1981 Winter Simulation Conference Proceedings
T.I. Ören, C.M. Delfosse, C.M. Shub (Eds.)

MANAGE -- AN INTERACTIVE SIMULATION MODEL FOR EVALUATING THE EFFECTS OF MANAGEMENT STRUCTURE ON ORGANIZATION PERFORMANCE

Michael D. Sherman, Ph.D.
Associate Professor - Finance
University of Toledo

This paper reports on progress to date in developing a computerized simulation - optimization model of the general management structure of a firm. This model called MANAGE, offers a framework wherein the profit performance of a company can be simulated and assessed under a variety of structural configurations. MANAGE also incorporates certain behavioral parameters that impact upon successful communication within corporate organizations. The paper describes the general framework of the model; the manner in which various structural, behavioral, and economic variables are incorporated into the model or can be set as desired by the user; and the nature of the outputs that are produced. The paper also describes the manner in which MANAGE generates profit solutions under various combinations of behavioral, heirarchical and economic conditions and compares them with traditional optimal economics results. The paper concludes with a brief discussion of the potential applications of MANAGE.

Recently, a series of articles appeared in the July 1981 issue of Decision Sciences dealing with prospective trends in the study of organizational behavior (OB) in the 1980's (see the first five papers presented in that issue).

One common strain of thought among the contributors was the need for "some bold experimentation in theory construction from conservatives and radicals alike" (Organ 1981) and the importance of increased reliance on the "construction, validation, and experimental use of simulation models" in OB research (Rose 1981). These are not new prescriptions, they were offered by members of the so-called systems modeling approach to organization study as early as the 1960's. Unfortunately, this school of thought has found little or no favor with "mainstream" organization theorists and many of those institutions and agencies funding research in this area. Thus, most management scientists and other systems advocates have turned elsewhere to more hospitable topics. This "new" attitude of organization behaviorists is encouraging, although this author has found little direct evidence of the change in his pursuit for the acceptance of and funding for such studies over the past few years. Nevertheless, having completed the important first phase of my research along these lines, I offer this paper with others to follow.

The motivation for developing MANAGE came from the strong debate that has raged for years among economists, management scientists, organization theorists, and others as to whether firms seek as their basic objective to maximize profits and, if they do, whether this goal is realistically achievable. Unfortunately, there has been no means of resolving these issues. This is because (a) published data as to intentions and performance, unobstructed by the myriad influences on corporate actions, is unavailable and (b) the only available economic and/or management computer models that generate data to permit the joint study of corporate goals in a managerial context are mechanistic in nature (see, for example, Kornai and Liptak 1965, Baker and Freeland 1972, Ruefli 1971a, 1971b, 1973, Sayeki and Vesper 1973, Cramer 1980). Individuals in such models are most often represented as mathematical programs, each with an objective function to be optimized and each subjected to certain constraints. While probabilistic events may or may not be considered in the model, the objective is always to achieve some optimum goal through the coordination of sub-goal achievements. Only passing, if any, attention is given to behavioral considerations and to the effect of communication difficulties. Consequently, while rich in results, these models are somewhat unrealistic in their representation of managerial communication and coordination. Therefore, the question of whether profit maximization (or other goal) results are achievable in a realistic communications environment remains unresolved.

MANAGE seeks to overcome the limitations of these models while at the same time incorporating their desirable features. MANAGE offers a framework whereby the achievement of the proffered profit maximization goal of the firm can be studied more realistically within the context of heirarchial structure and certain relevant behavioral variables that affect intraorganizational communication.

1. OVERVIEW OF THE MODEL

The basic format of MANAGE is that of a multi-echilon communication system similar to that outlined but not operationalized by Mesarovic, Macko, and Takahara (1970). In addition, certain features discussed in Flament (1963) are incorporated.

The firm, as conceived in the model, has a sequential production process governed by a hierarchial management structure similar to that illustrated in Figure 1 below. The process specifies the technical input-output relationship. To ease computation, the firm is assumed to produce only one product and it is assumed to have one goal -- profit maximization.

Because of the structure of the simulation routine, it has also been found more convenient to treat each element of the hierarchy as a decision unit rather than as an individual as have Mesarovic, Macko and Takahara (1970) and Marchak and Radner (1972). As demonstrated in Sherman (1977), the viewpoint causes no loss of generality. From this perspective, the goal of the firm, i.e., profit maximization, is taken to be that of the highest ranking unit, the supremum.

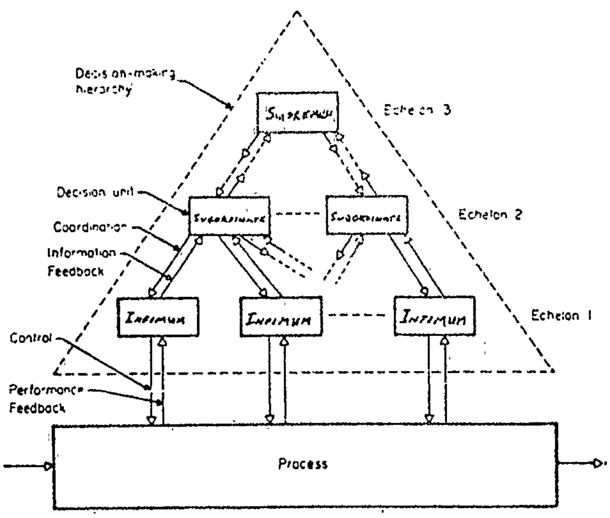


Figure 1. Multilevel Organizational Hierarchy; Multiechelon System

The prices of all inputs and the resultant output and the resultant output are determined exogenously as is the hierachical configuration of the firm. The latter must be specified initially by the program user.

The role of the management structure, as in all firms in the real world, is to translate the objective of the supremal unit (acting in behalf of the firm) into actuality with resultant goods produced for society's consumption. To accomplish this objective, the supremal decision unit sends orders to lower-level units in the hierarchy to instruct them as to what must be done. These orders are interpreted and verified through a process similar to that of negotiation, and the results are forwarded as orders to the next level in the structure, and so on. Eventually, instructions are received by the infimal decision units at the bottom of the hierarchy who directly control the production process of the firm. Based on the directives that reach them and their interpretation of these, they proceed to operate the manufacturing process and produce final outputs.

The importance of the hierarchy lies in its influence upon the nature of the orders which the infimal units ultimately receive. If the structural arrangement of the component departments in the organization generates a great deal of distortion in those commands, the profit performance of the company will be much poorer than if the framework were to be one in which little or not distortion can take place. By examining various hierarchical configurations, it then becomes possible to observe the profit impact, and thus the impact on the performance of the firm, of each.

The system is portrayed as a budgeting-planning model rather than as a operating model. This is because the operations of the firm are not considered in the model to be tailored to a time frame. However, the production decision itself is based on planning criteria and the necessary budgeting of corporate units that is consistent with such plans. The latter are constrained somewhat by time. The model, thus, abstracts somewhat from the real world where time and output are inexorably tied. The sacrifice has been made to reduce the added complexity that such recognition would require.

2. THE METHODOLOGY OF THE MODEL

MANAGE may be thought of as possessing four distinct components, although these are highly integrated in the program. The first portion sets up the exogenous variables and background conditions (e.g., the hierarchy and sequential changes in the hierarchy) for the simulation runs, reads in all necessary data, performs error checks on the model, and writes out a copy of the inputted information. The second section of the model consists of the optimization algorithm which determines the optimal level of output to be produced and, from that information, the optimal amount of capital and labor to be used, maximum profits, and, based on these profits, the optimal budget for the firm. In addition, the procedure also determines the optimal budget for each subordinate decision unit. (The derivation of this algorithm is based on Sherman 1977 and is similar to that found in Beckmann 1977 and Musgrave and Rasche 1977).

The third segment of MANAGE simulates the communication process which takes place between the decision units. By far the longest and most complicated portion of the program and the one containing the most subroutines, it adjusts for such features as multiple command, changing span of control, insertions of new levels into the hierarchy, changes in noise, and the effects of time pressure and capacity limits on decision unit performance.

The fourth section of the program contains the scheme for evaluating the performance of the firm and all of the decision units within it. The performance of each is based on comparisons of actual (realized) profit with optimal returns, actual budget used versus the optimal budget, actual output in comparison with optimal production, output per unit of input, etc. In addition, comparisons of achievement levels are also made using quasi-optimal indicators for some elements of the decision structure. Quasi-optimal is herein expressed in terms of the performance of a unit based on information sent to it from other, non-supremal departments. It derives from the fact that these latter units, themselves, may have misinterpreted the optimal information sent to them before generating orders to be forwarded to the divisions under them. Figure 2 provides a simplified flowchart of the procedures followed by MANAGE.

In order to run the program, certain information must be supplied by the user to initialize its exogenous parameters. Failure to supply any of the necessary data and/or incorrect specification of certain of the information will cause the program to abort immediately and a verbal description of the nature of the error which resulted in the abort will be produced. Some of the information which is required, particularly that which describes the individual characteristics of each decision unit is subjective in nature. Therefore, so long as such data is provided, the simulation will be carried out although the quality of the results will be reflective of the care and skill of the user in realistically specifying appropriate parameters.

As indicated above, MANAGE permits the analysis of firms with hierarchies containing between three and five levels, not including the production process itself. Corporations which require a management structure, i.e., those which are large, can be expected to contain at least three tiers -- an executive level (the supremal decision unit), a managerial level (the subordinate decision units), and an operating level (the infimal decision units). Although few major businesses possess more than seven levels, a number of studies by Carzo and Yanouzas (1969), Filley and House (1969), Williamson (1967) and others indicate that most have more finely divided authority distinctions than those permitted by only three graduations. Therefore by permitting up to five levels in the structure portrayed by MANAGE, the effect of these graduations and the concommitant impact of communication distince on organizational performance can be explored. Accordingly, the model permits the insertion of a level between the supremum and the subordinate decision units. The departments on this echilon are, therefore, intermediate-level subordinate decision units and are equivalent to the divisional executive levels in segmented or multi-product firms. The procedure also permits the insertion of a level between the subordinate decision units and the infimal decision units. The divisions here are intermediate-level infimal decision units. These correspond to the supervisory level in most corporations.

There is a dichotomy of functions performed by units on different levels in the simulated firm. Those at or above the subordinate level are involved exclusively in the determination and communication of the final output requirements for the company and the associated budget needs of each sector. Those units below the subordinate tier are solely responsible for the communication of required capital input purchases (the intermediate-level infimal units) and for the fabrication of the components and final production of goods using these inputs in the manufacturing process (the infimal units). Thus, the subordinate decision units are of particular importance in the configuration since they are privy to certain budget and output information not passed on to lower levels and must convert such data into capital input purchase orders for those serving under them. Thus, they provide the link between the upper and lower echilons in the firm.

The supremal unit is the only sector of the business which possesses knowledge of the desired profit level. It is its task to develop the overall budget limits for the firm. Budget requests by underling divisions are then reviewed in light of this limitation. The supremal unit also makes exclusive determination of the number of people to be hired into each division of the company.

The maximum number of decision units that may comprise any given level of the hierarchy, excepting the first (highest) echilon, is 12. There may be only one supremal decision unit. The 12 unit limit is based on a number of studies of the maximal number of subordinates that can be effectively controlled by any given unit beginning with those by Worthy (1950,) and Dale (1952) and continuing more recently with those of Carzo and Yanouzas (1969), Filley and House (1969).

An optional feature of the program permits evaluation of the effects of sequential changes in the span of control of a specified higher-level decision unit on the performance of the firm, the lower-ranking units under it, and of the senior unit itself. The procedure is designed to increase gradually the span of control of a selected superior department from one unit up to a total of eight units through the re-assignment of subordinate divisions. To allow the widest interpretation to be made, the program will perform the step-wise evaluation for departments on any of the intermediate levels of the hierarchy. Infimal units are excluded since they control no divisions.

The supremal unit also does not posses this feature. Changes in its span of control can only occur by adding new units to the structure, and not through internal reorganization. The addition of subordinate units would change the optimal solution results for the firm with each inclusion. This alteration would cause evaluations of performance under alternative authority configurations to be non-comparable. On the other hand, sequential changes in span of control can be accomplished on the other three (intermediate) levels without altering the total number of units on any tier. Thus, for the latter gradations the optimal solution, against which performance comparisons are to be made, remains unchanged throughout the analysis. Therefore, the effects of gradual changes in span of control can be assessed consistently.

Another optional feature of MANAGE allows the user to examine the impact of multiple command structures on the performance of the firm and its components. This procedure can only be implemented if a level of intermediate subordinate decision units has been inserted into the hierarchy. Further, joint authority is permitted only over the subordinate decision units. These constraints are a consequence of the dichotomy of budget versus output communication that exists between different hierarchical levels.

Both the supremal unit and/or one or more intermediate-level subordinate departments may exercise simultaneous authority over a common subordinate division. However, no more than four senior sectors -- three intermediate-level groups and the supremum -- may direct a common unit at one time. The three intermediate authorities must be positioned above and immediately to the left, center, or right of the jointly directed unit.

An algorithm has been developed as a part of MANAGE to provide a consistent means of enabling the subordinate decision unit to "decide" upon which superior group it will accept orders from. The procedure, though somewhat complicated, is based on the average historical penalty that that unit has suffered by having chosen to adhere to orders sent from a particular commanding sector. The penalty is derived from an assessment of the accuracy of the budget information forwarded to the unit over time from each senior authority group. A higher penalty is imposed for underbudgeting than for overbudgeting. This is because acceptance of too low a budget ensures deficient performance by the subordinate unit and its underlings.

Finally, the program possesses one additional elective. Each of the subordinate and intermediate-level subordinate decision units may play strategies in negotiating their assigned budgets. This feature allows these departments to be risk-takers, risk-averters, or risk-neutral. In the first case, such a division would request budgets below what it feels is necessary to elicit optimal performance and, upon receipt of an allotment, would attempt to reach this ultimate goal. In the second instance, it would seek a larger budget than necessary to ensure its achievement. If risk-neutral, the component would solicit financial capital strictly in accordance with its anticipated need. The latter alternative is the only one of the three utilized in this study.

3. LEARNING, ANXIETY, NOISE, AND OTHER FEATURES OF MANAGE

In addition to the above options, MANAGE also contains several built-in routines which add to the realism of the model. First, MANAGE allows decision units on all levels to "learn" as negotiations are carried forth. Senior departments gain a clearer "understanding" over time of the performance reports sent by sectors reporting to them. Similarly, the comprehension of orders by junior divisions also grows as they increasingly interact with superior units.

The program incorporates the learning feature through an adaptation of procedures found in Thomopoulos and Lehman (1969) and Baum and Bohlen (1975). According to these authors, the learning function assumes the form:

$$f(n) = \alpha n^{-\beta}$$

where: $f(n)$ ≡ the rate of learning, i.e., the learning curve, which measures performance on the nth repetition of an assignment,

α ≡ the initial level of performance

n ≡ the cumulative number of repititions of the assignment,

β ≡ the exponent of the learning function which reflects the rate of learning.

The learning function in MANAGE refers to the cumulative understanding acquired by a decision unit as it receives repetitive communication of information or orders. The variable α is interpreted in the program to be the initial level of noise assigned in a particular simulation run. n is the number of passes (communications) of the same information or orders between any two units. The parameter β is as defined above and is built into MANAGE.

MANAGE evaluates both corporate and individual unit performance in each simulation sub-study for three alternative levels of noise, unless the user chooses either to restrict the selections or to examine performance in a noiseless context. Thus, there are normally at least three runs in every sub-study. The alternative noise levels are 5%, 15%, and 45% distortion of the contents of the communications. Each alternative is specified in the model as the probabilistic degree of variation over $\pm 3\sigma$ (standard deviations) of the desired (i.e., mean) communication, based on a normal curve.

The approach centers around the use of a random number generator that draws values from a normal probability distribution. Thus, to "create" a level of noise, the methodology requires that the mean and standard deviation of the distribution be specified. The mean value represents the intended communication while the standard deviation reflects the standardized degree of variation in that message that can be expected to occur slightly over 68% of the time (for 1σ, and 99.7% of the time for 3σ).

To clarify this procedure in more detail, suppose that an order is sent from a senior division to a junior one requesting the latter to produce an output of, for example, 100,000 units. Further, let us assume that the noise level to be simulated is 5%. The noise generation technique within MANAGE will then require that the mean value of 100,000 units and the standard deviated value of 833.33 units to be fed to it to begin the process ($\pm 1\sigma$ of 100,000 is 1667 units). The command that the junior division will actually receive when noise is thus allowed to impact on the communication, given the stipulation of a 5% level of noise over $\pm 3\sigma$ standard deviations, will then vary between 97,500 and 102,500 units 997 times out of a thousand! (Since distortion can occur both in transmission and reception, the actual order will vary by the compound influence of noise on both ends of the communication). The effect of learning is to reduce this degree of distortion over time.

The basis for the selection of the 5% noise level is to be found in the works of Williamson (1967) and Monsen and Downs (1965), particularly the former. Williamson found that compliance typically will not reach 100% and is most likely to be around 90%. Furthermore, Williamson concluded, as have Carzo and Yanouzas (1969) and others, that the failure to comply is fundamentally responsible for limitations to firm size. Monsen and Downs offer discussion to support a maximum compliance value of 95%.

At the other extreme, both Tullock (1965) and Downs (1967) have explored the performance impact on an institution of having a compliance factor as low as 50%. They found that in a seven-tiered organization, the last recipient of a communication will receive only 1.6% of the intended meaning (6.3% in a five-level entity). This assumes that no measures are taken at any point in the transmission to reduce distortion. These boundaries, i.e., 5% and 50% distortion, provided the practical basis for establishing the range of alternative noise levels.

The parameter n, i.e., the number of communication passes of a specified message between any two decision units in any run, is automatically incremented as negotiations are carried out. Its value is limited by a complicated procedure which governs the negotiation process on a decision-unit-by-decision-unit basis. Briefly, the next round of correspondence by unit is permitted only if it possesses sufficient unused and unassigned capacity to send, receive, and interpret the next communication from its inter-acting partner, to carry out its assigned duties, and to allow sufficient communication of future orders and information between itself and all of its remaining adjunct departments. If sufficient uncommitted capacity no longer remains for either the partner or itself, negotiations are terminated and final data is sent to the subordinate decision unit. Obviously, all learning as related to communication between the two partners ends at that point for the simulation run.

The final parameter in the learning function, i.e., the exponent β that reflects the learning rate, has been built into MANAGE at a fixed level. The value that was chosen is based on several considerations. Unfortunately, there has been only limited research into the typical or most appropriate value(s) which β should be expected to assume. In general, investigators have found that β falls in the range $0.0 < \beta \leq 0.7$ (see, for example, Thomopoulos and Lehman (1969). The choice in these investigations as well as this one has depended on the mathematical formulation for the learning curve that was adopted, the focus of the study (i.e., aggregate comprehension at the firm or industry level versus individual and group understanding of an assignment or communication), and/or the values selected for other parameters in the equation. A number of alternative values of β were explored during the model validation precess. The figure which seemed to produce the most realistic results, given the nature of the model formulation, was 0.1.

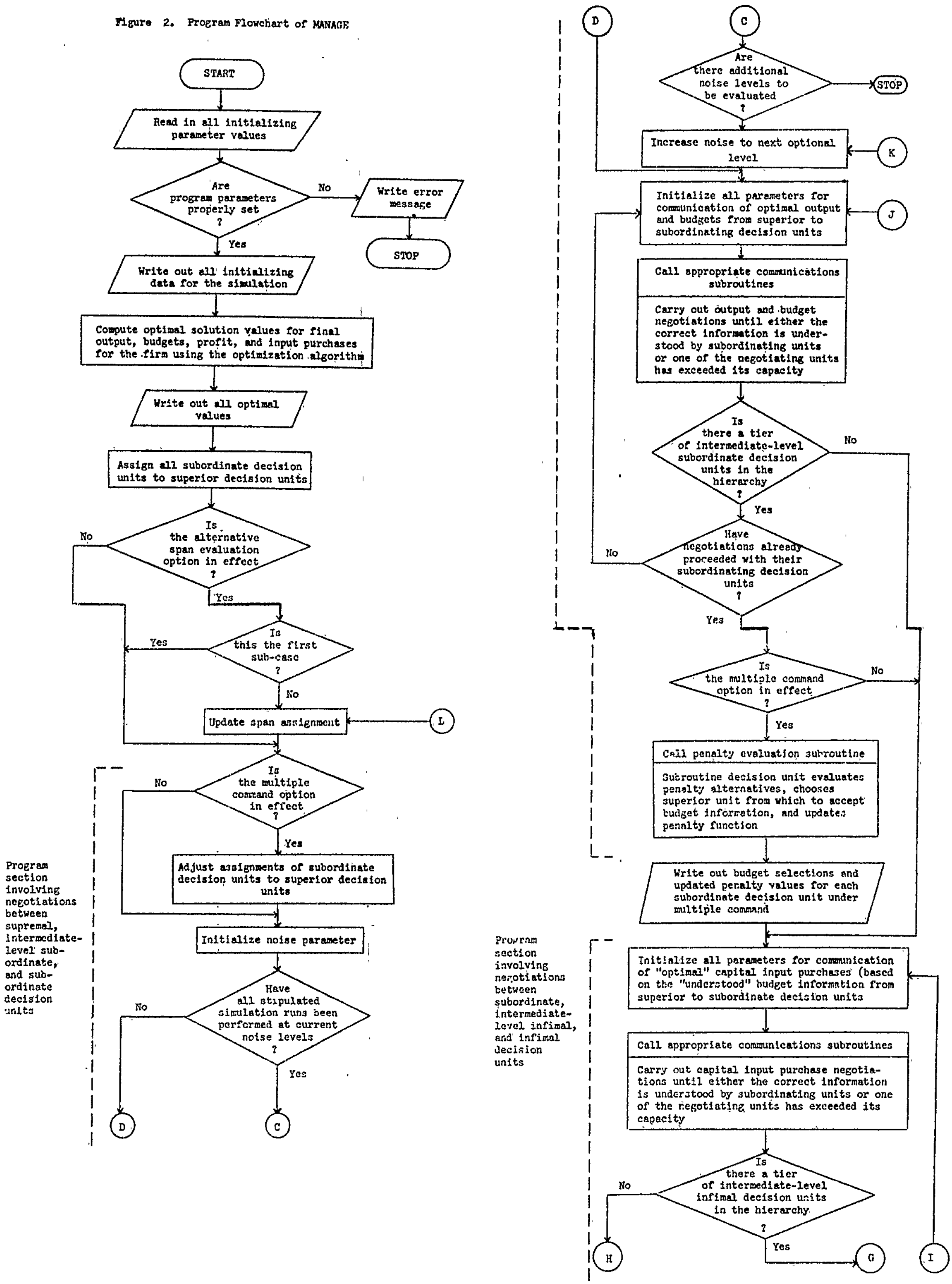
At the same time that learning takes place, decision units exhaust their capacity to perform. The need to carry out communication and other assignments gradually overloads the unit as available time and capacity are increasingly imposed upon. It is this imposition which has led many theorists to the fundamental conclusion that there is an increasing need for hierarchy as organizations grow (Downs 1967 and Tullock 1965). In fact, in nearly every study of organization, there is either an explicit or an implicit assumption of increased transmission error arising because of the effects of capacity overload (see, for example, Huber 1974, Arrow, 1964, and Moncan and Downs, 1965). Unfortunately, little work has been done towards the quantification of the impact of this phenomena on performance. However, efforts by Drenick and Levis (1974), Marchak and Radner (1972), and Kleinman (1974) offer very general relationships.

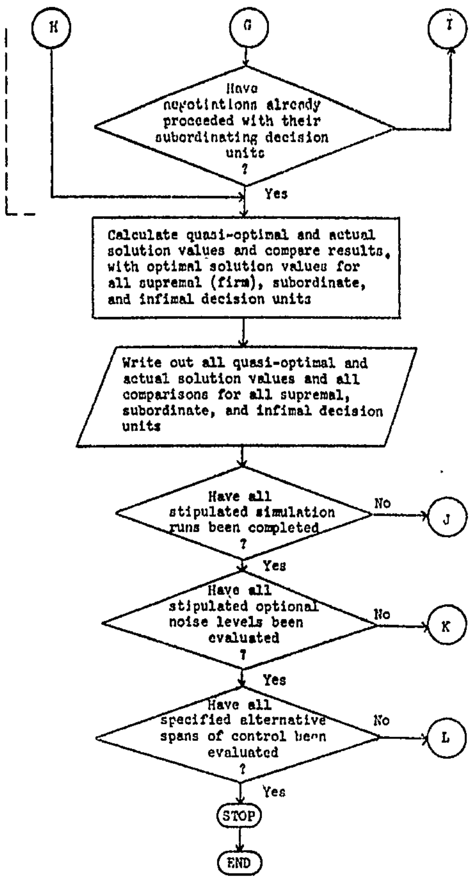
Without previous guidance, but requiring such a formula (or procedure) in the model to enable it to reflect realistically such occurrences, the author queried several industrial psychologists, sociologists, and management consultants regarding the nature and effect of this process. Two important considerations became evident from the discussions. First, a suitable means for measuring capacity was required. Second, the functional form necessary to relate capacity and performance had to reflect three stages of impact -- (1) early, when little, if any, distortion would appear, (2) intermediate, when distortion would be growing simultaneously with reduced capacity, and (3) final, when all capacity would be used up and distortion would be complete, i.e., no communication would take place in the vicinity of the decision unit. The first problem was particularly difficult to surmount since it requires that the capacity measure jointly represent both available time and ability.

On the strength of further discussion, the second difficulty was overcome by adopting a functional form which permits distortion-free communication until a decision unit has used up 75% of its capacity (See Sherman 1977). Thereafter, the level of anxiety-induced noise increases monotonically up to its maximum (45% error between -3σ and $+ 3\sigma$ of the desired (i.e., mean) quantitative information or order being communicated) as unused and/or uncommitted capacity falls to zero.

Anxiety is mitigated to some extent by another automatic feature of MANAGE, the generation and transmission of Type I orders as replacements for Type II commands. Type I orders are general commands that may be sent simultaneously to several subordinates. On the other hand, Type II orders are very specific in nature and can be communicated only on a one-to-one basis between a unit and its underlings. Type I orders, therefore, serve the important function of enabling a superior group to maintain the flow of commands as capacity nears

Figure 2. Program Flowchart of MANAGE





exhaustion. The penalty for this substitution is reduced compliance by subordinates because of the higher noise and lack of specificity of such directives.

The program incorporates this feature, i.e., order substitution, through a set of formulations appearing as a subroutine (again, see Sherman 1977). The procedure also permits similar substitutions to be made among the performance reports sent back from subordinate to superior units. Again, since there is no literature support for the specific formulation of the procedure or for the parameter values selected, the subroutine has been constructed on the basis of the author's interpretation of discussions held with experts in the fields noted above.

The subroutine has been designed so that no Type I orders (or performance reports) are generated by a unit until at least 75% of its uncommitted capacity has been exhausted. This corresponds to the anxiety-induced error threshold just discussed. Thus, from the viewpoint of MANAGE, as a unit begins to "feel" the pressure of time, it seeks to conserve its capacity by sending briefer, more general, but also more ambiguous communiqués. As time shortens, the relative frequency of such transmissions increases, thereby compounding the effects of distortion. However, this trade-off of message-types stretches out the remaining period over which the decision unit can continue to communicate with its adjunct division. As noted earlier, a complicated set of decision rules located at appropriate points throughout MANAGE constantly updates used capacity and evaluates the uncommitted portion for each unit to determine when negotiations between that department and any other are to be terminated.

4. THE OPTIMIZATION ALGORITHM

Of all of the components of MANAGE, the optimization algorithm is perhaps the most essential. It is this procedure which, based on the initial parameter values supplied by the program user, determines the maximizing criteria against which the actual performance of the firm is measured.

The algorithm is predicated on the classical economic assumption that the goal of any firm is to maximize its profits. Furthermore, it has been designed to reflect the fact that this goal is constrained by the nature of the firm's production process, as specified by its production function. The latter expresses the input requirements necessary to achieve the profit maximizing, or any other, level of output in terms of the manufacturing techniques employed by the company. In addition, the procedure satisfies certain economic conditions that ensure that profits are in fact optimized (see Sherman 1977, Mirrless 1976, Beckmann 1977, and Musgrave and Rasche 1977).

The specific form of the profit function used in the algorithm has been determined by the revenue and cost functions for the firm. The former is simply the product of price and output since revenut is assumed to be market determined. Thus, the firm is viewed as being purely competitive. The latter is found by solving simultaneously the Lagrangian formed from the input cost and production functions and the equations specifying the economic conditions for minimum production costs, i.e., that the ratio of the marginal physical products of any two inputs be equal to the ratio of their prices (see Ferguson, 1972 for more detailed discussion).

The production function that has been chosen for the firm was developed by the author and shall be referred to as the Modified Cobb-Doublas (MC-D) form. As pointed out by Shepherd (1953) and Stephens (1971), the popular Cobb-Douglas (C-D) equation, as well as certain other varieties of economic production functions, suffer from the shortcoming that they do not yield U-shaped cost curves necessary for the determination of the point of optimum profit, except under very rigid and unrealistic assumptions. The alternatives to the Cobb-Douglas formula are mathematically complicated. Furthermore, when conditions are imposed on the C-D form to yield the necessary cost function, it, too, becomes somewhat untractable. The Modified Cobb-Douglas production function, of which the C-D equation is a special case, produces a U-shaped cost curve, requires no limiting assumptions, and is mathematically less complex. Furthermore, this functional form satisfies the condition that minimum costs be yielded independently of assumptions regarding factor prices, market structure, and scale efficiencies (see Shephard 1953, Färe 1974, and others).

It may be argued that the use of an economic production function, particularly one of the Cobb-Douglas form, is somewhat unrealistic and that one based on engineering criteria would be more appropriate for an analysis such as this. However, a number of authors have offered arguments supporting the suitability and representativeness of economic functions vis-à-vis those based more on technological considerations in evaluating overall firm behavior, at least for certain types of processes or for aggregate corporate behavior (Smith 1961, Marsden, Pingry, and Whinston 1974, and others). In general, it is argued that with engineering functions neither enterpreneurial inputs nor non-technical (staff) operations, such as marketing and finance, are explicitly represented. Thus, these relations reflect only individual process or plant operations. Furthermore, these authors have found that many technical processes can be adequately described by economic functions.

None of these arguments preclude the use of engineering production functions. In fact, as shall be pointed out later, such process representation may be more appropriate in the simulation model employed herein than in other types of economic studies. Nevertheless, it is incumbent upon the investigator using such functions to modify them to overcome the limitations discussed above.

The Modified Cobb-Douglas function used in the algorithm to represent the overall production relationship for the firm is of the form:

$$q = A \prod_{i-1}^{n} \chi_i^{\alpha_i/q}$$

where

$q \equiv$ the number of units of final output produced

$A \equiv$ the technical (input-output) coefficient

$\chi_i \equiv$ the number of units of the ith input used in the production process

$\alpha_i \equiv$ the unadjusted elasticity of production with respect to the ith input

As demonstrated in Sherman (1977), this function provides one of the bases for the determination of the total cost function for the firm. In addition, it is also used in the evaluation scheme to derive the actual output produced from the factor inputs purchased.

The algorithm, itself, provides a unique solution to the profit equation, formed from the firm's revenue and cost formulas. It is one which maximizes its returns. The profit function has the form:

$$\pi = P_q - \sum_{i-1}^{n} r_i \left(\prod_{j=1}^{n-1} R_j^{-a_j/s} Q^{q/s}\right)$$

where

$P_q \equiv$ the market price of the final output produced

$r_i \equiv$ the wage rate of the ith input

$$s = \sum_{j=1}^{n} \alpha_j$$

$$R_j = \left(\frac{\alpha_j r_n}{\alpha_n r_j}\right)$$

$$Q = q/A$$

and

$$a_j = \begin{cases} \alpha_j & \text{for } j \neq i \\ \alpha_j - s & \text{for } j = i \end{cases}$$

and the remaining variables are as previously defined.

In order to locate the point of optimum earnings, the profit equation must be differentiated with respect to q and the result set equal to zero (the familiar marginal conditions of microeconomic theory). This produced a transcendental equation of nonlinear form which cannot be solved directly. The optimization algorithm uses search techniques based on Newton's iteration method (see Thomas 1960) and those by Fritch, Shafer, and Crowley (1973) to locate extremely accurate approximations with high efficiency.

The algorithm produces the following information:

1. The optimal level of output, q.
2. The optimal level of profit, π, for the firm.
3. The optimal budget for the firm (which is derived from the company's total cost function under optimal output conditions).
4. The optimal number of units of labor in each decision unit.
5. The optimal labor budget for the firm.
6. The optimal number of units of each "type" of capital input.
7. The optimal capital input budget for each subordinate-level decision unit.

The solution developed by the algorithm is completely dependent on the parameter values provided to the program by the user. However, these information requirements are relatively small. The investigator need only supply data for the unadjusted production elasticities, α_i, for each of the inputs, both capital and labor; the wage rate for each of these factors of production, r_i; and the market price of the final output produced, P_g. The problem lies in the determination of these, especially the α_i's, since the literature provides little guide to these. The problem is compounded by the need for consistency among the parameters (as well as that for the capacity variable), the need for realism in the model, and the technical considerations inherent in MANAGE which limit one's choices if consistency and realism are to be maintained. These problems are discussed in Sherman (1977).

All of the remaining variables in the production, cost, and profit equations, excepting the input-output coefficient, A, are determined endogenuously. The model assigns a value of unity to A both for simplicity and realism. It should be noted that relatively little attention has been paid to this parameter in the literature. However, this assumption is not inconsistent with the data that is infrequently cited (see Smith 1961, Marsden, Pingry, and Whinston 1974, and others).

5. CURRENT AND POTENTIAL APPLICATIONS OF THE MODEL

MANAGE offers a medium for examining a wide variety of issues concerning managerial communication, coordination, and effectiveness. It has already been used to explore the validity of various theoretical propositions regarding the effect of hierarchial structure on organizational functioning and to examine goal achievement in large bureaucratic institutions (see Sherman 1977). MANAGE offers a potentially useful vehicle to assist organization planners in designing new and/or reorganizing existing management structures to improve organizational effectiveness and performance. It also offers a means of evaluating current or potential key control and reporting locations within an organization's management structure. MANAGE could also be of substantial use as a means of exploring the structural impact of mergers and acquisitions. Another important potential contribution of MANAGE would be as a vehicle for exploring the reasons why identical or closely resembling management structures work well in one division of an organization, but poorly, in another.

By focusing on the interaction of people, structure, and organizational functions, MANAGE offers a previously unavailable means of testing in a more realistic laboratory-like setting, the pragmatic impact and influence of different hierarchical structures on organizational functioning and performance. Although further extensions and refinements in MANAGE are contemplated, it has already proved valuable to users in certain of the above contexts. The author intends to pursue these enhancements to the extent that enabling grants and other sources of funds become available.

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