CVLT (18 weeks in this example) in advance of the current date taken from the average seasonal sales analysis.

FSE.K = TABLE(SABC, INTD.K, 0, 50, 2) N-7, A

FSE	Future Sales Estimate (units/week)
TABLE	functional designation instructing DYNAMO to interpolate linearly for a value in a table
SABC	the name designating the table from which interpolated value is to be drawn, a boxcar train can be used as a table
INTD	the interpolating variable (weeks)
0	the first value of the interpolating variable for which a number is stored (weeks)
50	the last value of the interpolating variable for which a number is stored (weeks)
2	the interval between stored values (weeks)

Equation N-8 replaces Equation 16-1 and bases advertising on the estimate of future seasonal sales:

VDF.KL = (UPF)(AVS)(FSE.K) N-8, R

VDF	adVertising Decision at Factory (dollars/week of advertising authorization)
UPF	Unit Price of goods at Factory (dollars/unit)
AVS	constAnt, adVertising as fraction of Sales revenue (dimensionless)
FSE	Future Sales Estimate (units/week)

These eight equations generate a seasonal average and a seasonal sales forecast based on it.

APPENDIX O

Beginners' Difficulties

It seems that a discussion of what should be done in a new activity does not constitute adequate instruction. The positive approach alone does not provide forwarning against the pitfalls that lie along the road. Therefore, I shall try in this section to explain some of the difficulties experienced by students and staff members who have undertaken the kinds of systems studies discussed in this book.

The following are arranged as a collection of isolated topics somewhat in the sequence in which they arise in a systems analysis.

Courage

Industrial dynamics is an approach that should help in important top-management problems. Very few workers in the area of management science have had their aspirations conditioned to the expectation of major successes in the more difficult and challenging fields. The solutions to small problems yield small rewards. Very often the most important problems are but little more difficult to handle than the unimportant. Many men predetermine mediocre results by setting initial goals too low. The attitude must be one of enterprise design. The expectation should be for major improvement in the systems. The attitude that the goal is to explain behavior, which is fairly common in academic circles, is not sufficient. The goal should be to find management policies and organizational structures that lead to greater success.

Defining the Questions

A model should be designed to answer specific questions. A systems study must be for a purpose if it is to be productive. The questions must be meaningful and tangible and specific if they are to serve to guide a program. Determining the problems and the goals is the most critical part of almost any undertaking. The beginner tends to forge ahead into detailed construction of a model before its purpose has been adequately defined.

Scope of System

An important decision is to determine the boundaries of the system under study. The beginner can easily err on either side. On the one hand, he may lack boldness to be comprehensive enough and thereby limit his attentions to a subsystem within which the answers to the questions do not lie. On the other hand, he may define questions so vaguely that the objectives cannot be used to limit the scope of what must be included initially. The key to success will lie in clear questions which are broad enough to encompass matters of major consequence but which initially limit a system to proportions that fit the skill, time, and experience of the investigator.

Automatic Formulation and Evaluation

Many beginners in the study of system dynamics seem to feel that there must be a "scientific method" that will ensure their ability to create a proper model. They look for statistical procedures that can be applied to the scanty data ordinarily available, in the hope of having an orderly procedure that will create a system model by objective methods. They seem unwilling to express a professional opinion and to take risks on the basis of personal knowledge and judgment about the character of the system being improved. For the present, there seem to be no such objective methods that are effective. The attitude of requiring such safety and assurance of accepted methodology is not the attitude of the risk-taking manager. One does not achieve innovation and creativity by being timid.

Similar attitudes arise with respect to model evalution. The insecure system designer looks for "objective" criteria for the evaluation of the pertinence of a model. The compulsion to use such objective measures is sometimes so strong that refuge is taken in procedures that lack a sound foundation.

The world has thus far been run on the basis of judgment applied to the making of individual decisions. We are now on the threshold of moving the decision-making procedure back by one level of abstraction. When this has been done, judgment must cope with policy detection and policy design.

Hypothesis about Dynamic Behavior

The beginner usually fails to realize the importance of an initial hypothesis about dynamic behavior. There is often a feeling that to propose modes of dynamic behavior before a system model is constructed is to prejudge the answers. In a sense this is exactly what is needed. We start with a hypothesis for behavior. We build a model to see if the mode of behavior could exist and whether or not it can result from the initial assumptions. The experimental work is designed to prove or disprove the initial hypothesis.

The initial hypothesis is part of the establishment of the initial questions and goals for the study. Without this initial mental and verbal model of the dynamic behavior being studied, there is no basis for deciding what factors might be important and which ones could be neglected. It is very unlikely that a meaningful model will result from wandering through an organization and incorporating into the model whatever happens to come to one's attention.

A model of a chemical pilot plant serves as an analogy to what we are attempting here. It is made after a very tangible hypothesis about the plant's probable method of operation and the product it is to make. A pilot plant is designed and built to see if the hypothesis is correct and to see what new problems and insights are developed as one goes from a proposed method of operation to the experimental testing of the ideas. This is the way we use our dynamic model of an enterprise. A pilot plant is not constructed before a statement of objectives and probable mode of operation. We do not build a plant at random and then wait to see what kind of product it might produce.

Verbal Descriptive Model

Following closely after the hypothesis about dynamic behavior is the verbal model or verbal description of the system with which one is dealing. In general, the verbal model should come before the mathematical model. The verbal model should treat the description of how the parts behave and how they interact with one another. The verbal model is the support and the rationale for the hypothesis about dynamic behavior. If the verbal model is sufficiently complete, the mathematical model will follow as a consequence. The beginner is apt to fail to recognize the essential importance of the descriptive model as a step toward the creation of the equivalent formal mathematical model. The latter is a translation and clarification from the initial verbal language.

System Perspective

It is easy to view the system under consideration from the wrong distance. Students of economics tend to view from too great a distance, and they fail to see the essential decision points, nonlinearities, and interconnections of the system.

Managers and those having personal, intimate, first-hand knowledge of the system tend to view it from too close a distance. They want to put in too much detail. Separate, individual decisions take on too much importance. Apparent exceptions, which can be treated as noise disturbances, blind them to average behavior.

Each decision point should be represented as it might be seen by the next higher or the second higher administrative level. Very often the proper viewpoint from which to model a corporation is that of the perceptive banker or the skilled management consultant. At the levels of these men, it is the broad sweep of the system that catches the attention. They are aware of technical progress, of managerial and employee skills, of system objectives, and of markets. Yet, these viewpoints do not get enmeshed in the hour-by-hour and day-by-day details of the separate parts of the system.

Use of Descriptive Knowledge

The beginner usually neglects information that is in descriptive form and is inclined to look too long and futilely for sufficient information in the form of numerical data. He fails to appreciate that the overwhelming preponderance of our information about social systems is now in descriptive form. There is often an unwillingness to translate this descriptive knowledge into quantitative form. Descriptive information almost always implies relative magnitudes and differing importance of factors and assumptions. Attaching arbitrary scales and quantitative values to these concepts can provide orderliness without carrying any implications about accuracy. Once the system has been cast in the terms of formal equations and numerical values of parameters, one can then determine much about the required accuracy. Creating a quantitative description of a system is a separate matter from achieving accuracy. These two different considerations are often confused by the person who does not think of mathematical and numerical notation as being merely another language for expressing ideas.

Our descriptive knowledge is rich in information about the probable form of decision functions under extreme limiting conditions. The use of the full nonlinear breadth of all the information that we have available makes the task of successfully describing system components much easier.

Creating Definitions

A companion to the reluctance to use the available descriptive information is the reluctance to create precise definitions and arbitrary scales of measurement for the quantities that exist in the descriptive knowledge. Many of the concepts and the so-called intangibles do not have generally recognized scales of measurement. This does not keep the investigator from creating his own precise definitions and his own arbitrary scale of measurement. It does require that he crystallize and clarify what he means by the terms which he uses. Here again, courage becomes important. The man must take the leadership in creating a field of knowledge, a vocabulary, a precision in descriptive terms, and a method of ranking and measurement. He must be willing to accept criticism that can be leveled only at the person who steps forward with a proposal. He must decide whether to defend himself against the criticism as being unwarranted or to use it to strengthen further the structure that he is building.

Insensitivity to Cause-and-Effect Mechanisms

The beginner may often fail to look at the system closely enough to observe the factors that create the dynamic behavior in which he is interested.

There is often a tendency to want to disaggregate into too fine a structure within any given flow channel, and at the same time to neglect to separate the flow channels well enough from each other.

In very many places, as discussed in earlier chapters, the "worse-before-better" sequences occur. These can often be very important to system dynamics but can be overlooked if one is unperceptive of system interactions. For example, the expansion and training of an engineering department does not just happen. It requires the diversion of managerial and technical time that might otherwise be put to different purposes. The whole structure of skills and the development of people and organizations must take place before they can produce an output. Many of the actual practical working mechanisms of a system tend to create the conflict between short-term and long-term results.

The aggregate flow channels must represent the sequences that are traversed by individual items following the channels. Very often a single event must be traced in order to discover the information channels of the system. But one must not let this study of the individual event trap him into an unduly close view of the system and a desire to model separate decisions rather than policy.

In all of these warnings against the hazards of system analysis we see that the investigator is faced by the usual form of decision wherein he must not do too much or too little of any of the things that are a part of success. As in the systems he is modeling, his own decisions are balancing the amount of his action against the goal which he has set.

Perceived versus Actual

We have said earlier that the decision maker in a system 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 system analyst faces the same problem. He 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 were present. The man with no experience with actual organizations may come with a strong idealized but unrealistic concept of their behavior acquired through academic study of simplified abstractions. On the other hand, the man who has been immersed in a particular system too long may be unable to distinguish the actual system from what he wishes it were. 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. Both of these, of course, are probably different from how it should operate. Wishful thinking and strongly formed past prejudices are both hazards to successful dynamic analysis.

Decision Points in System Context

The novice at system modeling may underestimate the importance of extensive, detailed, first-hand observation of the system with which he is dealing. He may rely too much on what he is told are the factors and objectives at a certain place in the system. He may not take the time to discover that the pressures on people at that point come from quite unexpected places in the organization. He may not observe that the sources of information that are assumed to be necessary may simply not exist. He may not discover the extent to which the goals and objectives are purely local ones designed to keep the participants out of difficulty rather than goals that constructively promote the welfare of the whole organization. A model of system behavior depends on an adequate representation of the decision-making policies within the system. The beginner usually does not realize the depth to which he must probe to distinguish the superficial veneer of rationalization from the deeper effective motivations.

Model Permanence

The beginner often looks upon a model as something that he should build to last. He thinks of *the* model that can be constructed and then used to answer all questions. As he progresses in his understanding of enterprise design, he comes to realize that each new question may carry with it an extension and a variation of the system previously defined. A model evolves with one's understanding of the system with which he is dealing. It can start with a very simple structure aimed at the essence of one particular phenomenon. It can then be extended to bring in new facets and to study new questions. The typical life of a model may be but a day or week before new extensions give it new form and meaning.

Decisions versus Policy

Management and management education have given such emphasis to decision making that the inexperienced systems analyst usually has a hard time grasping the full significance of dealing instead with the policy that creates the flow of decisions. A new orientation in attitude must take place. Time is required to develop an understanding of the full meaning of policy. It takes time to gain confidence that our existing knowledge of policy is sufficient for at least a major start in understanding system behavior.

Excessive Detail

The beginner typically includes too much detail in model formulation. This is a natural result of the fact that it is easier in the kinds of models discussed in this book to include a factor than it is to present a convincing argument that a factor does not matter. Junk is added in the model structure to avoid discriminating thinking about whether or not various factors are necessary. This is understandable and probably will always happen. Again it is a matter of degree. The beginner is more conspicuously vulnerable to including too much than he will be after some experience in building models and after the discovery of how much simplification is possible.

Some detail, even when it does not affect system performance, is justified in order to provide apparent reality and easier communication with others less skilled in model building. For this reason the models in Part III of this book are more detailed than would be necessary to capture the essence of the dynamic performance exhibited in the various figures of Chapters 15 through 18.

The clarity of the initial dynamic hypothesis and the initial verbal description of the system will largely determine one's vulnerability to wandering off into unnecessary complexity and detail.

Underestimating Time Constants

The beginner almost invariably underestimates the lengths of delays and time constants that will exist in our social systems. He overlooks the long educational delays. He fails to appreciate the persistence of prejudice and past personal experience. He fails to examine the sequential steps through which an action must go, and may estimate a total over-all time so short that it is a physical impossibility in the actual system. Time estimates by students are often so short that they do not even fall within the limits of plausibility, once there has been a thorough discussion of the actual real-life mechanisms involved.

Discontinuous Functions

The beginner tends to be carried away by his knowledge of the discreteness of various decisions and actions. This arises partly from viewing the system from too close a range. He wants budgets established once a year, production quotas each quarter, inventories reported each month, individual model years of product handled separately, and so forth. These are all factors that may be important in some of the more subtle questions that may be asked as a study progresses. However, they seldom involve the broad interactions that lead to conspicuous success or failure.

System dynamics can best be visualized if cast first in terms of continuous flows until the interactions of the major time constants, decisions, and levels can be understood.

Another amateur tendency in the area of discontinuous functions comes from carelessness in thinking about the nonlinear forms of decision functions. There is a tendency to make up decision functions from a straight-line linear section that is abruptly terminated when some limiting threshold is reached. In general, decision functions are not discontinuous. Much of the essential character of our industrial organizations arises because of the changes that begin to occur progressively as various limiting conditions are approached. In actual systems, pressures build up gradually, leading progressively over a period of time to awareness and action. Spurious system behavior is very apt to be introduced by artificial breaks and discontinuities in decision functions. One can very seldom argue that life continues as normal up to some very particular point at which the entire character of an organization changes.

Coefficients without Meaning

The beginner may not take the time to be certain that every parameter and variable in his system has a solidly defined meaning that can be related to the actual system with which he is working. Coefficients are often inserted to make dimensional units correct without thinking through whether or not these coefficients arise out of the actual structure and practices of the system. I believe it is possible to make every variable and every coefficient relate directly to its counterpart in the real system and be discussable with and understandable by the practical operating people in the organization. Forcing this degree of reality in equations and parameters helps to clarify thinking and to lead to greater model validity.

Dimensional Units of Parameters and Variables

The careless analyst may fail to define the dimensional units of measure of variables and parameters. This is apt to merge into a lack of a clear understanding of their meaning, and from this there rapidly follows a departure of the model system from the relationships of real life and from those intended in the initial verbal description. The units of measure of every factor should be carefully defined, preferably in terms that are as close as possible to those that have meaning in the verbal description and practical use of that factor.

Defective Decision Functions

Very often the beginner develops decision functions which he recognizes as having major defects but which he defends on the basis that the information-feedback loops threaded through the remainder of the system will prevent the occurrence of those circumstances under which the particular decision function would be wrong. This is a dangerous practice. One is now dealing with a system that fails to pass the test of "not being obviously wrong." It contains relationships that can be established as wrong on the basis of a logical argument. In general this is unnecessary. A little thought and care can make the relationships compatible with at least the obvious tests and challenges. The most powerful defense of a dynamic model lies in the extent to which all of the components are acceptable. The complex information-feedback behavior is usually not subject to strong intuitive argument. To depend on the information-feedback network in order to avoid a state of affairs wherein defective decision functions would have the opportunity to create unexpected difficulty is to compromise in that region where soundness can be achieved and confidence can be greatest. One's trust is relegated to that area of the model about which he knows the least. The dynamic behavior is what we are trying to learn about the system. We want to know the dynamic behavior that will result from the best knowledge we have about the component parts and how they must contribute to the total system.

Simultaneous Initial-Condition Equations

The beginner usually has a great deal of difficulty in the establishment of initial-condition equations for a model and very often finds himself in the position of having to solve a system of simultaneous algebraic equations to get a consistent set of system parameters. This often arises from a poor choice of what is to be independently specified and which parameters may necessarily have values dependent on others already picked.

It is my feeling that a skillful handling of the way in which parameters are defined and numerical values are chosen can always lead to a direct determination of initial conditions without solution of simultaneous equations for the initial condition of the system. This was true in the models of Chapters 15 through 18, although it must be recognized that those systems are not complex. A thorough treatment of the methodology for handling initial conditions is beyond the scope of this book, and the matter will be left at present simply with the assertion that I have always found it possible to achieve a straightforward determination of initial conditions. This, however, is not the usual experience of the person first undertaking model construction.

Infinite Ratios

Sooner or later the model builder usually encounters a situation where he has set up a functional relationship as the ratio of two variables where the denominator can take on a small or zero value. Since real life does not contain infinite values for significant variables, this can be looked on as a defect in the equation formulation. In fact, some of these do exist in Chapters 15 through 18, and the difficulties would become apparent were the model called upon to create properly system activity all the way from zero sales rate upward. The difficulty is especially likely in transient growth models, where all of the variables may have initial values of zero. In general, the difficulty is surmounted by an adequately realistic and wide-ranging statement of decision functions that cannot under any circumstances take on impossible values.

Loops without Levels

In the discussion of model structure in Chapter 6, it was pointed out that rates create levels and that levels are the only proper inputs to the determination of rates. It was, however, further noted that as a practical matter one sometimes uses a rate instead of a short-term average as an input to another rate. This must be watched very carefully, because it is rather easy to create a loop whereby a chain of auxiliary equations may arise from one rate to control another rate that may eventually lead to a third which appears as an input to one of the first equations. In the flow diagram of the system this leads to a loop in which no level equation exists. Such a situation is contrary to the concepts on which the model structure was built. This kind of erroneous structure can lead to a high-frequency numerical instability in the model structure, where the instability is a characteristic of the model defect and not of the system being modeled.

Engineers

A number of the people entering the field of dynamic analysis of business systems have a background in engineering. They may wish to carry over familiar methodology which may not be appropriate in the industrial context. They may have strong tendencies to want to convert the structure and the terminology of the business system into an electrical or a hydraulic network. This greatly increases the communications difficulty between the systems analyst and those in the actual business system. It is also a handicap because the engineering systems are not well equipped with examples of highly nonlinear phenomena. This conversion to, for example, an electrical network tends to initiate a very inappropriate line of thinking that restricts consideration to linear systems.

Those coming from the field of servomechanisms may have difficulty in distinguishing fundamental concepts from the practical art of the engineering field. The fundamental concepts of information-feedback systems are universally applicable. The practical art is apt to depend on the particular classes of systems that are encountered. Most especially, the physical systems are usually characterized by having their own internal natural periods well separated from the frequencies that are imposed upon them in their ordinary operation. This leads to certain practical design procedures that may not carry over into nonlinear systems in which the noise frequencies, the natural frequencies of the system, and the frequencies to which the system should respond all lie within approximately the same frequency band.

The engineer is more accustomed to thinking in terms of differential equations than he is in terms of integral equations. The difference equations used in this book are all essentially integrations of rates. It is common in engineering to speak of velocity as the derivative of position and acceleration as the derivative of velocity. However, nature does not usually take derivatives. Actually the inverse sequence is a more natural viewpoint. Forces create acceleration. Acceleration is integrated to get velocity, and velocity is integrated to get position. Mathematically these are equivalent. Conceptually they give one a somewhat different viewpoint of the system and its structure.

Scientists

Students coming in from the areas of science, whether it be physics, mathematics, or the social sciences, are apt to have their attention focused too exclusively on methodology and technique. They are accustomed to looking for analytic solutions to problems. This habit has in turn forced them to the consideration of only linear systems.

They may have been trained so exclusively in linear systems and linear approximations to systems that they lack an awareness of the extent to which our life and our world depend for their very existence on nonlinear behavior.

A fascination with methodology is apt to lead to a quite disproportionate amount of attention to peripheral questions of technique. The mathematician may want to substitute some more elegant methodology for the first-order integration such as used in this book, even though there can probably be no objective demonstration of the necessity. He may become involved in the discontinuities and the computing phenomena that revolve around the selection of a solution interval DT. He may become involved in trying to determine how large this interval can be made, rather than merely making sure that it is small enough to raise no questions.

The science student may lack any first-hand awareness of the political factors that enter into even the so-called scientific and technical decisions. He is apt to feel that rigorous and objective methods must of necessity be found for the construction of models, even though in his home field there are no rigorous and objective methods that ensure the success of the design of engineering systems and models of engineering devices.