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Decision Order Technique (Dot);The Integration Of Decision Concepts Into System Analysis.

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DECISION ORDER TECHNIQUE

(DOT)

The Integration of Decision Concepts Into Systems Analysis

By

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CHAPTER I

INTRODUCTION

Statement of the Problem

Much of the systems work of the past few decades has tended to be oriented toward resolving specific operational problems. This has given an aura of trouble-shooting to all of systems work and has often produced a patchwork of systems and procedures that may not necessarily be compatible with each other.

A system is an orderly arrangement of interdependent activities and related procedures which implements and facilitates the performance of activity of an organization.

Office automation applications, including the use of computers, has similarly followed specific problem orientation that has not permitted its optimum utilization as a powerful systems tool. This has also added the problem of narrow technical orientation and inflexible manual-machine relationships and an erroneous assumption that mechanization, per se, provides maximum efficiency. Systems analysts have also tended to concentrate on one facet of systems work, such as procedure writing, forms control, or on specific types of systems, such as those for accounting or inventory control.

Management is now beginning to recognize that neither continuous trouble-shooting nor narrow specialized approaches can provide the dynamic systems to solve the real administrative problems.

Thus there is a growing acceptance of the newer total systems concepts which recognize an organization as an organic system composed of many interdependent subsystems; concepts which call for the determination of the real management information needs, and which will utilize fully the unique capabilities of the computer and other new tools to produce better, more accurate and more timely information and more integrated administrative processes.[1]

Using this total systems concept, a business or industrial organization can be thought of as a complex network of information channels established for the purpose of accomplishing certain objectives. These channels emerge at various points to control physical processes such as production of goods, hiring of employees, and the building of factories. Every action point in the system is backed by a local decision point whose information sources reach into other parts of the organization and the surrounding environment. Decision making in this context is the process of converting information into action. Decisions are made at multiple points throughout the system. Each resulting action generates information that may be used at other decision points, which in turn will result in additional action.[2]

Three new systems analysis techniques have recently been created that are concerned with these decision points. They are

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[1]Carl Heyel (ed.), The Encyclopedia of Management (New York: Reinhold Publishing Corporation, 1963), pp. 966-67.

[2]Jay W. Forrester, Industrial Dynamics (Massachusetts Institute of Technology: The M. I. T. Press and New York: John Wiley & Sons, Inc., 1961), p. 94.

Operational Sequence Diagram (OSD), Industrial Dynamics, and Decision Order Technique (DOT). The purpose of this paper is to develop Decision Order Technique and discuss the value of DOT as an effective instrument for systems analysis.

Dunlap and Associates, Inc., have incorporated decision symbols in their Operational Sequence Diagram (OSD), which is a process charting technique modified for the peculiar needs of human factors work. Its primary use has been in determining man-machine interaction sequences, in analyzing communication requirements between groups of men and machines, and in coordinating information-decision-action sequences between parts of a system.[3]

The Industrial Dynamics approach examines each decision point in a system and considers decision making as a continuous process that is a conversion mechanism for changing continuously varying flows of information into control signals that determine rates of flow in the system. The amount of control action is some function of the discrepancy between goals and the observed system status.[4]

Decision Order Technique considers each decision point in a system from three different points of view: (1) the relevance that the decision has to established objectives, (2) the decision order level of the decision which is determined by how well the decision is defined by decision rules, and (3) the position level

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[3]Martin I. Kurke, "Operation Sequence Diagrams in Systems Design," Human Factors (March, 1961), pp. 66-73.

[4]Forrester, pp. 96, 132.

of the decision maker. DOT also develops a comparison of these three factors and evaluates the relationships between them in a given system.

DOT differs from OSD in that DOT examines each decision process and the relationship of a sequence of decisions, where OSD indicates only the relationship of the decision to subsequent actions.

DOT and Industrial Dynamics are similar in their view of decision making in systems analysis but differ in the distance from which the decision process is viewed. The Industrial Dynamics approach is close enough to be aware of the decision point and its place in the system but is not close enough to see each separate decision in the system or to be concerned with the mechanisms of human thought in the decision process.[5]

DOT takes a much closer look at the decision-making process at each locus in order to analyze it in terms of the decision order level and the degree of relevance the decision has to established objectives and the position level of the decision maker.

Methodology Used in the Development of Decision Order Technique

After the conception of DOT the literature was researched in the fields relating to decision making, systems analysis, and model building in order to further develop DOT as an instrument to be used by management to better understand their operations and to improve their systems.

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[5]Forrester, p. 96.

The principal phases of decision making and some of the basic theories of decision making are discussed in Chapter II to establish a base for the development of DOT. In Chapter III a conceptual framework is established and quantitative scales are created for each of the three factors considered at each decision locus as well as a discussion of the contribution each factor makes to systems analysis and management. DOT is further developed as an analytical instrument in Chapter IV through the investigation of the relationships between the factors and the development of mathematical and analogue techniques to evaluate these relationships and compare them to real world situations. The conclusions in Chapter V delineate the contributions that DOT makes to systems analysis and business management along with criticism of assumptions and methodology used in the development of Decision Order Technique.

CHAPTER II

CONCEPTS OF DECISION MAKING

Decision making -- choosing one course of action rather than another -- finding an appropriate solution to a new problem posed by a changing world -- is commonly asserted to be the heart of the business manager activity.[1] Dr. Simon of Carnegie Institute of Technology speaks of the whole process of decision making (which he treats as synonymous with managing--not merely the final act of choice among alternatives which many considered as decision making). The decision-making process is comprised of three principal phases:

1. Finding occasion for making a decision. (To which of his many problems should the manager direct his attention?)

2. Finding possible courses of action. (How much time, effort, and expense should the manager invest in resolving uncertainty about that problem?)

3. Choosing among courses of action. (What solution to the problem should he use?)

Managers spend a large fraction of their time on Phase 1, an even larger fraction (either individually or with associates) on Phase 2, and a small fraction of their time on Phase 3.

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[1]Richard M. Cyert, Herbert A. Simon, and Donald B. Trow, "Observation of a Business Decision," Journal of Business (Vol. 29, 1956), pp. 237-48.

Simon has identified these three phases of the decision-making process as follows and, generally speaking, in this order:

1. Intelligence Activity (using the military meaning of intelligence) -- Searching the environment for conditions calling for decision.
2. Design Activity -- Inventing, developing, and analyzing possible courses of action.
3. Choice Activity -- Selecting a particular course of action from those available.

The cycle of phases is far more complex than this sequence suggests. Each phase in making a particular decision is itself a complex decision-making process. The design phase, for example, may call for new intelligence activities. Problems at any level generate subproblems that in turn have their intelligence, design, choice phases, and so on. Nevertheless, the three large phases are often clearly discernible as the organizational decision process evolves.

Most decision theories of problem solving are theories of the last phase of this process, but recent research suggests that the first two are more important.[2] (See Figure I.)

Edwards considers two distinct categories of decision theory: Static Decision Theory and Dynamic Decision Theory.

Static decision theory is concerned with that aspect of decision making which is characterized by a well defined set of possible courses of action. Associated with each course of action

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[2]Herbert A. Simon, The New Science of Management Decision (New York: Harper and Row, 1960), pp. 1-4.

CONCEPTS OF DECISION MAKING

Principal Phases of Decision Making		Theories of Decision Making		
	Simon's Identification	Economists and Some Psychologists	Edwards' Theory	Carnegie-Rand (Simon, Newell, Shaw)
Finding Occasion to make Decisions	Intelligence Activity			Highly Non-Programmed ↑
Finding Possible Courses of Action	Design Activity		Dynamic Decision Theory	↕
Choosing Among Alternatives	Choice Activity	Traditional Decision Theory	Static Decision Theory	↓ Highly Programmed

Figure I

and each possible state of the world is a value. Collectively these values form a payoff matrix. The decision-maker chooses one of his courses of action.[3]

Economists and a few psychologists have produced a large body of theory and a few experiments that deal with individual decision making. The kind of theory with which this body of theory deals is categorized by Edwards' static decision theory--that is, given two states, A and B, into either one of which an individual may put himself, the individual chooses A in preference to B (or vice versa). The economic theory of decision making is a theory about how to predict such decisions. In recent years the development of economic theory of consumers' decision making has become exceedingly elaborate, mathematical, and voluminous. This literature is almost unknown to psychologists in spite of sporadic pleas in both psychological and economic literature for greater communication between the disciplines. Edwards has prepared a very comprehensive paper in which he reviews this theoretical literature and also the rapidly increasing number of psychological experiments (performed by both psychologists and economists) that are relevant to it. He points out that psychologists and the economists are approaching the problem from different ways and neither of them are really getting down to the actual problem at hand.[4]

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[3]Ward Edwards, "Dynamic Decision Theory and Probabilistic Information Processing," Human Factors (April, 1962), p. 59.

[4]Ward Edwards, "The Theory of Decision Making," Psychological Bulletin (July, 1954), pp. 380-415.

In Edwards' dynamic decision theory decision-makers are conceived of as making a sequence of decisions. Earlier decisions, in general, produce both payoffs and information; the information may or may not be relevant to the improvement of later decisions. The objective of the decision-maker may be taken to be maximization of total profit over the long run, but it is quite likely to be desirable to give up short-run profit in order to increase long-run profit. The most common instance of such a conflict would arise in situations where some courses of action lead to more information and less profit, while others lead to less information and more profit.

In dynamic situations a complication not found in the static situation arises. The environment in which the decision is set may be changing, either as a function of the decisions, or independently of them, or both. It is this possibility of an environment which changes while you collect information about it which makes the task of dynamic decision theory so difficult and interesting. Most of the manageable cases are those in which the environment is not changing or is changing only in systematic response to the decision-maker's decisions.[5]

Cyert, Simon, and Trow at Carnegie Institute of Technology speak of the two categories of decision theory as the traditional theory of decision (the rational choice process in statistics and economics) which appears applicable only to the highly programmed decision problems and a revised theory which takes into account the

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[5]Edwards, Human Factors, pp. 60-61.

search process and other information processes that are characteristic of nonprogrammed decision making. Decisions in organizations vary widely with respect to the extent to which the decision-making process is programmed. At one extreme we have repetitive, well defined problems (e.g., quality control or production lot-size problems) involving tangible considerations to which the economic models that call for finding the best among a set of pre-established alternatives can be applied rather literally. In contrast to these highly programmed and usually rather detailed decisions are problems of a non-repetitive sort often involving basic long-range questions about the strategy of the firm or some part of it, arising initially in a highly unstructured form and requiring a great deal of intelligence (search) activity. In this whole continuum from the great specificity and repetition to extreme vagueness and uniqueness, decisions that lie toward the former extreme are called programmed, and those lying toward the other end are called nonprogrammed with decisions of all shades of gray along the continuum.[6] (See Figure I.)

To further clarify this dichotomy it can be said that:

> Programmed decisions are those decisions that are repetitive and routine and those for which a definite procedure has been worked out for handling so they do not have to be treated as new each time they occur.

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[6]Cyert, pp. 237-38.

> Nonprogrammed decisions are those decisions that are novel, unstructured, and consequential. There is no cut-and-dried method for handling the problem because that problem has not arisen before, or because its precise nature and structure are elusive and complex, or because it is so important that it deserves a custom-tailored treatment.

Making programmed decisions depends on relatively simple psychological processes that are somewhat understood, at least at the practical level. These include habit, memory, and simple manipulation of things in symbolic form. Making nonprogrammed decisions depends on psychological processes that until recently have not been understood at all. Because they have not been understood, the theories about nonprogrammed decision making have been rather empty and practical advice only moderately helpful.[7]

New techniques for programmed decision making have been developed through the evolvement of operations research. Some of the tools created to solve concrete managerial problems are linear programming, dynamic programming, game theory, and probability theory. Several related innovations have contributed to the revolution in programmed decision making:

1. The electronic computer is bringing about with unexpected speed a high level of automation in routine (programmed) decision making and data processing that was formerly the province of clerks.

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[7]Simon, pp. 5-6.

2. The area of programmed decision making is being rapidly extended as new ways are found to apply the tools of operations research to the types of decisions that have been regarded as judgmental--particularly, but not exclusively, middle-management decisions in the areas of manufacturing and distribution.

3. The computer has extended the capability of mathematical techniques to problems far too large to be handled by less automatic computing devices and has further extended the range of programmable decisions by contributing the technique of simulation.

4. Companies are just beginning to discover ways of bringing together the first two of these developments of combining the mathematical techniques for making decisions about aggregative middle management variables with the data processing techniques for implementing these decisions in detail at the clerical level.[8]

The development of techniques for programmed decision making and the reduction of some unprogrammed areas to sophisticated programs still leave untouched a major portion of managerial decision-making activity. Many of the problems that have to be handled at middle and high levels in management have not been amenable to mathematical treatment and probably never will.

Simon mentions "Gresham's Law of Planning," which states that programmed activity tends to drive out nonprogrammed activity. In this same conceptual area March set up a laboratory experiment to reproduce some of the critical characteristics of the executive's

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[8]Simon, p. 21.

decision problem as to which problem to solve. He had two significant results:

1. Despite instructions to spend only one-third of the time on routine matters, the subjects spent a good deal more than that even when the work load was relatively light.
2. Consistently, as the work load increased, subjects spent a smaller portion of their total time on planning activities. At peak loads virtually no planning was evidenced.[9]

The organizational implication of Gresham's Law is that special provisions must be made for nonprogrammed decision making by creating specific organizational responsibilities and organizational units to take care of it.

Based primarily on psychological research and observations conducted by Newell, Shaw, and Simon, Simon posed this central hypothesis of the theory of problem solving:

> "In solving problems, human thinking is governed by programs that organize myriads of simple information processes or symbol manipulating processes into orderly, complex sequences that are responsive to and adaptive to the task environment and the clues that are extracted from that environment as the sequences unfold."[10]

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[9] J. G. March, "Business Decision Making," Industrial Research (Spring, 1959).

[10] Simon, pp. 25-26.

Since programs of the same kind can be written for computers, these programs can be used to describe and simulate human thinking.

One such program is the one labeled GPS (General Problem Solver--developed by the Carnegie-Rand research group), which can reason in terms of means and ends about any problem that is stated in a certain general form. Problem solving proceeds by erecting goals, detecting differences between the present situation and goal, finding in memory or by search tools or processes that are relevant to reducing differences of these particular kinds and applying these tools or processes. Each problem generates subproblems until we find a subproblem we can solve, for which we already have a program stored in memory. We proceed until by successive solution of such subproblems, we eventually achieve our over-all goal--or give up.

The General Problem Solver mirrors this process. Its programs enable it to formulate and undertake three kinds of goals: (1) transform goals, (2) reduce difference goals, and (3) apply operator goals. With each of these types of goals is associated one or more methods for accomplishing it. When the goal is formulated by GPS, these methods are evoked from memory and tried.[11]

An important method that was used by subjects, especially the more skillful subjects, for achieving transform goals was a method Dr. Simon calls <u>planning</u>. By applying abstractions, images,

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[11]A. Newell, J. C. Shaw, and H. A. Simon, "A General Problem Solving Program for a Computer," <u>Computers and Automation</u> (July, 1959), pp. 10-17.

or models to the problem, the irrelevant details are discarded and only the essential aspects of the situation are retained. The new problem will generally be far easier to solve than the original one. Once it has been solved, it provides a series of trail markers to guide the solution of the original unabstracted problem. The planning method has been incorporated as one of the methods available to GPS.[12]

Programs which, like GPS, carry out complex information processes by using the same kind of selectivity in exploration and the same sort of rules of thumb that are used by humans are called heuristic programs. Heuristic programming represents a point of view that programs should not be limited to numerical processes, or even to orderly, systematic non-numerical algorithms of the kinds familiar from the more traditional uses of computers such as processing and recording personnel data, but that ideas should be borrowed also from the less systematic, more selective processes that humans use in handling those many problems that have not been reduced to algorithm.[13]

GPS is not the only program that has been written which simulates some aspects of human thinking. Computer programs have been developed that enable computers to prove theorems in logic and geometry, to play checkers and chess, to design motors, and

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[12] Simon, pp. 28-29.

[13] H. A. Simon and A. Newell, "Heuristic Problem Solving: the Next Advance in Operations Research," Operations Research (January, February, 1958), pp. 1-10.

to compose music. These examples provide some indication of how far research has progressed in explaining through computer simulation the heuristic processes that humans use in their nonprogrammed problem-solving and decision-making activity.[14]

Success in simulating human problem solving can have two kinds of consequences: (1) It may lead to the automation of some organizational problem-solving tasks. (2) It may provide us with means for improving substantially the effectiveness of humans in performing such tasks.

With the rapid dissolving of the mysteries surrounding nonprogrammed decision making, the question of how far decision making shall be automated ceases to be a technological question and becomes an economic question. The fact that a computer can do something a man can do does not mean that we will employ the computer instead of the man. Computers today are demonstrably more economical than man for most large-scale arithmetic computation, but Dr. Simon's experience to date suggests that computers do not have anything like the comparative advantage in efficiency over humans in the area of heuristic problem solving that they have in arithmetic and scientific computing.[15]

As computer design evolves and as the science of programming continues to develop, the economics of heuristic problem solving by computer will change rapidly. As it changes, we shall

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[14]Ibid., p. 10.

[15]Simon, The New Science of Management Decision, pp. 32-33.

have to reassess continually our estimates as to which tasks are better automated and which tasks are better put in the hands--and heads--of the human members of organizations.

In summary, adequate knowledge of the processes that are involved in decision making has been grossly lacking in the past. Human thinking, problem solving, and learning have been mysterious processes which have been labeled but not explained. Decision making is not just the choice of alternatives, as believed by the economists and some psychologists who are engrossed in traditional decision theory, but instead a complex process of finding occasion to make decisions and developing possible courses of action before a choice can be made among these courses of action.

Edwards' theories transcend traditional decision theory and represent the work that psychologists and human factors people are doing primarily in the fields of information processing and man-machine systems. Edwards appears to be concerned more with the structure of the decision-making situation than the purely human aspects of the process. His theories greatly overlap the Carnegie-Rand continuum concept, as shown in Figure I, but are limited for application to business situations because they are based on controlled laboratory situations and do not relate as readily to complex business systems as does the Carnegie-Rand concept.

The Carnegie-Rand concept that highly programmed decisions and highly nonprogrammed decisions lie at opposite ends of a whole continuum with partially programmable, partially nonprogrammable decisions all along the continuum is the most comprehensive and progressive decision-making theory that has been presented. With its broad conceptual coverage of all levels of decision making that may be encountered in a complex system, the Carnegie-Rand concept affords an ideal foundation from which to engender the decision order level factor in the development of Decision Order Technique as an instrument for systems analysis.

CHAPTER III

THE DEVELOPMENT OF DECISION ORDER TECHNIQUE

A Conceptual Framework

The improvement of a system presupposes knowledge of that system. The consideration of a business system as a complex communications network consisting of a series of decisions and actions with the decisions controlling the actions accentuates the importance of decision processes in systems operation. These decision points can be identified and evaluated in terms of selected criteria. Problems arise when an attempt is made to quantify what are normally considered as qualitative values, but these problems can be minimized by creating abstract models that represent real world situations. By constructing such models and watching the interplay of factors within them, the analyst and manager can gain a better understanding of the system with which they are dealing and create new organizational designs that yield more favorable performance and better achieve desired objectives.

A word or description is a model; a mental picture of how the organization functions is a model. A verbal model and a mathematical model are closely related. Both are abstract descriptions of the real system. The mathematical model is the more orderly; it tends to dispel the hazy inconsistencies that can exist in a verbal description. The mathematical model is more "precise."

By precise is meant "specific," and "sharply defined." The mathematical model is not necessarily more "accurate" than the verbal model, whereby accuracy is meant the degree of correspondence to the real world. A mathematical model could "precisely" represent the verbal description and yet be totally "inaccurate."

Much of the value of the mathematical model comes from its "precision" and not from its "accuracy." The act of constructing a mathematical model enforces precision. It requires a specific statement of what is meant. A model should be based on the best information that is readily available, but the design of a model should not be postponed until all pertinent parameters have been accurately measured; values should be estimated where necessary.

A model can be useful if it represents only what is believed to be the nature of the system under study. Such a model imparts precision to thinking and forces a commitment on what is believed to be the relative importance of various factors.[1]

A review of Bellman's philosophy of mathematical models will further develop a perspective for the creation of abstract models. His philosophy is:

> "The goal of the scientist is to comprehend the phenomena of the universe he observes around him. To prove that he understands, he must be able to predict; and to predict, one requires quantitative measurements.

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[1]Jay W. Forrester, Industrial Dynamics (Massachusetts Institute of Technology: The M. I. T. Press and New York: John Wiley & Sons, Inc., 1961), pp. 56-59.

A qualitative prediction, such as the occurence of an eclipse or an earthquake or a depression sometime in the near future, does not have the same satisfying features as a similar prediction associated with a date and time, and perhaps backed up by the offer of a side wager.

"To predict quantitatively, one must have a mechanism for producing numbers, and this necessarily entails a mathematical model. It seems reasonable to suppose that the more realistic this mathematical model, the more accurate the prediction.

"There is, however, a point of diminishing returns. The actual world is extremely complicated; and as a matter of fact, the more that one studies it, the more one is filled with wonder that we have even 'order of magnitude' explanations of the complicated phenomena that occur, much less fairly consistent 'laws of nature.' If we attempt to include too many features of reality in our mathematical model, we find ourselves engulfed by complicated equations containing unknown parameters and unknown functions. The determination of these functions leads to even more complicated equations with even more unknown parameters and functions, and so on. Truly a tale that knows no end.

"If on the other hand, made timid by these prospects, we construct our model in too simple a fashion, we soon find that it does not predict to suit our tastes.

> "It follows that the scientist, like the Pilgrim, must wend a straight and narrow path between the Pitfalls of Oversimplification and the Morass of Overcomplication."[2]

The decision-making process should start with some ethical premise or standard that is taken as "given." This premise describes the objectives of the organization in question. In order for a premise to be useful in rational decision making, the organizational objectives must be definite, so that their degree of realization can be assessed. It must also be possible to form judgments as to the probability that the particular actions will result in the attainment of the objectives.[3]

The decision processes represented by a given locus (L_n) in a certain system can be analyzed and evaluated in terms of the degree of relevance that decision has to the established objectives of the organization. A numerical value (o_n) can then be assigned to locate the relative position of L_n on a pre-established numerical scale that represents the objective levels in the organization hierarchy.

Using the Carnegie-Rand concept, an evaluation can also be made of the degree of programmability of the decision at L_n and a numerical value (d_n) can be assigned to the locus based on how well the decision is defined by decision rules. The well-structured,

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[2]Richard E. Bellman, Dynamic Programming (Princeton: Princeton University Press, 1957), p. x.

[3]Herbert A. Simon, Administrative Behavior (New York: The Macmillan Co., 1957), p. 50.

routine decisions that can be readily defined by decision rules and that can be adapted to existing computer programs can be indicated by a number on the low end of the scale. The numerical values on the upper end of the scale would then represent those decisions that are not defined by decision rules and are extremely difficult, if not impossible, to program with present techniques. Between the two ends of this continuum will fall a mixture of partially definable, partially programmable situations. The value assigned (d_i) is called the decision order level of the decision.

A value can also be assigned to the position level (p_n) of the decision-maker in accordance with his relative position in the hierarchy of the organization.

The basic parameters of DOT used for the analysis and evaluation of decision loci (L_i) in organizational systems are o_i, d_i, and p_i, where:

o_i = the degree of relevance the decision has to established objectives,

d_i = the decision order level of the decision,

p_i = the position level of the decision maker.

Based on this conceptual framework numerical scales can be developed for each of the three parameters and models created to compare the relationship of the factors to each other and to the real world and to simulate new designs.

Relevance to Objectives

Before numerical scales can be established for o_i, the meaning of objectives and the hierarchy of objectives must first be understood. An objective is defined as "an aim or end of action" for a total organization as well as an aim or guide to intermediate decisions and actions. There are objectives within objectives, within objectives. They all require painstaking definition and close analysis if they are to be useful separately and profitable as a whole. In some orderly way we must relate the "grand design" type of objective with the much more limited objectives lower down in the organization.[4]

Organizational objectives give direction to activities and serve as media by which multiple interests are channeled into joint effort. Some are ultimate and broad objectives of the firm as a whole; some serve as intermediate or subgoals for the entire organization; some are specific and relate to short-term aims. Moreover, there is a hierarchy of objectives in an organization: At the top the entire organization aims in a given direction; each department in turn directs its efforts toward its own sets of goals; each subdivision of each department has its own meaningful aims. Each of the subgoals should be consistent with, and contribute toward, the goals of the next higher level. For example, it is generally assumed that a corporation has the broad objective of maximizing profit. To aid in achieving that over-all goal, it

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[4]Charles H. Granger, "The Hierarchy of Objectives," *Harvard Business Review* (May-June, 1964), p. 64.

is necessary to define more meaningful subgoals for the individual departments. The marketing department may have goals in terms of a certain increase in total sales, and its subdivisions may be given goals in definite geographical areas or in specific product lines. The production department may state its goals in terms of minimizing production costs, and its subdivisions may be given subgoals for particular types of costs. Other departments in turn have goals redefined for them so that they can visualize exactly their part in striving for the company's broad goal of maximizing profits. Each part of an organization can contribute toward companywide objectives if it clearly sees its own specific goals and can determine, through measurement, how well it is doing. The selection of the proper factors to be measured is an important decision, because usually that which is measured is that which receives attention.[5]

The over-all objectives of a firm generally are established by top management; yet it is desirable for each subordinate manager to have a voice in setting his own objectives. If each manager is to understand the relationship of his own organizational objectives to the broader objectives of the company, he will need to participate in the goal-setting process. If he is involved in establishing his objectives, he will feel that the objectives are proper once they are set and will tend to accept them more readily. In this way

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[5]Joseph L. Massie, Essentials of Management (Englewood Cliffs: Prentice-Hall, Inc., 1964), pp. 29-30.

each part of the organization will strive in a joint effort toward the recognized organizational objectives.[6]

A more specific approach is to view an organization as a hierarchical arrangement of decision matrixes with subobjectives defined at each level as shown in Figure II. Investigation of the interrelationship of the different levels in this arrangement as in a real organization reveals that the means of the upper level become the ends or immediate objectives of the next level down in the structure and the means of this level become the ends for the next lower level, etc., on down through the structure.[7]

Each organization under study will have a unique breakdown of subobjectives based primarily on the selected structure of that organization. For the purpose of this paper a four-level hierarchy, as shown in Figure II, will be considered with the objectives and subobjectives ranked in four general categories, one for each level of the hierarchy. The objectives of the uppermost level are considered as superobjectives or global goals. The objectives of the next level are classified as policy objectives. The objectives for the third level down are considered as procedural objectives, and the objectives of the bottom level consist of decision rules.[8]

A bit of a dilemma arises when an attempt is made to establish a numerical scale for o_i (the degree of relevance that

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[6]Ibid., p. 31.

[7]F. Parker Fowler, Jr., Lecture to a class in Operations Research at the University of New Mexico, October, 1963. (Unpublished notes.)

[8]Ibid.

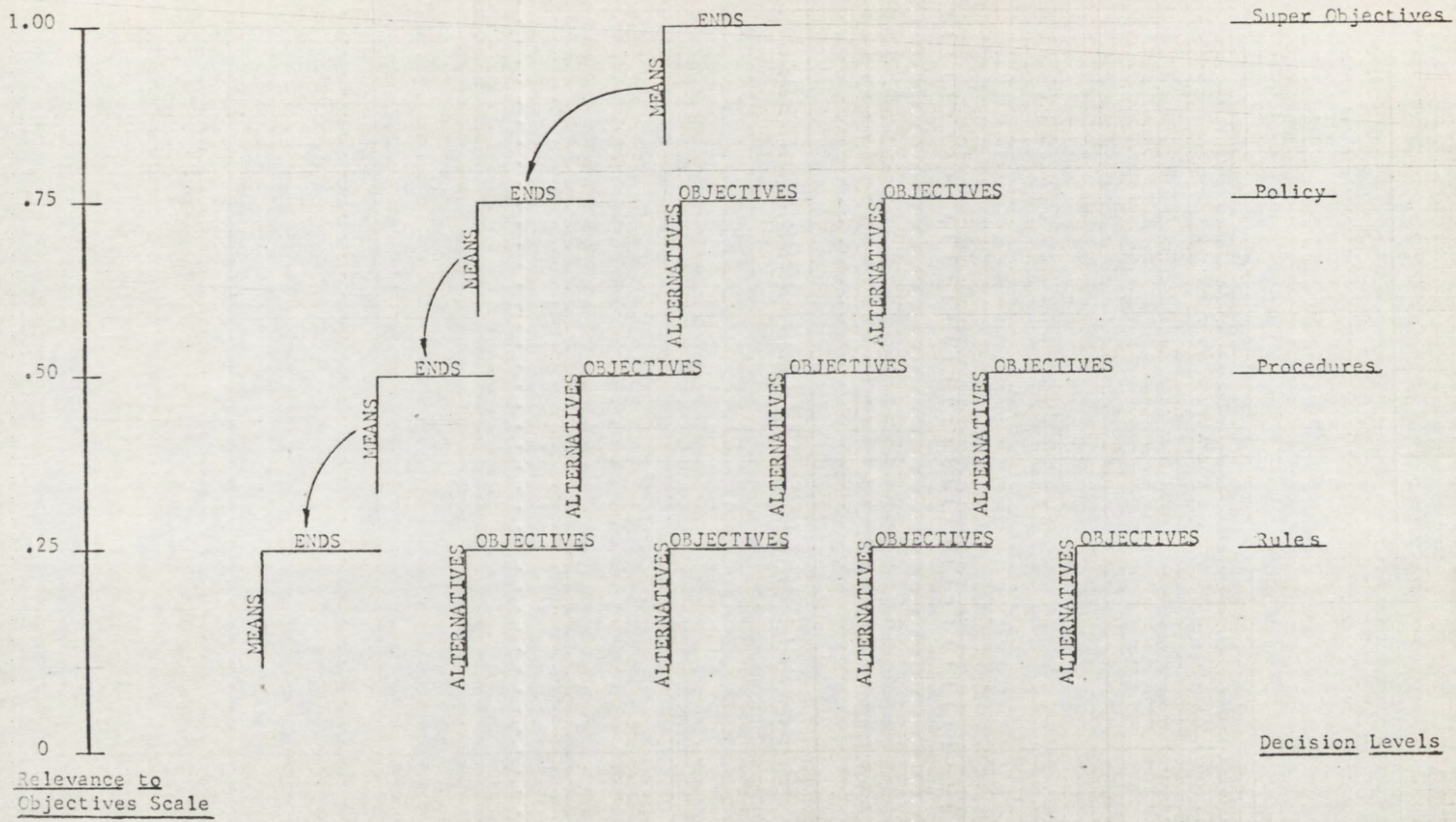

FIGURE II - THE HIERARCHY OF ORGANIZATION OBJECTIVES the decision has to established objectives). On one hand, the decision can be viewed in light of the subobjectives of the organization level in which the decision falls and, on the other hand, it can be viewed in terms of the superobjectives established for the total organization. This dilemma can be resolved by considering each subobjective in light of the superobjectives and establish a degree of relevance of each subobjective to the superobjectives.

A numerical scale is established from 0 to 1.0 on which the degree of relevance each subobjective has to the superobjective can be indicated. Relative values are then assigned to the various levels in the hierarchy as shown in the left margin of Figure II. For convenience the value of o for the bottom level is selected as .25; for the next level, .50; for the policy level, .75, and naturally, for the top level, 1.0. The objective continuum for the organization displayed in Figure II has now been established. Evaluation of a decision locus based on the established scale will indicate its relevance to the superobjectives as well as the subobjectives for the level in which the decision is made. For example, a decision made at the level next to the bottom is evaluated as $o_n = .40$. This would mean that the decision has a 40 per cent relevance to the superobjectives and an 80 per cent relevance to the subobjectives of that level.

These values are determined by using the following approach: The decision is evaluated in terms of its relevance to the established objectives for the procedures level of decisions and is found to be 80 per cent relevant. The pre-established degree of relevance for procedures level of decisions in terms of superobjectives is 50 per cent. The resulting degree of relevance of the decision to superobjectives is the product of these two values (.80 x .50) or .40.

Consideration of the o_i factor in the application of DOT forces management to define objectives for the different levels in the organization, establish relationships among these levels, and focus attention on individual decisions and their relevance to these objectives.

The feasibility of this approach is supported by its similarity to Peter Drucker's management by objectives approach, in which objectives are supplied to "every area where performance and results directly and vitally affect the survival and prosperity of the business."[9]

Decision Order Level

A decision order scale as developed conceptually above evolves as a finite numerical scale of decision levels of the form:

$$0 \leqq d_i \leqq D$$

$$(i = 1, 2, \ldots N)$$

where: d_i = the decision order level,

D = the maximum decision order level selected for the organization under study,

i = the number of a particular decision locus in the system,

N = the total number of decision loci in the system.

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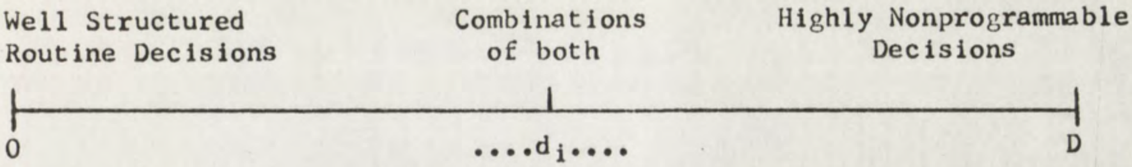
[9] Peter F. Drucker, The Practice of Management (New York: Harper and Row, 1954).



All decisions in a given system will fall somewhere on this scale with their relative positions determined by the decision order level assigned.

The assignment of a decision order value (d_n) for a given locus (L_n) is the most difficult of the three factors. The analyst must ascertain the decision rules in use for L_n and the environment in which the decision is made. He must analyze the decision process used by the decision-maker, evaluate the process in terms of its programmability, and determine where the locus would come on the decision order scale. The numerical value of d_n will be established by the relative position of L_n on the decision order scale. Further scrutiny of the decision process at L_n may indicate whether that decision might be better defined by decision rules and, therefore, become more programmable. Action to revise the decision process based on the recommendations of the analyst is management's responsibility. A review of all decision loci in the system will possibly reveal the obvious division points for automation of segments of the system.

Position Level

The development of a position level scale is fairly straightforward. Most organizations today have a formal job-grading structure, such as the GS system in the federal government,

CHAPTER IV

DOT AS AN ANALYTICAL INSTRUMENT

Premise

In the preceding chapters individual instruments, o_i, d_i, and p_i, have been developed that can be used independently by the analyst to give him a greater understanding of a system and to indicate where corrective action should be taken to improve the system. An even greater contribution can be made by DOT to systems analysis through the comparison of the three factors and evaluating relationships between them.

Correlation Between the Degree of Relevance to Objectives (o_i) and the Position Level (p_i)

In an ideal system it is reasonable to believe that a positive relationship exists between o_i (degree of relevance the decision has to established objectives) and p_i (position level of the decision-maker). We cannot calculate directly a coefficient of correlation for these values, because we cannot assume a bivariate normal population. But we can determine the coefficient of rank correlation which depends not on the basis of the degree of association between actual observations shown in a sample, but rather on the basis of the association between the ranks of the observations.

The value of the coefficient of rank correlation (designated as r') is given by the formula:

$$r' = 1 - \frac{6 \sum a^2}{N(N^2 - 1)}$$

where a is the difference between ranks of o_i and p_i, and N is the number of loci compared. The values of o_i and p_i can be tabulated for each L_i in a given system and the differences a, a^2, and $\sum a^2$ calculated. Using these values and the formula above, we can determine the coefficient of rank correlation for that system. Once r' has been determined, the question comes to mind: How is it known that a positive correlation actually exists?

The coefficient of rank correlation (r') is a statistic and is subject to sampling error. A statistical decision rule to provide a basis for the decision on assuming or not assuming positive association has been formulated which fixes the risk of assuming a positive association if actually there is none. The table below gives critical values of r' for a risk of .025 for some sample sizes. If the value of a sample r' is equal to or less than the critical value of r' given in the table, it is assumed that no positive relationship exists. If the sample r' is greater than the critical value, it is assumed that the variables are positively correlated.[1]

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[1]Ernest Kurnow, Gerald J. Glasser, and Frederick R. Ottman, Statistics for Business Decisions (Homewood: Richard D. Irwin, Inc., 1959), pp. 438-41.

CRITICAL VALUES OF THE COEFFICIENT OF RANK CORRELATION

Sample Size (N)	Risk (.025)
10	.65
15	.43
20	.37
25	.34
30	.31
50	.23
100	.16

Decision Order Level (d_i)

Compared to Position Level (p_i)

The position level (p_n) can be compared with the decision order level (d_n) for each locus (L_n) in a given system for all loci in that system by considering the relationship between d_i and p_i. An examination of this relationship manifests that it is possible to develop an analogue model that is a reasonable facsimile to the real-life situation in an organization. Certain criteria must be met to achieve the facsimile desired. When $p_i = 0$, then $d_i = 0$. This indicates the condition that no decisions can be made if no position exists. When $p_i = P$ (the maximum position level in the organization), d_i must approach infinity, because there is no one above to make higher-order decisions. If we use the position level scale for the positive ordinate and the decision order scale for the positive abscissa, a rectangular coordinate system can be used as the basis for our model. The intermediate portion of the model must approximate the following conditions:

1. The curve must have an extremely sharp slope at the origin and decrease slowly for increased position levels in the

lower segment of the scale to show a narrow range of decision levels as expected for position near the origin.

2. As the position level (p_i) increases through the lower-, middle-, and upper-management positions, the slope should more rapidly decrease until it approaches a horizontal line when $p_i = P$. This dynamic slope concept indicates the increase in range and level of decisions as the position level increases as would be expected in real life.

The analogue model in Figure III is representative of the type of curve that could be expected. The dotted lines show the narrow range of decisions expected of a decision-maker at the four level in the position hierarchy and the wide range of decisions expected of a decision-maker at the eighteen level in the organization.

A mathematical model that describes the curve in Figure III can now be developed. With this model or one similar to it, the decision level expected for any position level in a given organization can be calculated. The actual relationship between decision order level and position level for a given organization and the resulting model is determined by management policy and the position hierarchy or organization structure of that organization.

The curve in Figure III is the graph of a logrithmic function of the form $d_i = \log p_i$. Further investigation indicates that a pure log function does not meet the basic criteria mentioned above, but a unique form of log function, $d_i = \log p_i!$, does closely approximate the curve except at the extremities. To rectify these discrepancies

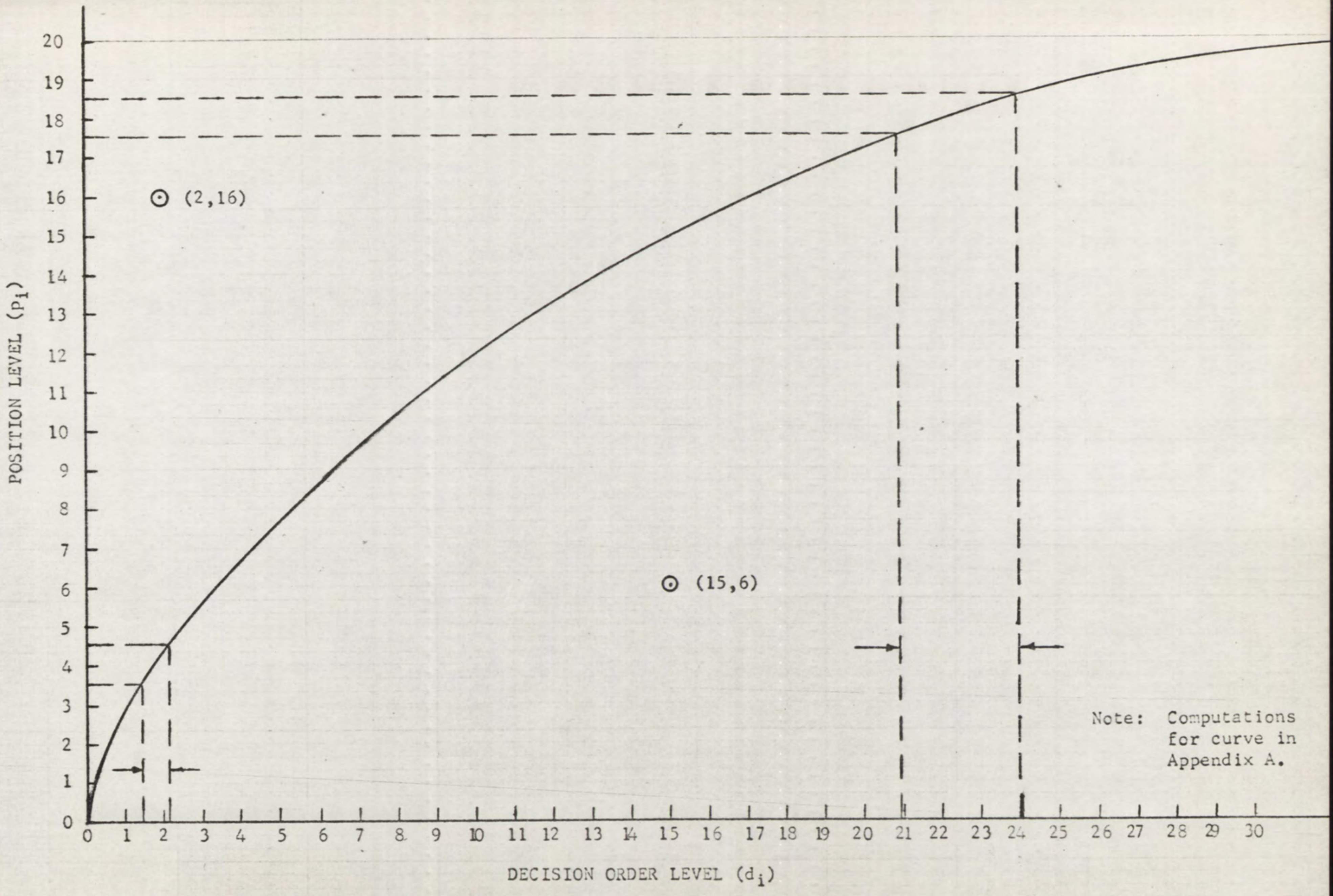

FIGURE III - ANALOGUE MODEL OF THE DECISION ORDER LEVEL AS A FUNCTION OF THE POSITION LEVEL a dampening factor of the form, $\frac{p_i}{P - p_i}$, has been developed which, when combined with the preceding relationship, meets the established criteria.

The fully developed equation that meets the established criteria and describes the curve in Figure III takes the form:

$$d_i = \log p_i! + \frac{p_i}{P - p_i}$$

where: $0 \leq p_i \leq P \quad (i = 1, 2, \ldots N)$

d_i = the decision order level,

p_i = the position level of the decision-maker,

P = the maximum position level in the organization under consideration,

i = the number of a particular decision locus,

N = the total number of decision loci in the system.

Once an analogue model has been developed that represents the desired characteristics of a given organization, it can be used as an optimal standard for evaluating each decision locus. When a series of points are plotted that represent (d_i, p_i) for a given system, whether it is what the system purports to be or as it actually exists, the results could possibly be groups of points located at various position levels on the graph. When this condition occurs, the analyst should attempt to fit a curve to the groups of points or change his approach and look at the system in terms of decision areas which could be shown on the graph as sets of decision order levels for given position levels. Deviations from this standard model revealed in the system study will indicate the problem areas that require corrective action to improve the system.

Let us review an example of how this concept would function in a real life situation: An analyst has consulted with the appropriate members of management, has reviewed the existing job structure, and has developed the model desired as the standard for this organization. He thoroughly studies the system, determines the decision loci, and assigns values to o_i, d_i, and p_i for each locus in the system. He then plots (d_i, p_i) for each decision locus (L_i) on coordinate axes along with the standard model. Any points (d_i, p_i) that deviate substantially from the standard are flagged, and the respective loci are analyzed in detail to determine the causal factors and the corrective action required.

For example, a point (d_3, p_3) with $d_3 = 2$ and $p_3 = 16$ plotted on the coordinate axes would deviate noticeably from the standard curve as shown in Figure III. An analysis of L_3 indicates that an individual in a high position is expending time and effort on a decision that could be readily programmed or reassigned to a much lower level position in the organization.

Conversely, a point, such as (d_5, p_5) where $d_5 = 15$ and $p_5 = 6$, that falls well below the standard curve indicates a high order decision that is made by a decision-maker in a relatively low position. This individual may be making decisions beyond the scope of his assigned position level through his own volition or through delegation from above. This situation is typical of the old-timer who is carrying a heavy decision load but has not been moved up in the organization because of potential repercussions throughout the organization. Corrective action would be recommended in both cases when the analyst redesigns the system. The actual correction of deviations is the responsibility of management.

CHAPTER V

CONCLUSION

The distinction that has been made between deciding and acting is certainly an oversimplification. Such a neat distinction cannot always be made. A decision initiates an action which in turn will generate the need for new decisions. The process is a never-ending one, and the decision-maker is immersed to some degree in both parts.

A conceptual separation of deciding and acting permits concentration on those aspects of the decision segments of the process which yield useful insights into the relevance to objectives, the position level of the decision-maker, and the decision rules necessary to make the decision. The prime reason for constructing a model of an organization or system is to gain an understanding of the abstract characteristics of the organization or process in terms of the total organization. One of the most difficult tasks in the art of model building is that of balancing realistic description against the power of available analytical and computational techniques. Quite often elaborate solutions are given to problems which have been meaninglessly simplified; and conversely, overly complicated versions of processes have gone unattended because of mathematical difficulties present.[1] An attempt has been made to avoid these pitfalls in the development of DOT but has not succeeded fully.

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[1]Richard E. Bellman and Stuart E. Dreyfus, Applied Dynamic Programming (Princeton: Princeton University Press, 1962), p. 279.

Decision Order Technique is very similar to Forrester's industrial dynamics approach to business problem solving, except that Forrester considers a dynamic model as one that deals with time-varying interactions.[2] The DOT model is a static model of a system at a given point in time that does not reflect oscillations within the system. An organization is like a living organism that is continually in motion, but DOT attempts to look at this organism in a state of equilibrium in order to assist management in the establishment of criteria for organizational structure and decision processes and to evaluate the existing structure and decision processes in terms of the established criteria.

Organizational objectives do not usually change very rapidly if continuity is desired in the system for an extended period of time. Therefore, at a given point in time objectives can be defined, evaluated, and ranked in importance and decision processes evaluated in terms of these objectives.

Decision processes are also continually fluctuating. They are affected by the environment, the skills and knowledge of the decision-maker, the information available, and the end objectives of the decision process. At any time, t, when the analyst is evaluating a given decision locus, the decision process may be in a transition from a lower order level to a higher order level or vice versa. In order to effectively evaluate the process, the analyst must assume a steady-state pattern, which is one that is

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[2]Jay W. Forrester, Industrial Dynamics (Massachusetts Institute of Technology: The M. I. T. Press and New York: John Wiley & Sons, Inc., 1961) p. 50.

repetitive with time and in which the behavior in one time period is of the same nature as any other time period.[3]

There are inherent weaknesses in DOT due to the judgmental aspects of the technique. When an analyst reviews a system, he acts on what he perceives to be the state of affairs. This perception is usually not identical with the actual state of affairs but depends on the sources of information used and the amount of prejudice and distortion with which the information is viewed. The analyst usually comes with ideas already formed about the system with which he is to deal. If he does not have sufficient firmness in his approach, he may never reach decisions and effective action. If his prejudices lead to blindness, the system he analyzes may be merely the one that he initially thought to be present or which he wished to be present. A system model is apt to become a reflection of how the participants hope the system operates rather than a picture of how it does operate, or should operate. Wishful thinking and strongly formed past prejudices are both hazards to successful systems analysis.[4] When a given decision locus falls within the confines of the standard model, there will always be a question as to whether it naturally should be there or is there due to some devious action on the part of the decision-maker or analyst.

The ethical application of DOT by a capable analyst to an organizational system forces the analyst and the management of that

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[3]Ibid., p. 51.

[4]Ibid., p. 452.

organization to consider the operation in view of the hierarchy of objectives, an established job structure, and the realization of the existence of decision levels.

When a framework of objectives is worked out for an organization and the system is analyzed with DOT, the danger of misdirected effort is greatly reduced. One of the most interesting uses of the framework of objectives is in management development. Most executives are keenly aware that the difference between their organization and other organizations in their field is personnel. They recognize that development of people is a key issue in the health and success of any enterprise. Recent theory, i.e., McGregor's Theory Y, as well as actual practice in management development, has stressed the concept of identifying the objectives of the individual with the objectives of the organization. It also suggests making these objectives as specific as possible and measuring their exact success in meeting them.[5] The application of DOT, especially the comparison of relevance to objectives and position level, facilitates the implementation of this concept.

The establishment of decision order level as mentioned before is based primarily on Carnegie-Rand decision theory of decision programmability. Given the present state of the art in computer programming, DOT will be most effective when used to analyze decision processes that are below the executive level. Some programs, such as Newell, Shaw, and Simon's General Problem Solver, have been

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[5]Charles H. Granger, "The Hierarchy of Objectives," Harvard Business Review (May-June, 1964), p. 73.

developed to handle decisions in the heuristic area, but these are still in the laboratory stage.[6] As computer technology and programming improve, economics will continue to be the dictating factor as to what man will do and what computers will do.

It is realized that the automation of decision making will alter the climate of organizations important to human concerns, but it is felt that the computer revolution, like the industrial revolution, will motivate man to make more effective use of those faculties with which man and man alone is equipped.

Richard Bellman confirms this belief in a recent article:

> "In order to apply mathematical theories to the treatment of decision processes, we must be able to describe the state of the system in precise terms, to describe the effects of decisions upon these states, and evaluate the worth of a sequence of decisions. In practically any decision process that one can think of in the realm of politics, industry, warfare, sociology--in other words, in processes involving people--we face difficulties in all three of these requirements. The major obstacle to the use of mathematics lies not in the solution of the formidable equations as most people believe, but in the formulation of questions in exact mathematical terms, the very first step.

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[6]A. Newell, J. C. Shaw, and H. A. Simon, "A General Problem Solving Program for a Computer," Computers and Automation (July, 1959), pp. 10-17.

Since a digital computer requires absolutely precise instructions for every step it takes, for every operation it performs, we cannot use a computer to solve any problem which we ourselves cannot state unambiguously. A computer has no judgment! As a matter of fact, it has none of the abilities we customarily associate with human intelligence. It has no power to recognize or formulate problems. Its ability to store and recall information is so primitive as not to be classified as 'memory.' It is incapable of making decisions on the basis of incomplete, ambiguous, and inconsistent data--a characteristic ability of the human mind."[7]

The challenge is there. As people are replaced by machines in performing those tasks that the machine can do best, other people will be needed to construct, program, operate, and maintain these machines.

Through the use of the computer man will be able to gain a better understanding of himself and his thought processes, so that he can develop those systems that optimize the utilization of machines for what the machine can do best and man for the things that man can do best--all for the purpose of bettering man's lot in life. Once the basic concepts of DOT have been grasped and its functional value has been established, further development of the technique

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[7]Richard E. Bellman, "Computers and Decision Making," Computers and Automation (January, 1963), pp. 10-14.

may make it possible to introduce methodology such as statistical decision theory and possibly some aspects of dynamic programming. The test of experience is the only arbiter as to the success of a specific model.

The use of DOT as a management tool in the evolution of the computer revolution is limited some by the constraints that we have established in our conceptual framework, but we feel that its contribution to the development of more effective management far exceeds its limitations. As techniques are devised to better define decision-making processes and heuristic programs are developed that use humanoid problem-solving techniques, DOT will become more effective over a wider range of decision processes. That is to say, the effectiveness of Decision Order Technique (DOT) rests primarily on man's knowledge of decision processes, the stage of development of computer programs to handle these decision processes, and the application of these techniques to real-life situations.

APPENDIX A

Computation of Analogue Model $d = f(p)$

Mathematical Model:

$$d_i = \log p_i! + \frac{p_i}{P - p_i}$$

For Values: $0 \leq p_i \leq P$

Where, Maximum $p_i = P = 20$

Curve Characteristics:

$$0! = 1, \log 1 = 0$$

When $p_i = 0$, then $d_i = 0$

As $p_i \rightarrow P$, then $d_i \rightarrow \infty$

p_i	$\log p_i$	$\frac{p_i}{P-p_i}$	d_i
0	0	0	0
1	0	.053	.053
2	.30	.111	.411
3	.79	.176	.966
4	1.38	.250	1.630
5	2.08	.333	2.413
8	4.61	.667	5.277
10	6.56	1.000	7.560
12	8.68	1.500	10.180
14	10.94	2.333	13.270
16	13.32	4.000	17.320
17	14.55	5.667	20.217
19	17.09	19.000	26.090
20	18.39	∞	∞