISION-PROBLEM SEQUENCES

Further, let us assume instead of three levels of decision-problem conditions, that paths have different numbers of decision-problem conditions. In other words, in the classical decision tree the linearity reflects a level of simplicity not encountered in most situations; therefore, instead of making three levels of balanced choices, one at each level, we must address three or four decision-problem conditions dependent on initial and later path choices (fig. 3). This is not to imply that the decision level is not important, but that this concept emerges too early in the classical decision-tree methodology

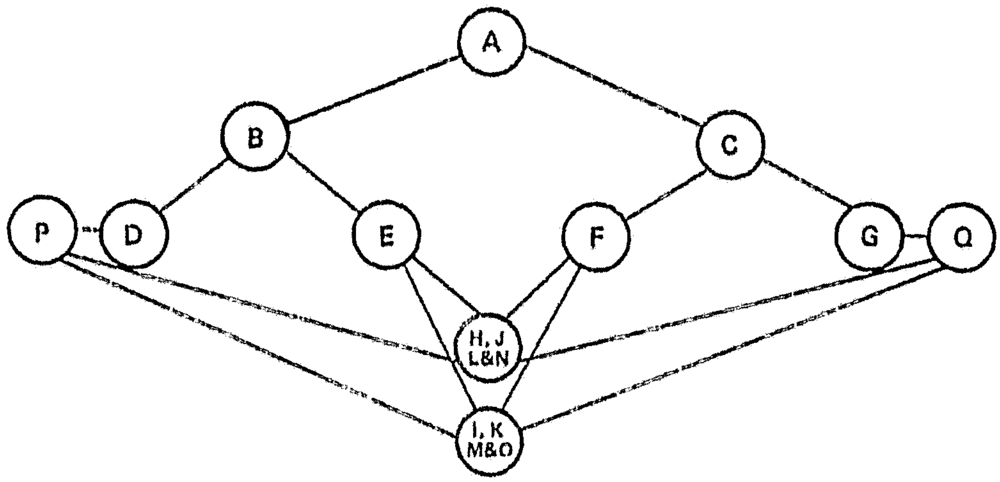

Figure 3.- Unequal decision-problem sequences.

and tends to evolve a balanced set of decision-problem sequences. As additional assumptions are introduced, this concept will reemerge with a different emphasis. The initial decision-problem condition resolution may, therefore, set in motion the selection of a decision-problem sequence that consists of many decision-problem conditions. The initial decision-problem condition resolution may be crucial for later phases of the decision-problem state.

TEMPORAL FLEXIBILITY

Another modification that should be introduced is that of the idea of decision interaction. Under the classical model there existed a level dependency that was usually based on some functional breakdown from complex to simple or from broad to fine. What is being proposed here is a more complex variation that demands that a given decision-problem condition be resolved prior to another decision-problem condition while others may be independent. Another consequence of a symmetrical decision-tree model is that all levels appear to be an equal distance from each other. To introduce time difference, the decision-problem sequence will look like that shown in figure 4. This produces a decision-problem sequence that reflects interdependence, time dependence, and final state focus. This situation is shown graphically in figure 4. Making a resolution of BE (fig. 4) will occur at approximately the same time as CG, but no further resolution would be required until later in the BE case. In the CG sequence, another resolution would be required almost immediately. Therefore, a state exists in which all resolutions are acceptable, but certain resolutions require the resolution of additional conditions that may induce a higher workload than for other strings.

Therefore, once the decision-problem sequence is specified, the appropriate resolutions may be required at different points in time, allowing for a temporal flexibility across sequences. Within a sequence there may also

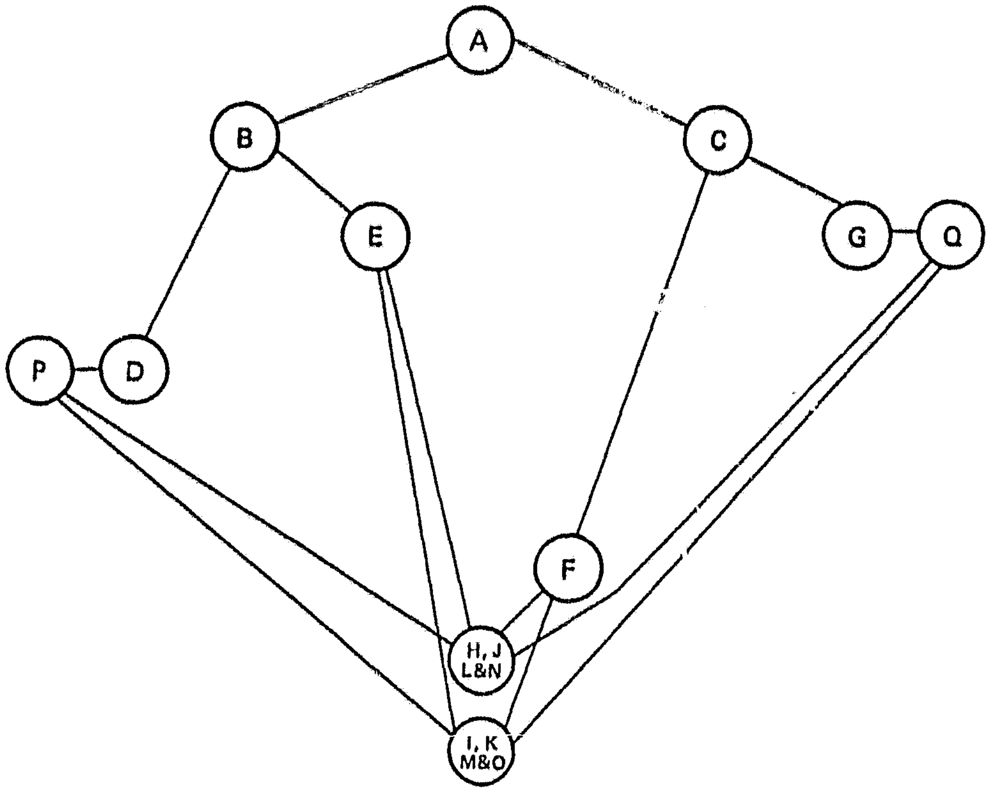

Figure 4.- Different time decision-problem conditions.

be interdependent and independent decision-problem conditions allowing for some flexibility as to when resolution occurs.

INDEPENDENT DECISION-PROBLEM CONDITIONS

There could exist within a decision-problem state a decision-problem condition that is independent of the other conditions. Decision-problem conditions AB and AC are dependent and must be sequentially resolved; decision-problem conditions BP and BD are independent. This is shown by the dashed line (fig. 5) used to indicate a decision-problem condition that may be addressed at any time and is not dependent on a prior choice. The decision-tree technique, which normally unfolds from left to right, or from top to bottom, in an exploratory fashion, finally depicting the options and paths and resulting end points, has been constrained by end-state fixity and the other assumptions so what we develop as the basic model a map of all decisions that must be made, their relationship, and appropriate sequencing.

The implication is that there exists a subset of decision-problem conditions required to meet the end objective. Once these are known and resolved, the end state will be attained. The obvious problem is that most situations do not fall so neatly into place; what normally is available is a model of

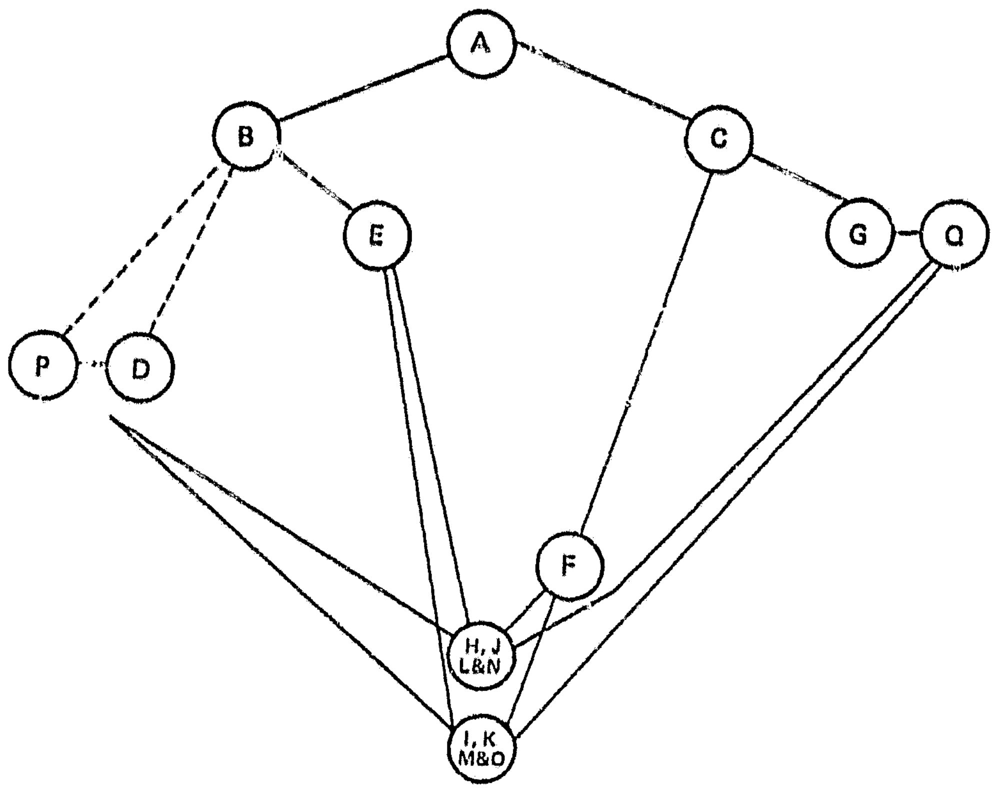

Figure 5.- Nonsequential decision-problem condition pair.

decision-problem conditions in which the transitions are not known nor the outcomes fixed. The idea of a priority of resolutions is also apparent. Certain resolutions must be made at a given point in time or it is too late. We now have a model that reflects more adequately the type of decision-problem sequences that may be encountered in a typical decision-problem state. By introducing a series of assumptions — final condition state fixity, unequal decision-problem sequences, temporal flexibility, and independent decision-problem conditions — the analysis of a decision-problem state reflects the more complex realities of the situation.

HIERARCHICAL MODEL

Although the initial attempt was made to use a modified decision-tree technique to plot a decision-problem state, the assumptions have changed the concept enough that a new term appears appropriate. Therefore, the method adapted to handle the decision-problem state will be called the hierarchical model of a decision-problem state. To review, the characteristics introduced were: (1) final condition fixity, (2) critical conditions, (3) unequal condition sequences, (4) temporal flexibility, and (5) independent conditions.

Acceptance of the assumptions and resultant characteristics produces a radically different model of the decision-problem state from that achieved through the decision-tree approach. In figure 6, a hierarchical model is applied to an example. There are 25 decision-problem conditions in the total state. There are 20 possible condition sequences, 10 of which result in a positive outcome (Z) and 10 of which result in a negative outcome. An end result may be obtained by resolving 3 to 7 conditions. The number of conditions resolved is dependent on the first and second condition choice. Either a positive or negative outcome may be attained after resolving three to seven conditions.

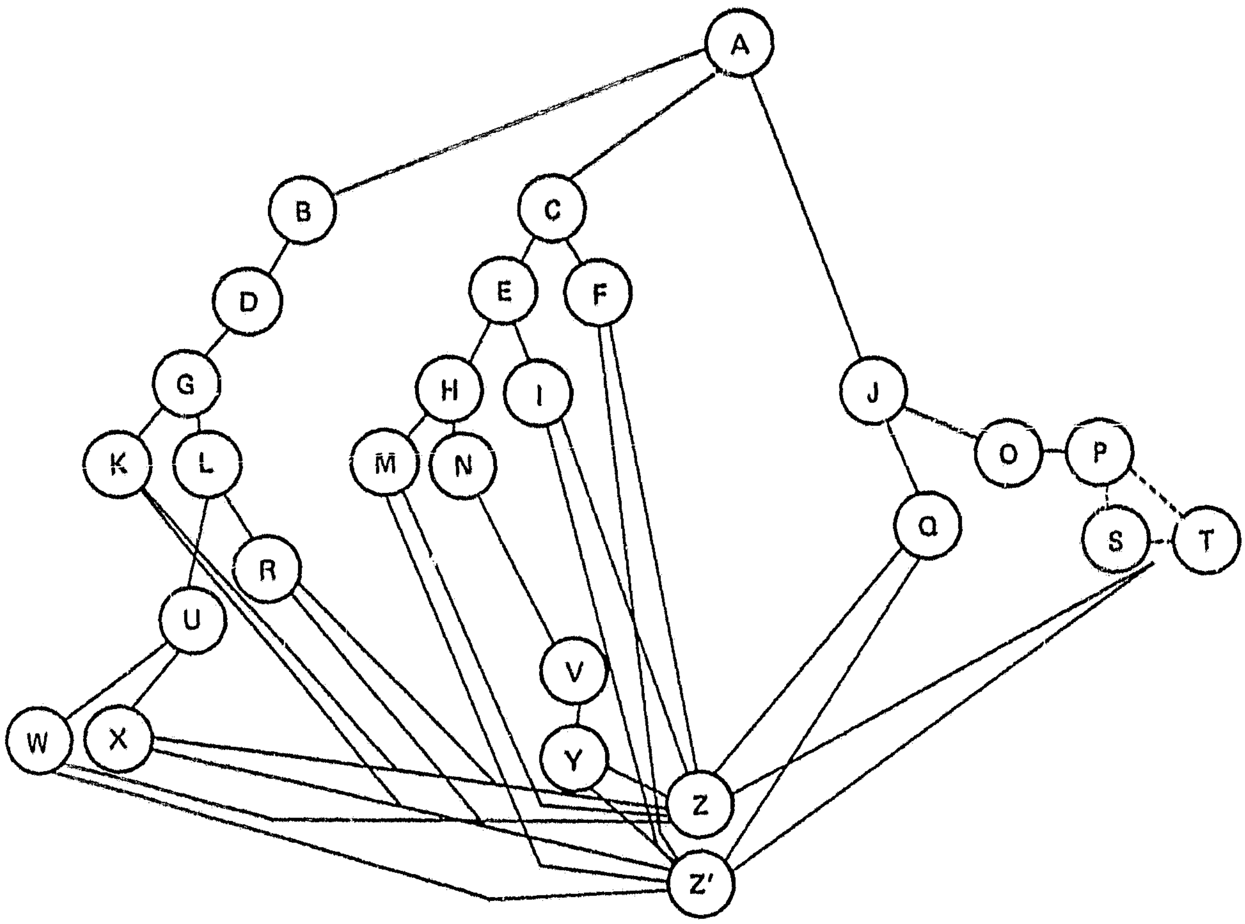

Figure 6.- Hierarchical model of decision-problem state.

In table 1 the possible condition sequences are shown. Set one shows the condition sequences available with equal starting points and ending points. Set two shows the condition sequence with varying starting and finishing times, which is more characteristic of the actual state. It would be anticipated that the more resolutions to complete the longer the total process. However, since each condition may vary in difficulty or complexity, the number may not be indicative of the time required.

TABLE 1.- HIERARCHICAL DECISION-PROBLEM STATE PATHS

SET ONE	SET TWO
ABDGK Z	ABDG K Z
ABDGK Z'	ABD G K · Z'
ABDGL R Z	A BDGL R Z
ABDGL R Z'	A BD GL R Z'
ABDGL U X Z	ABDGL U X Z
ABDGL U X Z'	ABD GL UX Z'
ABDGL U X Z	ABD GLU WZ
ABDGL U W Z'	ABDGLUWZ'
ACEHN VY Z	AC EH N VY Z
ACEHN VY Z'	A CE HN V Y Z'
ACEHM Z	ACEHM Z
ACEHM Z'	ACEHM Z'
ACEI Z	ACE IZ
ACEI Z'	AC E I Z'
ACF Z	ACF Z
ACF Z'	AC F Z'
A J[OP][S/T] Z	A J[OP] [S/T] Z
A J[OP][S/T] Z'	A J [OP] [S/T] Z'
A JQ Z	AJQZ
A JQ Z'	AJQZ'

If the state itself had a time-to-completion of a fixed length, such as a work day, a flight schedule, or a deadline, then the number of conditions, complexity, and difficulty might be indicative of the concept of workload. In any event, an individual who selects a low number of nondifficult, noncomplex resolutions would be involved in the process of reaching the end state to a lesser degree than an individual in the reverse situation.

To fully realize the scope of the task shown in the model, the types of possible classes of decision-problem conditions should be included. In figure 7 the same state is transformed into one with different condition models. The task faced by the individual is not only one of resolving the conditions, but one of having some grasp of the total state while making the resolutions. In the basic case, in which all conditions are known and only choices need be made, there is still a considerable amount of information to manipulate and manage.

MANAGEMENT DECISION-PROBLEM STATE

Each decision-problem condition within the model may vary in complexity; that is, it may be represented by a simple, known initial and end state with only one transition, or it may be represented by an unknown end state with multiple unknown transitions. Therefore, the amount of effort required to resolve the decision-problem condition may range considerably. A strategy for resolving the set of decision-problem conditions may be adopted that

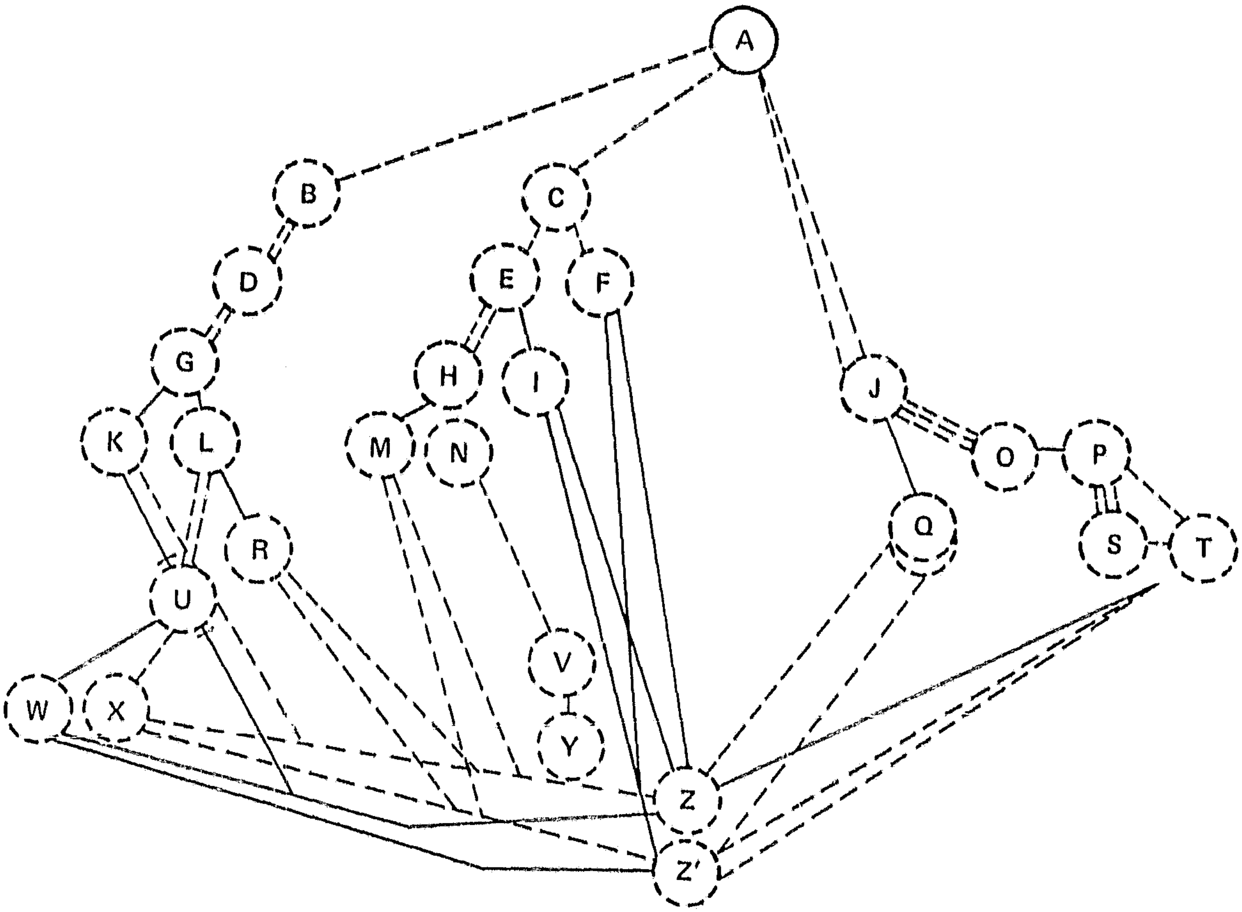

Figure 7.- Hierarchical model of decision-problem state with unknown and multiple end states and transitions.

instead of being sequential takes more difficult conditions first. As can be seen, a set of strategies could be generated each having advantages and disadvantages. The task of resolving a decision-problem state requires the ability to not only resolve single decision-problem conditions, but also an ability to manipulate a set of conditions to complete the task. The task, then, becomes one of decision-problem state management.

The necessary skills involved in the clarification process are only part of the skills necessary to resolve a decision-problem state. The resolution of the state requires more than optimized resolution of independent decision-problem conditions. It requires the knowledge of the total state to the degree that (1) the expected decision-problem conditions are anticipated and (2) some contingency responses are known in case of unexpected conditions. The importance and difficulty of each condition should be established and a management strategy developed to accomplish the task under varying external circumstances. In order to adequately manage a decision-problem state, the individual must develop: (1) a concept of the decision-problem state, (2) a strategy to resolve the conditions, and (3) a priority awareness of critical conditions and time points. This type of management is far more complex than the resolution of a single decision-problem condition.

EXAMPLE OF HIERARCHICAL MODEL ANALYSIS

To better visualize the application of these modifications to a major problem-decision state, a sample situation is provided. Suppose a company wished to build a new factory somewhere in the continental United States. It selects a group of members as a board to make the decision. The major decision-problem state consists of three levels of decision-problem conditions: (1) cost of land, (2) tax rate, and (3) access to shipping. A simple set of criteria is defined to make these decisions so that cost of land is high or low, tax rate is high or low, and access to shipping is either excellent or average. Now the Board could either screen all states or select a subset. An additional constraint had been established by the president that any state that already had a company factory was not to be considered. Therefore, only 10 states were involved in the decision: Oregon (OR), South Dakota (SD), California (CA), Kentucky (KY), North Carolina (NC), Ohio (OH), Texas (TX), Indiana (IN), Minnesota (MN), and Louisiana (LA).

Applying the decision-problem state model, the outcome is shown in figure 8. If the Board decides, however, that access to the sea is a critical decision and that only those states indicated as excellent in that respect will be considered as good options while those with average access will be considered bad options, we modify the model as shown in figure 9. If the Board further stipulates that any optimum or minimum path must be looked at closer to insure appropriate selection and that, in the best case, a decision-problem condition about air freight must be made and, in the worst case, a decision-problem condition about rapid transit capabilities is necessary, we have the type of model shown in figure 10.

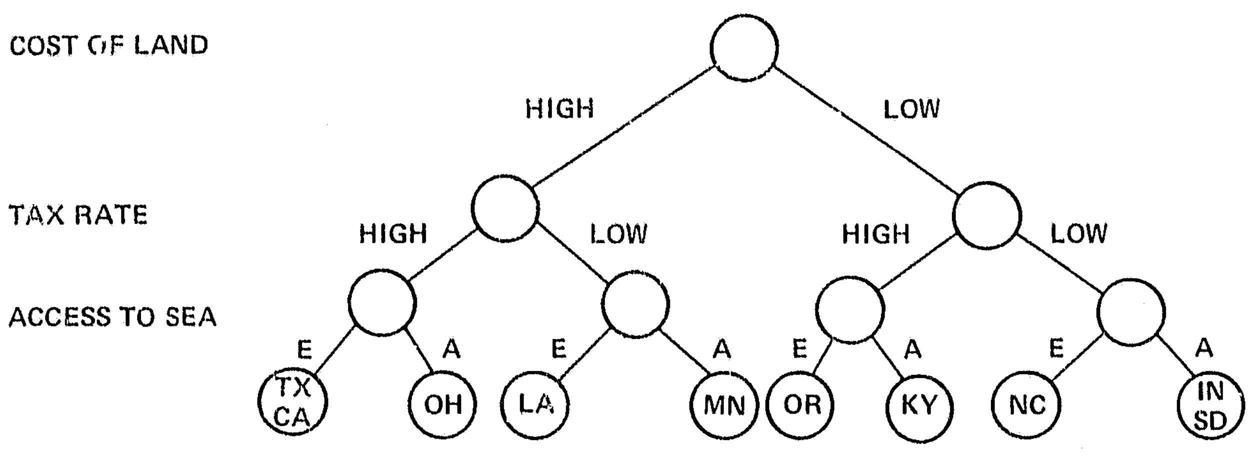

Figure 8.- Example in classic decision-tree model.

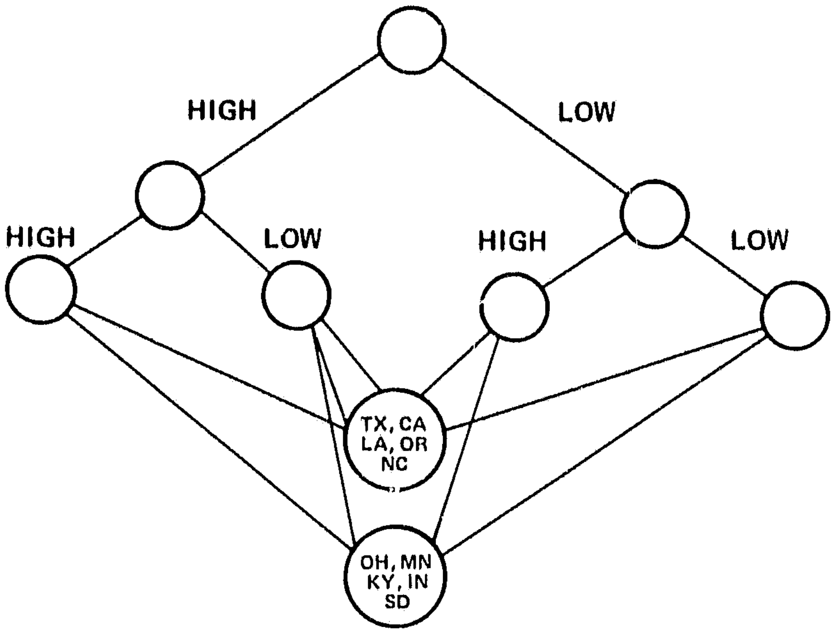

Figure 9.- Example with critical decision-problem condition.

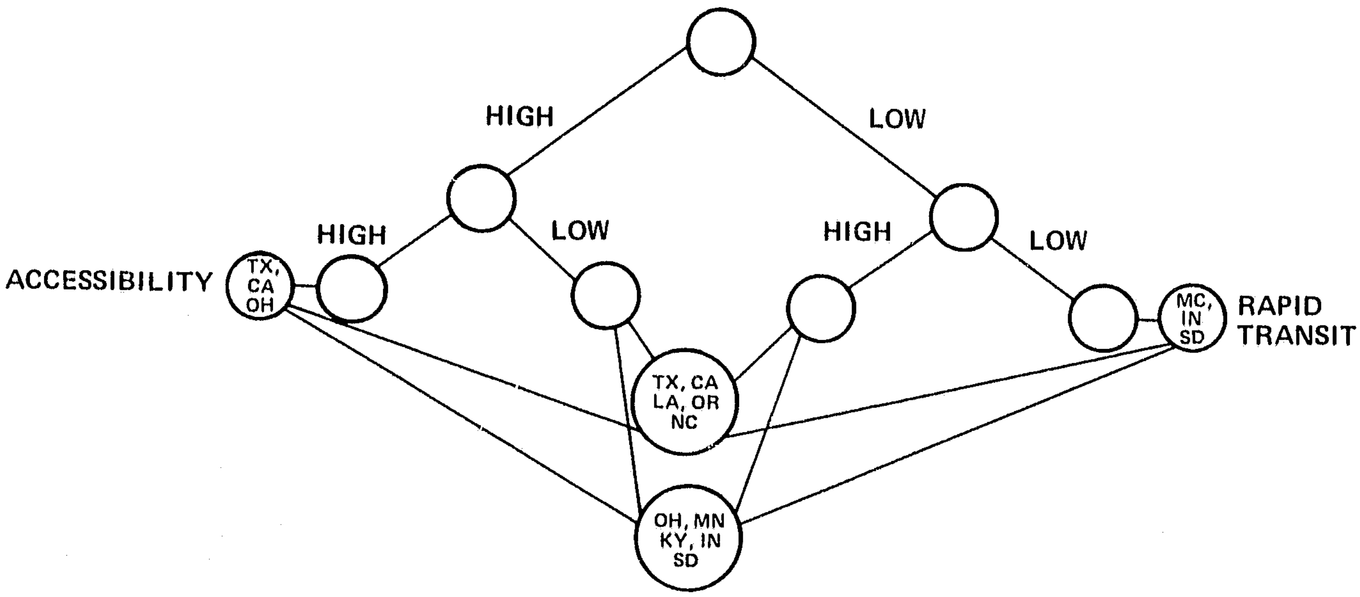

Figure 10.- Example with additional decision-problem condition.

However, the Board determines that SD, NC, and IN are about to raise their tax rates so a choice must be made about these states now to capitalize on the current lower rate, and that the cost of land in CA and TX is going up rapidly so a decision should be made about these states soon to control costs. The time dimension is introduced so that the model looks like that shown in figure 11. Finally, the Board determines that whether accessibility is

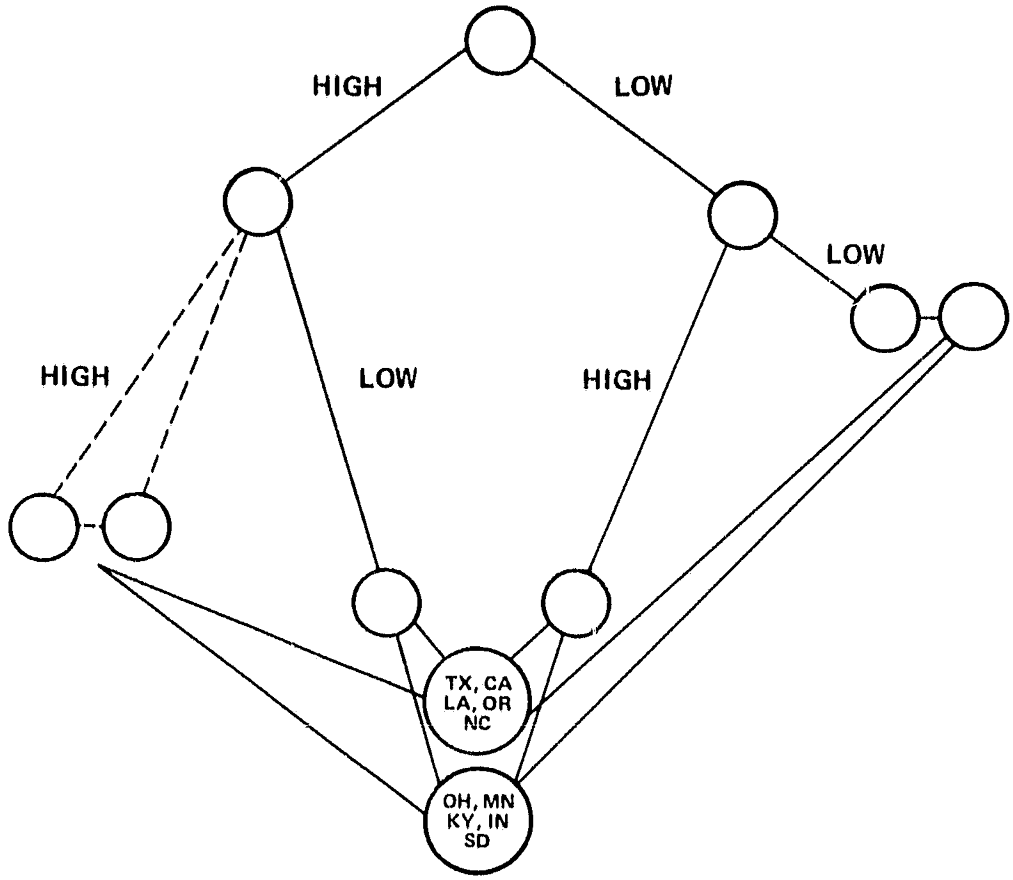

Figure 11.- Example with different time decision-problem conditions.

established or access to sea established for CA, TX, and OH is not important so that either decision can be made first. Figure 11 then represents the decision-problem state model.

Although this example may be simplistic, it shows the possible decision-problem sequence model that might be found in a major problem-decision state. Again, the model implies that all aspects are known as in the initial development. The type of decision-problem state actually encountered would be a set of decision-problem conditions. As shown in a previous paper, each decision-problem condition may have unique characteristics (Dieterly, 1978a). An attempt to resolve each with a uniform application of the clarifying process model is probably impossible. What will occur is that each decision-problem condition will be addressed in accordance with an established priority rule or importance rule that will emerge throughout the clarification process. In other words, when a decision-problem state is encountered each decision-problem condition may be given additional attributes relative to each other. Once some definition of the state is established and the set of decision-problem conditions is identified, then the following attributes may be considered: degree of importance, magnitude, speed for resolution, and priority of action. These types of attributes are not encountered in research on single decision-problem conditions.

CONCLUSION

A theory of the decision-problem state was introduced and elaborated upon in this paper. Starting with the basic model of a decision-problem condition, an attempt was made to explain how a major decision-problem state may consist of subsets of decision-problem conditions composing different condition sequences. In addition, the basic classical decision-tree model was modified to allow for the introduction of a series of characteristics that may be encountered in an analysis of a decision-problem state. The resulting hierarchical model reflects the unique attributes of the decision-problem state. The basic model of a decision-problem condition was used as a base to evolve a more complex model that is more representative of the decision-problem state and may be used to initiate research on decision-problem states.

The model breaks with the classic decision-tree approach and introduces characteristics of decision-problem states that are not usually considered. The more pragmatic model presented focuses on aspects of the relationship between decision-problem conditions and emphasizes the importance of decision-problem condition management in accomplishing the task. The iterative modification of the classic decision tree into the hierarchical model emphasized the differences between the theoretical and actual situation encountered in resolving a decision-problem state. The model adequately handles many aspects of reality and forcefully introduces the concept of decision-problem state management. That is, given a decision-problem state, the individual who can perceive or anticipate possible decision-problem conditions and introduce priority levels will have a better chance of success than the individual who handles each condition as it occurs without considering it in reference to the total state.

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