CONCEPTUALIZING DYNAMIC MODELS
OF SOCIAL SYSTEMS:
LESSONS FROM A STUDY OF SOCIAL CHANGE

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ABSTRACT

CONCEPTUALIZING DYNAMIC MODELS OF
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This report contributes in two ways to the sparse literature on the process of social system model construction. The emphasis throughout is on the early conceptualization phase of descriptive, generic, dynamic modeling. The special considerations necessary in modeling studies where implementation of results is the primary objective, are not discussed.

First, this report provides a description of the chronology of one modeling effort: one frank account of "how modeling really occurs." In that effort, six individuals, including the author, worked for ten months to construct a generic ("general theory") system dynamics model of social change induced by social movements. The essential information base for the project consisted of the individuals' practical experience with social action groups and their theoretical knowledge about them.

Second, this report provides a number of aids for more consistent progress of the modeling process. To pursue modeling efficiently, modelers must be conscious of the overall process. To increase such awareness the report explicates a conceptual framework and terminology describing the modeling process. The modeling process is seen as a never-ending iteration toward more useful (as defined by the modeler's objectives) models. The improvement occurs through generalized evaluation where most aspects of the model (detailed assumptions, characteristic behavior) are evaluated using all available knowledge of the real world (descriptive non-quantitative information, numerical measurements). Elimination of weaknesses through generalized evaluation is used to upgrade the model both in the initial modeling stage and the improvement stage of the modeling process. Twelve modeling activities, all performed by the modeler, are involved in the process. These modeling activities are described and apportioned into three categories:
conceptualization, formulation, and evaluation. Some modeling failures result from inappropriate organization of the modeling activities within the overall process. A set of ten guidelines for efficient modeling is provided, aimed at reducing useless iteration. The guidelines were derived in part from dysfunctional tendencies identified in the effort to model social change.

The account of the actual modeling effort focuses on the multitude of futile attempts made in the process, providing an example of the iterative, generalized evaluation procedure as it occurs in the initial modeling stage. The current model is documented; it arose from the twelfth in a series of initial models, and has completed some iterations in the improvement stage. The gradual evolution of model characteristics and content is traced through the eleven models that preceded it, the resulting trends reflecting the power of generalized evaluation in eliminating unacceptable attempts.

The guidelines stress the importance of a complete dynamic hypothesis and indicate how to arrive at it; it consists of a reference mode and assumed underlying basic mechanisms. The reference mode provides a clear problem definition and encourages modeling of problems rather than useless striving for the model of a system which is equally relevant for all problems, that is, an imagined "map of reality." The inclusion of basic mechanisms from the outset, forces the modeler to address a meaningful whole at all stages of model development. It is further found advisable to build out from a simple model; to maintain a wide scope even when simplification is necessary; to produce models with balanced detail and to allocate most effort to the essential system structure.

This report is addressed to persons who have some experience in the more mechanical aspects of dynamic modeling of social systems, yet lack experience in independently performing a complete modeling study. The report is intended to satisfy the need of evolving modelers for realistic information about how a modeling study is actually performed (particularly the early, intangible steps), what problems are likely to occur, and how some difficulties can be avoided.

Thesis Supervisor: Jay W. Forrester
Title: Professor of Management
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I found it more pleasant to write the acknowledgements than any other part of this report. The enjoyment would have been complete had it not been for the need to find an equitable linear sequence for presentation of my thanks. The problem immediately brought back unpleasant memories of my exhausting struggle over the last couple of months to capture the elusive circular process of modeling in a linear account fit for reading. That struggle was resolved by choosing a chronological description, and by analogy, I acknowledge the assistance of my friends in their order of appearance in my life.

Thanks are due to:

Gerd, who was invaluable during the Ph.D. thesis-writing-depression which I now understand to be common experience among doctoral students.

Jay W. Forrester, who taught me how to view the world in a new way, and without whose brilliant presentation in M.I.T. room 26-100 on 3/12, 1970, I would probably still have been counting neutrons.

Dennis Meadows, Dana Meadows, and Bill Behrens, who had to work with the stupid Norwegian and to whom I owe all my concrete knowledge about system dynamics and the memory of two fabulous years.

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Barbara Wechsler, who removed an estimated 632 "the"s from the manuscript and otherwise upgraded the language before she typed it.

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In short, the doing of science is a much, much more personal, social, and subjective process than we have even dared to imagine in our wildest dreams.

Ian I. Mitroff
Management Science
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CHAPTER I

INTRODUCTION

Objectives and Contents

The Need for Descriptive and Normative Material on the Process of Building Social System Models

In spite of the existence of innumerable social system models, there is not much available literature, and probably not much knowledge extant, about the process by which such models are constructed. How is a problem chosen? By what process does one choose the model variables? How does one achieve a useful perspective on the problem area? How does one succeed in capturing in a simple model the essentials of a complex, real-world phenomenon? Models are, nearly without exception, presented in "final" form, as though such artifacts exist and as though the process of arriving at a fruitful description of some aspect of reality is straightforward and not worthy of mention. The lack of information about the modeling process, particularly its first stages\textsuperscript{1}, is probably due to the "pre-scientific" state of the art of model conceptualization and formulation. The conceptualization phase, in particular, seems to be

\textsuperscript{1}I see the model development process as involving three major phases: model conceptualization (obtaining a perspective on and mental understanding of the real-world phenomenon); model formulation (representing the intuitive understanding in some formal language); and model evaluation (comparing the formal model with various criteria of acceptability). See Chapter II.
governed largely by intuition, inspiration, and luck. The problem is accentuated in building models of social systems, where there is a need to represent aspects of the real world that cannot easily be observed and measured.

Due to lack of information to the contrary, the sequence of presentation in papers describing models is commonly mistaken for the actual steps involved in the creation of those models. It is likely that more study and description of the modeling process would resolve this and other problems which are barriers to effective modeling, as well as providing guidelines for the process of model construction useful to the inexperienced.

The need for description and analysis of the modeling process, however crude and tentative such analysis may be, is pointed out by Simon (Simon 1969). He emphasizes the need for knowledge about the process of synthesis: in his words, about the "science of design," or "creation of the artificial." Simon's conclusion may serve as an ultimate goal for studies of the modeling process:

"The professional schools will resume their professional responsibilities just to the degree they can discover a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process." (Simon 1969, p.58)

Morris (Morris 1967) makes the same point, more explicitly relevant to the model-building process:

"A basic distinction that must be communicated to the inexperienced is the difference between the 'context of justification' and the 'context of discovery'...Management science (and all other science) is reported and communicated
in the form of a logical reconstruction which aims at providing a justification for the inferences produced. This logical reconstruction has little if anything to do with the psychological process by which the inferences were first obtained. It is the custom in science to report a piece of work by stating the assumptions of premises which determine the model, showing the deductive steps by which the relevant consequences of the model were obtained, and then reporting the design and analysis of the experiment aimed at testing the hypothesis suggested by the consequences of the model. All this is very much *ad hoc*. The danger for the inexperienced is that, finding little else in the literature of their science other than such justification, they will begin to assume this is a description of the process of discovery.

"The experienced scientist knows that the psychological process is very different, but he seldom attempts to verbalize it. One may wonder, however, whether even those with considerable experience do not sometimes practice a little delusion of themselves and their colleagues by tending to read ad hoc justifications as descriptions of the context of discovery. One often senses that a writer is implicitly saying, 'See how logical, how methodical, how brilliantly inevitable was our progress in this study.' Since all of the writing in a science is likely to be of this sort, one must conclude that the experienced persons in a field are not of great help to the inexperienced, so far as the art of modeling is concerned. In fact, the inexperienced may be led far astray if they begin to imitate the logical process in seeking to develop their own intuitive skill. It is not at all clear that the teaching of models by exposing the inexperienced to the ad hoc contributes much to the development of creative model building ability. Indeed, this is the fundamental criticism that might be made of management science education. The teaching of modeling is not the same as the teaching of models."

The current report contributes to the sparse literature on the process of model construction in two ways. First, it provides a description of the chronology of one modeling effort, one frank account of "how modeling really occurs." In that effort, six individuals, including the author, constructed a model of social change induced by social movements. Second, the report presents a number of "conceptual tools" as aids to the more consistent progress of the modeling process.
The aids clarify what the overall process should be like, describe the activities that should be involved in modeling, and indicate how the activities should be combined in the overall modeling process. These tentative views on "how practical modeling should be done," were derived from the described modeling effort and the author's earlier modeling experience. Availability of additional introspective analyses would greatly enhance the utility of the present report.

The Focus of Interest: The Conceptualization Phase of Descriptive, Generic, Dynamic Modeling

The material in this report is most relevant to the construction of descriptive, generic, dynamic models of the type built in the case study. In addition, special emphasis is put on the conceptualization phase of modeling, the most difficult and least structured phase of model creation.

All model-building entails extraction and formalization of some segments of the vast store of (formal and informal) knowledge available about the system under study. However, all models are not made for the same purpose. One can, for example, distinguish between predictive, optimization, and descriptive models, although there is an overlap among the categories. Predictive models are constructed expressly for making accurate forecasts about future events. Optimization models are made with the intent of finding the best solutions to problems. Descriptive models, the focus of attention in this report, are representations of some real
phenomenon, made to gain and communicate insight about the operation of that aspect of reality and to help control it.

Descriptive models are more or less "generic." Some descriptive models fit one real-life situation specifically and have no general utility outside that context, while others provide insights into a wide range of situations. Most models fall somewhere between the two extremes. A model is defined as more generic if it is useful in understanding a larger class of real-world situations. A generic model focuses on the structure common to the members of the class and omits the special aspects that do not relate to the class. Most models contain some general aspects, and can be further generalized if so desired, thereby increasing the degree to which they are generic. Nevertheless, most models belong at a relatively fixed position on the scale which can loosely be said to extend from "client models," useful only for a specific problem, to "general theory models," applicable to a class of situations. This report centers on generic models. The multitude of special considerations necessary to achieve implementation of results are not discussed.

Finally, models are classified as dynamic or static, depending on whether they describe the development over time of the simuland.\(^2\)

The descriptive, generic, dynamic models discussed in this report are non-linear, continuous, deterministic and state-determined simulation models.

\(^2\)The term "simuland" has been suggested by John McLeod to denote the aspect of reality being simulated. The term is adopted here.
of the system dynamics type described in (Forrester 1961) and (Pugh 1970). These are formal mathematical models consisting of differential equations.

Generic models should be built by generalizing on the basis of keen insight into the operation of several specific cases and general knowledge about several others. The modeler can try to accumulate the necessary knowledge base through his own practical experience and abstract study. Another feasible approach, and the one used in the study reported here, is to have several knowledgeable people collaborate with the (naive) modeler in an attempt at combining the group's total knowledge into one model. One may thereby achieve for the model a final scope and generality exceeding the modeler's own initial insights.

The conceptualization phase of the modeling effort involves, first, defining the "right" (i.e. fruitful, relevant) question. Another major task in conceptualization is to localize a relatively small number of relationships that are of decisive importance in a large number of situations. It implies the inclusion in a framework of those factors that are common to most cases and yet capable of explaining the essentials of the individual case. It involves creation of a "typical," "average" picture which is not a copy of any specific situation, but still sufficiently resembles all situations to generate insight in most cases.

The insight with which the conceptualization task (defining the question; choosing a fruitful perspective; identifying basic mechanisms) is completed is decisive for the outcome of the modeling study, just as
competent problem definition is a prerequisite for a superior result to emerge from normal problem-solving (e.g., in an organization). This fact and the relative lack of literature on conceptualization (compared to writings on formulation and evaluation) inspired an extra emphasis in this report on matters related to conceptualization.

Review of the Contents of this Report

Chapter II presents a framework for description of the the process of dynamic modeling of social systems. The framework is useful for setting forth the ideal process, and for discussing the actual modeling effort presented in subsequent chapters. The modeling process is seen as a never-ending iteration toward more useful (as defined by the modeler's objectives) models. The improvement occurs through continuous generalized evaluation, by which most attributes of the current model are scrutinized in light of all available quantitative and descriptive knowledge. The model is upgraded through correction of the weaknesses that are discovered. The iterative process is split into two sequential stages: an initial modeling stage, culminating in a rough initial model that appears useful in addressing the chosen question; and an improvement stage, where the initial model is elaborated and extended through additional iterations. The same modeling activities are involved in both stages, but in varying combinations. Twelve discernable modeling activities are described in Chapter II, and partitioned into three categories: conceptualization, formulation, and evaluation. Conceptualiza-
tion activities take place in both stages of the iterative process, but
the major conceptualization effort is contained in the initial modeling
stage.

Chapters III and IV describe the process by which a group of
individuals formulated a system dynamics model of social change as in-
duced by social movements. The group initially gathered due to a common
interest in the subject. The information base for the study was essen-
tially the individuals' practical experience with social action groups
and their theoretical knowledge of them. Chapter III describes the
actual chronology of the modeling effort from two perspectives. First,
the sequence of activities is presented as it appears in retrospect.
Second, the chapter includes a diary written during the project, report-
ing on the study's progress as it was perceived week by week, and on
the sense of success or failure it instilled in the work group. The
chronology provides an example of the iterative generalized evaluation
procedure as it occurs in the initial modeling stage. Only very late
in the project (after nine of the ten months duration) was the model
judged sufficiently useful to warrant transfer to the improvement stage.

Chapter IV describes the gradual evolution of model character-
istics and content during the project period. Eleven versions of the
developing model, as it appeared at different points in time, are com-
pared, and trends are identified. The current, twelfth, model is docu-
mented in some detail. Chapter IV reveals the major changes that took
place in the model: it reflects the difficulty in completing the initial
conceptualization and the power of the generalized evaluation procedure in eliminating unacceptable attempts.

In looking at the actual chronology of the study, it appears that progress was hampered by certain dysfunctional tendencies on the part of the work group. The tendencies are identified in the first part of Chapter V. Next, an attempt is made to provide guidelines for the modeling process. The guidelines offer advice on what constitutes an effective ordering of the modeling activities in both stages of the modeling process, and in what way they should be emphasized. The guidelines focus in particular on the early, intangible conceptualization phase in the initial modeling stage. Emphasis is put on the utility of indentifying a reference mode and a set of basic mechanisms when attempting to create a useful initial model. Compliance with the guidelines forces the modeler to model a problem rather than a system.

Chapter VI summarizes the main points of the report, expressing the hope that others will proceed to corroborate or refute the framework and the guidelines presented here.

Guide for Readers

This report contains large amounts of material which will be of interest to just a few readers. Readers desiring a more thorough overview of the substantial parts of the report than that available in the self-contained Chapter VI (summary) should read Chapters I (defining the topic) and II (presenting a framework for description
of dynamic modeling); the last subsection of Chapter IV (reviewing trends in the development of the model under study); and Chapter V (analysis and derived guidelines). Readers with no modeling experience, who would like some insight into the "real life of a modeler," should add Chapter III (chronological description of one modeling effort). The diary constituting the second half of Chapter III contains a large number of ideas regarding procedure which may be of interest even to the more experienced. Finally, the reader with deep technical interest in model-building should also study Chapter IV, in toto, and perhaps look at the fifty pages of program listings in Appendix A.

The reader should note that the description of the current model, NEWIDEA#12, is a self-contained unit (the second section of Chapter IV) which discusses model structure, equations, and runs. The model addresses some questions relevant to environmentalist pressure groups. It is intended for readers interested in improving upon a model of social change.

Past Work on Conceptualization of Dynamic Models

This report aspires to present material that is of direct use to the practicing model-builder in his daily struggle to conceptualize and formulate social system models. Hardly any relevant literature exists on the topic. Most volumes on "problem definition," "conceptualization," "theory construction," and the like, treat the matter on levels of aggregation that are too low (e.g., pattern recognition on colored
cards), or too high (e.g., discussions of the meaning of explanation), to help the modeler make a practical decision (e.g., on what perspective to choose in a study of the decline of organized religion). The lack is felt even in such well-established fields as economic modeling:

"In closing this review of some of the current and recent trends in research on economic models, it must be pointed out that an extremely difficult, but most important, area is receiving very little attention. This is the area of model formulation and the organization of model-building efforts. The methodology for finding and developing good models is hardly existent except, perhaps, in the form of an art at which some individuals seem particularly gifted." (Hamilton et al. 1969, p.32)

The lack is unfortunate, but understandable, given the elusiveness of the human invention process when applied to a confusing social reality. Similarly, there is a complete lack of revealing descriptions of actual modeling efforts, deplorable, but again, understandable; one rarely gains recognition by exposing one's mistakes. One may also question whether modelers are, normally, consciously aware of their own activities.

Seven areas of the literature, which were expected to contain material describing actual modeling chronologies or analyses or the process, will be discussed here. They are

--information processing psychology
--psychology of creativity and concept formation
--historical accounts of invention and discovery
--finished models
--the use of models and implications for their construction
--model-building techniques
--philosophy of science
A short comment on each follows, with an attempt to indicate representative works. No attempt has been made to restrict the discussion to the conceptualization of generic, dynamic, models, since an empty set would have remained.

The literature on information processing psychology focuses on human problem solving, and attempts to formulate formal simulation models of the process. It does not discuss the task of problem-finding; the focus is on strategies for optimal solutions to simple (relative to those facing a social systems modeler) problems. There are no results which are, as yet, helpful for model conceptualization. (Simon 1969) is a short introduction to this fascinating field; (Newell and Simon 1972) give a thorough analysis of short-term human problem solving.

The psychological literature on creativity, invention, categorization, concept formation, and similar cognitive processes, is also too reductionist to be of practical use for modelers looking for powerful concepts describing social reality. The various theories propounded are of little help in increasing one's own creativity or concept formation ability; however, they do raise awareness about the ongoing processes. Some typical samples are: (Mackworth 1965), arguing that problem-finding is the critical element in creativity; (Bruner et. al. 1957), presenting their view that concept formation is a process involving selective search for similar attributes in objects; and (Polya 1945), with a more applied description of how humans solve problems.

However, much inspiration and insight can be drawn from his-
torical descriptions of discovery in various fields. Personal accounts, primarily by physical scientists, abound in volumes like (Beveridge 1951) and (Hadamard 1945), which convincingly eradicate any belief one might have had in the orderliness and objectivity of scientific progress.

A volume like (Watson 1969), describing the incidents which led to the discovery of the structure of DNA, is probably the closest one can get to a description of an actual modeling process.

Overviews like (Rugg 1963) and (Kuhn 1962), discussing scientific and artistic discoveries in many fields, do bring some order into what seems like a chaotic process when it is studied on the micro level. However, the types of conclusions reached ("the spark of insight is usually preceded by a period of light activity," or "paradigm change does not occur easily"), are not of direct use in day-to-day model-building. The main benefit to be obtained from reading this literature is a more realistic view of the creative process, especially regarding the extent of subjectivity involved. This point is accentuated by (Mitroff 1972).

The existing literature dealing with social system models focuses largely on the finished product, that is, on the final model resulting from the process of conceptualization, formulation, and evaluation. Work is presented in an after-the-fact manner, in which little or no trace remains of the process through which the result was obtained. One positive exception to this rule is the revealing discussion by (Brunner and Brewer 1971) of their model of political development in Turkey and the Philippines. The volume contains sufficient self-criti-
cism to raise awareness about the difficulties involved in model construction. A complete review of existing simulation models on human behavior is given by (Dutton and Starbuck 1971) in their monumental work. The review indicates that most simulation work is done on smaller and less abstract systems than the one attacked in this report.

Through the literature on practical use (or rather, the lack of practical use) of models, one can obtain information about what properties models ought to have, and in some cases, even about how one ought to go about constructing them. The models described in this literature are mostly management models; the recurring complaint is that the models are not used by practicing managers. The problem is seen as a result of the modelers' misplaced emphasis when building the model and the clients' lack of involvement and knowledge about the final model.

(Little 1970) suggests that the problem would be solved if management models were made 1) simple, 2) robust, 3) easy to control, 4) adaptive, 5) complete on important issues, and 6) easy to communicate with.

(Urban and Karash 1971) support these guidelines, but emphasize that the model must be developed gradually in order to enable the managers to gain confidence in simpler, more understandable models, before less transparent (and more powerful) versions are introduced. (Roberts 1972) takes the large step of recommending that the manager actually take part in the development of the model from its very beginning. Apart from stressing the necessity of having the modeling effort address a problem of importance to the client, and maintaining close contact with him
during the process, the management literature does not provide much insight about how modeling should be approached. (Gorry 1971) highlights incidents from one approach, describing an actual process where a simple dynamic model was implemented; he draws the conclusion that the model must be simple to gain confidence.

Attempting to summarize lessons from many areas of applied modeling, (Solberg 1972) presents a list of nine "principles of modeling," which seems an apt summary of the thinking of the current modeling community:

1. A Model Should Not be Taken too Literally
2. Do Not Oversell Any Particular Model
3. The Deduction Phase of Modeling Should be Rigorous
4. A Model Should Not be Pressed Beyond the Limits of Its Intended Capability
5. A Model Should Not be Criticized for Failing to Do What It Was Never Intended to Do
6. Models Should be Validated
7. Do Not Build A Complicated Model When A Simple One Will Do
8. The Medium of Expression For A Model Should be Selected According to Its Intended Purpose
9. Some of The Primary Benefits of Modeling Are Associated With the Process of Developing The Model

Similarly, (Lee 1973) lists "Seven Sins of Large-Scale Models," providing further insight into what the prospective modeler should avoid during conceptualization: Hypercomprehensiveness; Grossness (lack of purpose); Hungriness (for data); Wrongheadedness (hidden formulation
problems); Complicatedness; Mechanicalness; Expensiveness.

The operations research (Ackoff 1962), (Wagner 1969), (Naylor et. al. 1966) and systems philosophy (Churchman 1968) literature contains material focusing on the model-building process, but the streamlined descriptions are usually too general and idealized to be of practical value in guiding a conceptualization effort. Finally, the system dynamics literature does not say much about the model conceptualization process; what is said is reviewed in detail in Chapter II.

The operations research literature discusses modeling at a level of generality not much lower than that of the philosophy of science literature. Here we find problem definition and theory construction discussed in ways applicable to all theory formation. (Bunge 1967) is an excellent, thorough treatise on the subject, but it is not particularly enlightening about how one defines a problem or how one conceptualizes an elegant structure.

One thus must conclude that the literature addressing itself directly to the question of how to model is very limited. It appears, indeed, that W.T. Morris' paper, "On the Art of Modeling," is the only existing paper on the subject (Morris 1967). Morris sees the modeling process as one of enrichment, association, and alternating attention to different aspects of the task. For success in the iterative process, he advises the modeler to

--Factor the system into simpler problems

--Establish a clear statement of deductive objectives
--Seek analogies
--Consider a specific numerical instance of the problem
--Establish some symbols
--Write down the obvious
--Enrich a model, if it is tractable; otherwise, simplify it

Morris further argues that consciousness about model characteristics is helpful in developing modeling skills. He sees models as existing along dimensions of Simplicity, Relatedness (to known theory), Transparency, Robustness, Fertility, and Ease of Enrichment.

Nowhere in the literature is the chronological development of a modeling effort described. There are two fictitious published accounts which exemplify the evolutionary method of model construction. (Morris 1967) describes in pedagogical detail the hypothetical development of a scheduling model. (Simon 1954) presents a series of models of rational human behavior, showing how a more complex model results when more realistic assumptions are made. In short, no account exists of an actual model conceptualization effort, which describes its fruitless attempts and actual mistakes, and tries to derive guidelines on that basis.

The dearth of literature on the conceptualization process, regarding both how it actually occurs and how it should occur, makes it difficult for the novice to make quick headway toward professionalism. This report is intended as a step toward meeting the need for such descriptions.
CHAPTER II

THE PROCESS OF DYNAMIC MODELING

The outcome of a model-building effort is not determined by the model-builder's conceptualization abilities alone. This chapter discusses other factors which determine the form of the "final product": the objectives chosen for the project, the criteria used to guide the iteration toward a "better" model, the procedure followed in each iteration, and the methodological (and other) biases of the modeler.

The discussion is intended to emphasize the iterative character of all theory construction, and to indicate how models are continually upgraded through evaluation of the model relative to chosen criteria, followed by correction of uncovered weaknesses. In the physical sciences, models have been successfully improved by comparing model-based point predictions with quantitative observations using statistical tests. It is argued below that this procedure is not optimal for simple, dynamic models of social systems, because of the present infeasibility of making point predictions in such systems. In upgrading social system models, it may be better to employ a much broader form for evaluation of models. In the alternative generalized evaluation process, all model aspects (not only model predictions) are evaluated, using all available knowledge (not only quantitative data).

Note that our subject is constrained here to descriptive, generic models of the "general theory" type. The several special consider-
ations necessary when striving for implementation of a more pragmatic and specific, "client-oriented," model are not discussed.

Model Utility

The Multiple Objectives for Modeling

Models -- including dynamic simulation models -- are simply one type of theory about the world. Bunge (Bunge 1967, Vol. I, p.380) describes a theory as a closely knit system of hypotheses which are interrelated. Ackoff (Ackoff (Ackoff 1962, p.22) adds the requirement that hypotheses be mature; they should be "laws." A model is a system of more or less supported assumptions concerning the operation of some limited aspect of the real world and can be viewed as a theory. No distinction is made here between the words "model" and "theory."

In the most general terms, we may say that a theory is constructed in an attempt to increase understanding of the real world, often to aid in control of the human environment. On a less aggregate level, a multitude of different objectives exist, which one may try to satisfy through theory construction. Solberg (Solberg 1973, p.73) lists the following model objectives: description; design; prediction; optimization; management; training or education; detection; reduction of uncertainty; decomposition or aggregation. A given model will satisfy all of these objectives to a certain degree; however, the typical model satisfies a few objectives to a larger extent than others. The utility of a given model is determined by how well it satisfies the objectives
selected by the user as important. Thus the utility of a model cannot be objectively assessed without prior agreement on which objectives the model is to serve.

Prediction is not the only objective in model-building. Models can be useful even when they do not satisfy the objective of quantitative prediction of specific events at particular future times. It is necessary to accentuate this obvious point because the various producers of theories weigh the several objectives a model may serve differently, to arrive at a concept of model utility adapted to the inherent character and state of knowledge in the particular field. The physical sciences, for example, focus solely on the objective of detailed predictive capability.

The spectacular progress of the physical sciences appears to have induced a widespread unconscious tendency in virtually all fields to view detailed predictive ability as the only proper objective for theorizing. The tendency is intensified in the case of descriptive, generic mathematical modeling of social systems, since there is a superficial similarity between models of social systems and theories in the physical sciences: both are descriptions which take the form of a set of mathematical relations.

Is Point Prediction Feasible in Social Systems?

The single most important fact about scientific, theory-based prediction is that it is always conditional; it predicts that an event will occur if certain laws are "obeyed" and certain circumstances take place (Bunge 1967, Vol. II, p.69). Scientific prediction differs
from prophecy, which asserts that an event will occur regardless of all other factors.

It is useful to distinguish two types of conditional prediction. One is point prediction: quantitative prediction of specific events at particular future times. The other is prediction of behavior modes: qualitative prediction of future behavioral tendencies of a system. In talking about the path of a tennis ball through the air, prediction of behavior amounts to forecasting that the ball will follow a near-parabolic trajectory, and not, for example, a zig-zag path. Point prediction of the trajectory amounts to stating the exact position of the ball at any future time. In both cases the prediction is conditional on the continued existence of gravity, viscosity in air, and the like. Ability to point predict includes capability for prediction of behavior modes.

Accurate conditional point prediction has been proven feasible in the physical sciences. In the theoretical description of physical (relatively simple) systems, one can include a large fraction of the important mechanisms (factors strong enough to be measured) determining the time path of a variable. By prescribing the mode of operation of these mechanisms — by assuming certain conditions — over the forecasting period, one can make accurate point predictions of the variable's future values. An accurate conditional prediction is one that is actually fulfilled (in a probabilistic sense) when the conditions are controlled in the prescribed way.

There is disagreement on whether detailed conditional prediction is possible in social (relatively complex) systems. One would expect
prediction to be impossible because of the apparent infeasibility of
including even a small fraction of real-life processes in a model, forcing
inclusion of many interactions in a strong stochastic factor. However,
Naylor et. al. (Naylor et. al. 1966, p.318) express the opposite
view, in speaking of simulation models capable of including vast numbers
of social mechanisms:

"It is our position that the ultimate test of a computer
simulation model is the degree of accuracy with which the model
predicts the behavior of the actual system (which is being simulat-
ed) in the future. Furthermore, we would argue the possibility that
computer simulation models may be able to predict the future constitu-
tes the major source of justification for the use of computer
simulation as a tool of analysis. This is not to say that all
computer simulation models are capable of yielding accurate
forecasts about the future. In fact, at the present time the
number of computer simulation studies that can claim even a
modicum of success in predicting the behavior of some economic
system are meager indeed. However, we do not feel that the
limited success achieved thus far by computer simulation models in
terms of forecasting ability reflects some fundamental under-
lying deficiency in the technique itself. Rather, we strongly
suspect the principal difficulty stems from the limited experience
that has been accumulated by researchers using this technique.
There is also the further limitation imposed by the speed and
memory capacity of existing computer hardware. However, we re-
main optimistic on both of these points, conjecturing that
these are short-run problems that man is capable of dealing with
in due time."

Others are less optimistic, but argue that there are less
accurate "degrees of prediction" which may be quite useful. Even if
point prediction is infeasible, models may still be capable of predic-
tion of behavior modes. In Forrester's words (Forrester 1961, p.56):

"...a useful model of a real system should be able
to represent the nature of the system; it should show how
changes in policies or structure will produce better or worse
behavior. It should show the kinds of external disturbance
to which the system is vulnerable. It is a guide to impro-
ving management effectiveness."
"But note especially that quantitative prediction of specific events at particular future times has not been included in the objectives of a model. It has often erroneously been taken as self-evident that a useful dynamic model must forecast the specific condition of the system at some future time. This may be desirable, but the usefulness of models need not rest on their ability to predict a specific path in the future. This is fortunate because there is ample reason to believe that such prediction will not be achieved in the foreseeable future."

It thus appears that accurate point prediction is not a feasible objective for current modeling of social systems. The situation is likely to remain as long as it is required that the modeler shall have full control over his model, since any transparent, understandable model will always be a simplification\(^1\) and hence leave out several real-life processes, to be embraced by the stochastic element in the description of reality. A dynamic model influenced by noise in several places is incapable of accurate point prediction in most situations (for an illuminating demonstration, see (Forrester 1961, App. K).

Feasible Objectives for Modeling of Social Systems

Many objectives can be satisfied by building dynamic models of social systems with existing techniques. This section discusses three: prediction of behavior modes, description of real-world phenomena and generation of insight.

\(^1\) The argument would collapse if the real world proves to be a hierarchy of nearly decomposable systems (see [Simon 1969, Ch. 4]), each of which is sufficiently simple to be represented in all its detail by a transparent model. This seems unlikely, given the complexity of one decision-maker.
--Prediction of Behavior Modes

Prediction of behavior modes, the qualitative behavioral tendencies of a system through time, is one feasible objective for modeling of social systems. The behavior mode of a system is determined by its feedback loop structure, and is normally quite insensitive to changes in the assumptions made. Variation of assumptions over the full range of uncertainty, and inclusion of stochastic influences, will often have no effect on the behavioral tendencies of the model system. In other words, it is possible to achieve a sufficiently exact representation of reality to make well-founded predictions of behavior modes.

--Description of Real-World Phenomena

Description of real-world phenomena is another feasible objective. The distinction between describing reality and describing one aspect or manifestation of reality is highly significant. It is impossible to construct one model of a social system which is a realistic description of all aspects of the system, if for no other reason than because the model would have to be as complex as reality itself. A perfect map of reality is not a feasible objective for modeling. To obtain a model sufficiently simple to increase insight, one must focus on one (or a few) phenomena, to the exclusion of all others, realizing that different aspects of the same reality usually require different descriptions.

Description of the (simple) physical reality called "light" exemplifies the use of multiple descriptions of one reality. When passing
through a narrow slit, light produces diffraction patterns: a phenomenon most readily understood by describing light as a train of waves. On the other hand, when light knocks loose electrons from a surface, the phenomenon is best described by viewing light as a stream of particles. A simple description of the "true nature of light," which encompasses both phenomena, has not been found. But when focusing on one phenomenon at a time, useful theories (models) are readily obtainable.

The distinction between reality and its various aspects is crucial in social systems, which are very complex and can be viewed from a multitude of perspectives. For example, in studying a certain company, one may focus on the factors affecting its production, the employee morale, or the relationships among the top managers. Once cannot make a "model of the company" which is equally relevant to all aspects of the profusion of company-related phenomena. One must focus on one aspect (or a few) among them.

One meaningful way of delimiting a slice of reality is to select for study the factors of relevance to one perceived problem. The procedure will lead to exclusion of most aspects of the reality being considered, only retaining those needed to address the problem, while still addressing the problem from a systems point of view. In short, one should model a problem rather than modeling a system.

Descriptions cannot be proven to be "true." In Karl Popper's words, "Theories are not verifiable, but they can be corroborated." (Popper 1959, p.251) Theories can be more firmly established through confirmation or corroboration, that is, by passing increasingly severe
tests. Opinions differ on what constitutes a valid test, as well as on what conclusions should be drawn if a theory does not pass a specific test. (see [Bunge 1967, Ch. XIV] for a review)

--Generation of Insight

Generation of insight is a third feasible objective for modeling of social systems. Insights may result from the modeler having to take an overall view of the problem; he must summarize, explicitly and consistently, information of varying quality and type in one framework. More particularly, the process may well lead to

i) useful concepts for describing the real world

ii) understanding of how several concepts fit together in one structure representing the real world.

iii) knowledge about the behavioral tendencies of the model structure, including its response to changes

iv) a useful, simplified framework for intuitive analysis of real-world processes

A mathematical model (when presented in an understandable language) also serves the objective of increasing understanding in a wider audience: it is an effective communications tool capable of transmitting the model builder's perspective on some aspect of reality and his analysis of it.

The Iteration Toward More Useful Models

The construction of a model is not a one-shot process: there does not exist one single objective, which is either achieved or not. Theory construction is a continuing iterative process toward an increasingly
useful model, satisfying the chosen objectives to an ever-increasing extent.

For instance, model utility is affected by how well the model predicts behavior modes, describes phenomena of interest, and generates insights. None of these model objectives is subject to a clear yes-or-no dichotomy; they should all be measured on continuous scales. The purpose of iteration is to increase overall model utility, by simultaneously improving all three model qualities, for example, or by an intensive effort to satisfy further a single objective. The relative importance ascribed to each objective depends on the modeler's preferences and on the model's ultimate use. An obvious consequence of viewing objectives as continuous is that one will never arrive at The Ultimate Model. On the other hand, one may stop at any time during the iterative process and still have on hand a model of a certain utility, that is, with non-zero qualities along the three dimensions.

To evaluate the current model and find directions for improvement, one needs operational criteria for model utility, that is, for how well the model satisfies the chosen objectives. In the physical sciences, ability to point predict serves as a test of model utility, consistent with the emphasis on the objective of point prediction. To the extent that point prediction is infeasible in modeling of social systems, another basis for evaluating and upgrading such models must be found.

Upgrading Physical Science Models

In the physical sciences, rapid progress toward more useful
models has been achieved through iterations guided by the criterion of minimal discrepancy in point prediction, as determined through quantitative, statistical tests. The activities involved in the "scientific method," may listed as the following (Naylor et. al. 1966, p.5):

1. Observation of a physical system.

2. Formulation of a hypothesis that attempts to explain the observations of the system.

3. Prediction of the behavior of the system on the basis of the hypothesis by using mathematical or logical deduction.

4. Performance of experiments to test the validity of the hypothesis.

Upgrading Social System Models

The point prediction-observation-evaluation cycle has also been employed in the field of social system modeling, and an abundance of lists, similar to the one above, are presented in the literature, purporting to describe how social system models actually evolve. (For examples, the reader is referred to [Wagner 1969, p.13] [Ackoff 1962, p.26] [Naylor et. al. 1966, p.23].)

In view of the apparent infeasibility of point prediction using simplified models, the statistical comparison of model output with observed time series may well be a sub-optimal guide to better models of social systems. Another obstacle is the difficulty of performing experiments in a social system, due, for instance, to extreme costs, inability to control important variables, or impractical delays in obtaining results (see [Naylor et. al. 1966, p.5]).
The above problems are ameliorated if one removes oneself from viewing statistical, quantitative tests as the only guide to upgrading a model. It is unnecessary to restrict tests to only one characteristic of the model, viz., its ability to point predict events for which one can obtain quantitative data, thereby making statistical confidence tests feasible. Dynamic models have several other attributes that can be subjected to evaluation, for example:

--- the capacity of the model to generate behavior modes corresponding to those of the simuland, both under normal and extreme conditions

--- the acceptability of the individual structural assumptions (the choice of variables and their relations) as a representation of the simuland

--- the plausibility of the numerical values chosen for the model parameters

--- the extent to which the model includes the processes thought to generate the problem addressed

The first criterion achieves importance only if the other criteria are already satisfied; since there is always an infinite set of models capable of reproducing a collection of behavior modes, without being related to the underlying mechanisms in the simuland.

In judging how well a model meets the criteria above, one cannot restrict oneself to the small fraction of knowledge available in a numerical form fit for statistical analysis. Most relevant knowledge is in descriptive, nonqualitative form, contained in the experience of those familiar with the system; documentation of current
conditions; description of historical performance; and artifacts related to the system. In upgrading a model, as in its initial conceptualization, it is necessary to use all sources of available knowledge.

The process of judging all aspects of a model, using all available knowledge about the simuland, will be termed generalized evaluation here, to indicate its breadth relative to the more narrow evaluation of model predictions in terms of statistical tests.

Models can be subjected to generalized evaluation at all stages during their construction, and changes made whenever the model fails to satisfy a criterion. Other criteria can be added to those already listed:

--- The model must be transparent (understandable) and generate endogenously the dynamic behavior of interest.

--- The individual assumptions must be compatible with well tested knowledge, have independent real-life meaning and form a consistent, plausible whole.

--- The model must have a clear focus and include the major relevant mechanisms in a balanced whole.

Most tentative models do not satisfy these criteria, and selectivity is even stricter if one also rejects models that seem inelegant (e.g., not parsimonious)\(^1\).

Regardless of modeling technique, the use of descriptive knowledge and intuition is indispensable in the initial conceptualization

--- Adherence to the guidelines presented in Chapter V may save much time in eliminating unsatisfactory structures prior to their creation.
of a theory. The subsequent upgrading divides into two stages: one stage where the theory is judged by the modeler on the basis of his knowledge about the real-world system, and a second stage, where the theory is subjected to more formal tests. When dealing with descriptive models, it seems unreasonable to proceed to the second stage if the model does not pass the first "common sense" tests.

A model structure that satisfies the listed criteria is not an incontestable description of reality, nor is it The Only Model. But it is far from being a completely random accumulation of assumptions, since most conceivable structures are eliminated by unacceptable performance relative to one or more criteria. Having passed the important initial tests, the model is ready for as many additional, preferably rigorous tests, as time and interest will sustain.

The generalized evaluation procedure constitutes a filtering process where only the satisfactory tentative models survive. It is exemplified by the modeling effort described in Chapters III and IV. A rather explicit example of upgrading through evaluation not based entirely on quantitative information is given by Brunner and Brewer in their work on a model of political development (Brunner and Brewer 1971, pp.23-41). Forrester discusses the criteria for generalized evaluation in great depth (Forrester 1961, Ch. 13).

The Influence of Methodological Priors

Limiting the discussion now to one methodology for dynamic modeling, system dynamics, one can describe in more detail the activities
involved in the iteration toward more useful models. The modeling activities are listed later in this chapter. They are more meaningful when the methodological bias of system dynamics is known; the nature of this bias is the subject of this section.

The choice of a specific modeling technique has important implications for the final product, since technique largely determines the researcher's world view and his biases when approaching the problem. Urban (Urban 1973) calls for open recognition of methodological biases or "priors," as he terms them. Myrdal (Myrdal 1973, p.152) supports this view and extends it to embrace personal and political biases which also, in his view, influence the results of research in the social sciences:

"In order to avoid biased research and to make it "objective" in the only sense this expression can have in social science, we need to explicitly formulate [our] specific value premises...

"...valuations are, as a matter of fact, a part of the research activities from beginning to end. They determine the organization of the research; the definition of the employed concepts and, thereby, the observed facts; the way in which conclusions are drawn and even the way in which the conclusions arrived at are presented. Explicit value premises are thus necessary not only in order to draw meaningful and correct practical and political -- that is to say, sociotechnical -- conclusions, but already in order to determine relevant facts and relations between facts. Otherwise we draw conclusions with a collection of premises missing."

The important priors, usually implicit in system dynamics modeling, are listed below. In a short paper, Forrester (Forrester 1968) presents the systems dynamics technique in a manner which
makes particularly apparent the underlying priors.

The system dynamics approach encourages a true systems point of view. It does not focus solely on those aspects of the problem which happen to belong to one academic discipline or those which happen to be measurable. The approach entails a bias toward viewing any problem in its real-world, multidisciplinary context. Thus factors are included if they are judged important, even when this leads to reliance on subjective judgement. The system dynamics approach emphasizes dynamic, or time-varying, processes. A system dynamics study focuses more on the system's behavior over time than on its static properties. System dynamics attaches great significance to system structure, that is, the network of causal relationships among system variables. Different dynamic behavior modes can be generated by varying the parametrization of one causal structure. The structure is significant because it represents relatively fundamental, invariant relationships among variables. Special efforts are made to find the feedback loops: closed loops of causal influence responsible for the dynamic behavior. Of central importance in this connection is the feedback of information, creating the majority of the closed loops in the simuland. The emphasis on feedback loops arises from a fourth prior: the view that the most insight is gained from dynamic models which do not rely on exogenous variables (driving functions) for their dynamic behavior. The important dynamic behavior should arise from feedback loops contained inside the chosen system boundary. Next, there is an emphasis on continuous and deterministic processes, which are considered the essential backbone of the
more discrete, probabilistic development observed in real-world quantities. Another important prior views the world as state-determined; the rate of change is determined by existing conditions at that point in time. System conditions can only change through non-zero rates. The rates are seen as the points of influence and embody the system "policies," called so even when less subject to human control than is normally implied by the word. The seventh prior is the emphasis on the importance of non-linearities in determining system behavior.

Together the stated priors form the basis for the system dynamics practice of locating and including the few causal relations that determine the major characteristics of the behavior one wants to explain. The models are continually upgraded through generalized evaluation of the tentative structures.

The Activities Involved in System Dynamics Modeling

Having outlined the objectives sought and the process followed in generic system dynamics modeling, it is time to turn to a more detailed description of the activities involved in the iteration toward better models.

Past Descriptions

Three lists of activities exist in the literature. The first list of "steps in an industrial dynamics study," appeared in *Industrial Dynamics* (Forrester 1961 p.354):
1. Defining the objectives of the system under study  
2. Observing symptoms  
3. Detecting symptoms  
4. Visualizing the system at issue  
5. Estimating the boundaries within which lie the causes of the trouble  
6. Selecting the factors to be dealt with  
7. Constructing a formal model of the preceding  
8. Using the model to simulate system interactions under selected conditions  
9. Interpreting the significance of the simulation results  
10. Inventing system improvements  
11. Repeating all of these steps to move closer and closer to the true problems and to better management policies

The list indicates that Forrester starts by deciding on a problem, proceeds to determine the scope of the system needed to generate the problem endogenously, and then chooses a set of descriptors from inside the system boundary sufficiently detailed to be able to treat the problem. Upon completion of a version of the formal mode, it is run to insure that the assumed relations actually do reproduce the problem, and to help one decide how the model can be improved. The iterative nature of modeling is recognized. Forrester has given examples (streamlined and idealized for the purpose of smooth presentation) of his modeling strategy: descriptions of model objectives, scope and factors for a model of production-distribution system (Forrester 1961, p.137-140) and for a customer-producer-employment model (Forrester 1961, p.208-215).
The second list of "phases in the industrial dynamics approach," appeared in *The Dynamics of Research and Development* (Roberts 1964, p.317):

1. Problem identification
2. Verbal description of the dynamic system theory affecting the problem
3. Mathematical model development
4. Computer simulation of the represented system
5. Analysis of results to determine model validity and factor sensitivity
6. Double-checking of, and data collection regarding, the sensitive areas of the model
7. Simulation experimentation to help identify improved system parameters and policies
8. Implementation of results of investigation in the real-world problem areas
9. Evaluation of the effectiveness of the changes, and return to the first term of procedure (Item 1) for continuing improvement, if necessary

Roberts differs from Forrester mainly in his greater emphasis on the need for data collection and sensitivity analysis to increase model credibility, and for special efforts to insure implementation of results. In his book, Roberts explicitly describes the largely nonquantitative, descriptive information constituting the basis for his formal model. He also shows how increased understanding of system characteristics can be obtained through systematic changes in model parameter values. Roberts' later work discusses the implementation problem more thoroughly (Roberts 1972); the work emphasizes the need for client involvement from the outset
(for instance, in choosing the problem), and for validation to the extent judged necessary by the client.

The third list of activities was presented in *Systems Simulation for Regional Analysis* (Hamilton et. al., p.263), as a "schematic of research strategy" (Figure II-1). The major emphasis is on the iterative character of modeling, "accompanied by validation checks of the model using as much new data as possible" (Hamilton et. al. 1969, Ch. 5).

They argue that **problem definition** is important because a model is a means and not an end in itself. The second activity, **model construction**, should aim at inclusion of all feedback loops, however intangible, necessary to achieve the model's purpose. The amount of detail must be sufficient to address the problem in terms of stable relationships. Concerning **model simulation**, they argue that one should compare several runs rather than relying on a single "forecast." Finally, the **model validation** phase should be continued until one can ask, "Is the model good enough to answer my question?" and answer in the affirmative without undue reliance on the somewhat restrictive statistical confidence measures available today.

**A Suggested Framework for Analysis of the Modeling Process**

The above lists are helpful; but they are not sufficiently detailed to guide the novice through independent creation of a useful system dynamics model, nor for describing accurately the chronology of a modeling effort. To this end additional activities must be considered, and all activities must be defined more precisely. The first goal of
Stage 1:
- Statement of Objectives
- Feasibility Study
- Choice of Methodology

Stage 2:
- Preparatory Work
- Review of Literature
- Preliminary Data Analysis

Stage 3:
- Formulation of Initial Model, M₀
  - Computer Simulation Experiments
  - Checks Using Old and New Data
  - New Research Findings

  First Iteration:
  - Reformulation of Model M₀
    - Model M₁
      - Computer Simulation Experiments
      - Checks Using Old and New Data
      - New Research Findings

  Second Iteration:
  - Reformulation of Model M₁
    - Model M₂

* It is assumed that this study shows the project to be feasible.
† It is assumed that a “modeling” approach is selected.
‡ The iterative procedure may disclose problems in the original formulation of goals, feasibility, and methodology so that refining and reformulation of the effort may not be confined solely to the model itself. That is to say, goals.

Figure II-1: Hamilton's Schematic of Research Strategy.
this section is to complete the list of activities as well as to define several useful terms.

Similarly, the above lists indicate just vaguely what might constitute a useful sequence of the activities. It is unlikely that any modeling effort has ever, or ever will, progress in an orderly, sequential, iterative fashion through a list of activities. Normally, activities are interrupted before completion, completed in other sequences, or executed in parallel, due to sudden inspirations. Nevertheless, explicit guidelines for an efficient sequence are useful, at least to the novice until he accumulates his own experience. One purpose of the analysis in the following chapters is to identify an effective sequence of the modeling activities which are presented below in a rather arbitrary order.

Although the above lists recognize the iterative character of the modeling process, they do not emphasize sufficiently the critical difference between the art of conceptualizing and formulating an initial model (the "initial modeling stage"), and the more routine process of elaboration and extension of an existing model (the "improvement stage"). The difference between the creation of and the subsequent improvement of an initial model is similar to the difference between discovery and proof in research.¹ To accentuate the difference among the two processes Beveridge (Beveridge 1951, p.89) presents the following analogy:

¹Phillips finds it useful to distinguish between the "context of discovery" and the "context of justification" (Phillips 1971, p.69).
"The methods and functions of discovery and proof in research are as different as those of a detective and of a judge in a court of law. While playing the part of the detective the investigator follows clues, but having captured his alleged fact, he turns judge and examines the case by means of logically arranged evidence. Both functions are equally essential but they are different."

Both the initial modeling and the improvement stages involve iteration through the same activities, but the content of the activities changes, as does which activities are emphasized. An intent of this report if to emphasize the difference between the two stages; the activities are described within a format which reflects this distinction.

The list of activities presented below focuses on the model-building process itself. The special activities neccessary to perform relevant experiments and achieve implementation of the results are omitted. The list is a complete description of the activities involved in the creation of a generic system dynamics model, when experimental checks are infeasible.

--Familiarization with the General Problem Area

All types of available information related to the problem area serve to prepare one for its study. Relevant statistics and literature, subjective judgement by individuals with experience in the field, and one's own observation and common sense considerations are sources of such information. The activity need not be limited to highly precise
numerical data from one segment of the "quality spectrum of information," given the ease with which low quality descriptive information can also be included in system dynamics models (Meadows and Randers 1972 p.216).

--Definition of the Question to be Addressed

Deciding on a question involves selecting one aspect of the general problem area as the focus of the study. The choice will be influenced by the goals of the study, particularly by consideration of what audience one wants to address and one's methodological and topical biases. A perceptively chosen question is a significant step toward a useful model; but even very precise questions merely give the study a general direction. "How can one reduce the flow of natural resources to solid waste?" (Randers and Meadows 1972), and "How will material growth come to an end in a physically finite world?" (Meadows et. al. 1972) are past examples of questions asked.

--Exploration of Real-World Behavior and Structure Relevant to the Question

The activity includes exploratory identification of dynamic phenomena related to the question; search for a powerful perspective on the problem; definition of a meaningful slice of reality on which to focus; development of understanding of relevant real-world processes; identification of important variables and causal interrelations. The activity is a more or less random search for "good ideas," guided by one's earlier model-building experience.
--Description of Dynamic Behavior of Interest

The activity entails, first, the selection of a (observed or hypothetical) process occurring through time as representing the problem or phenomenon to be addressed. Second, that process is described in terms of the time-varying behavior of certain key variables and sketched in a graph. Only the most general features of the behavior are recorded. The activity is most germane to the initial modeling stage; during the initial conceptualization the depicted dynamic behavior of interest will be referred to as the reference mode. The reference mode serves as an approximate picture of the expected output from the initial model. The model is not necessarily restricted to one time pattern; one may need several characteristic behaviors to properly define the problem. If one is modeling past phenomena, the reference mode represents essential characteristics of the historically observed behavior to be reproduced by the initial model. When one is modeling a situation yet to be, the reference mode is the (small) set of alternative development patterns one would like the initial model to encompass through variations in parameters. Specification of the reference mode defines the problem more sharply and determines the time horizon of the study; it also hints at what processes must be included in the initial model.

An example of problem definition through reference modes is the discussion of oscillatory and smooth adjustments of population to the global carrying capacity in *The Limits to Growth* (Meadows et. al. 1972, pp. 91-92).

In the improvement stage, description of an interesting behavior
mode which the model cannot yet generate helps guide the extension of
the model to include additional processes.

--Development of Organizing Concepts

Organizing concepts are useful and powerful in describing the
dynamic behavior of interest and in pointing to possible underlying
causes for the reference mode. Organizing concepts often evolve through
the study process; but they may crystallize faster if they are actively
sought out.

In global modeling studies, for example, the organizing concepts
are "exponential growth"; "physical limits"; and "delays" (Meadows
1972, pp. 3828–9). These terms simplify discussion of the dynamics of
growth in a finite world.

--Definition of System Boundary Through Verbal Description of System

In the initial modeling stage the activity involves identification
of different, real-world feedback processes which may possibly underly the
dynamic behavior of interest, and selection of a few that are judged
essential. In choosing which processes are to be included in the model,
one simultaneously determines a perspective on the problem and a system
boundary which will be the perimeter of one's search for causal relation-
ships.

The smallest set of feedback processes considered sufficient to
generate the reference mode will be referred to as the basic mechanisms.
The assumption that the basic mechanisms actually can generate the
reference mode is called the **dynamic hypothesis**. The assumed basic mechanisms in the global models are, ceteris paribus, that more people lead to more children, that a larger capital plant leads to more investment in new plants, and that these growth processes are increasingly hampered after some delay by the finiteness of non-renewable resources, food supply, and pollution absorption capacity (Meadows et. al. 1972, Chs. 1-2).

In the improvement stage, the system boundary is occasionally expanded to obtain a more versatile model, making processes endogenous that were initially excluded from consideration.

---

**Representation of Feedback Loops in Causal Diagram Form**

The activity involves producing a graphical description of the overall feedback loop structure of the model system as a framework for later, detailed formulation.

A causal loop diagram for the major loops in the global model, World3, is presented in (Randers and Meadows 1972).

---

**Identification of System Descriptors**

The activity entails choice of a set of mutually independent descriptors (or state variables) sufficient to characterize the system inside the closed boundary. The choice of descriptors includes determination of the level of aggregation to be used.

An example of a partial list of system descriptors is given by Forrester (Forrester 1961, p.140) when he (in retrospect) decides that the central levels for describing one sector in a production-distribution
chain are the order backlog, the inventory of goods in stock, and the average sales in the recent past. The list of descriptors would have been more complete had it included the independent descriptors which are treated as parameters in the model, for instance, some of the time constants and delay times.

--Postulation of Detailed Model Structure

The activity involves the actual formulation of the model structure, e.g., in terms of a DYNAMO flow diagram. It implies deciding on the determinants of the rates; these, in turn, determine the values of the levels. Through the process of linking rates to the levels on which they depend, the detailed feedback loop structure of the model system is defined. The activity includes decision on the functional form of algebraic relationships, and on the general form of tabular relationships among variables.

One can obtain a good impression of the process of postulating detailed model structure from Figure 2-5 in Urban Dynamics (Forrester 1969, p.21). The figure depicts the major system descriptors in the urban dynamics model and shows the information network determining the value of one rate.

--Specification of a Parametrization

Parametrizing the model entails quantification of all system variables and assessment of the strengths of the relations among them. Numerical values are determined for time constants and delay times;
detailed assumptions are made about the parameters in the nonlinear model relationships. Upon completion of the parametrization activity, the final, detailed, and complete formalization of the model is achieved, e.g., in the form of a DYNAMO computer program.

The documented program listings which invariably appear as appendices in the system dynamics literature are examples of final products of this activity.

--- Evaluation of Model Assumptions

The activity includes a final check on the consistency of the total set of model assumptions and an assessment of the degree of realism of model structure and parameters. Information of all types, descriptive knowledge as well as quantitative data, may be used to corroborate or to weaken claims for the plausibility of the model. The activity constitutes one set of tests in the generalized evaluation process used to guide the iteration toward better models.

An example of the use of common sense data, tentative biological experiments, observations from similar situations, the principle of the conservation of matter, and well-established physical measurements to evaluate a model of an imperfectly known ecological system (environmental DDT flows) is given in (Randers 1972).

--- Simulation to Evaluate Model Behavior and Test Sensitivity to Perturbation

In the initial modeling stage, simulation runs of the model are
made to check whether the model actually can reproduce the reference mode, and whether it shows reasonable behavior in general. In the improvement stage one insures that the behavior is reasonable, and not overly sensitive to variations of model parameters and structure within the area of uncertainty. The activity forms an important set of tests in the generalized evaluation of the model.

The paper on DDT flows mentioned above also exemplifies the most crucial aspects of the whole-system evaluation: simulation of a historical development (to reproduce the historical part of the reference mode); investigation of the consequences of different future actions in the model (to reproduce alternative future modes); and variation of uncertain parameters (to determine the robustness of the behavior modes).

--Experimentation with Different Policies

The activity represents the first use of the model to discover the consequences, in the model system, of alternative policies, and possibly, to find improved policies. Experiments may include simple parameter changes, reformulation of rate equations, and addition of new structure to the model.

Through an elegant sequence of model runs, Forrester tests the consequences of reduced resource usage, increased rate of capital accumulation, reduced birth rate, and reduced rate of pollution generation (singly and in combinations) in his model of growth in a finite world, indicating the persistency of the collapse mode in such a system (Forrester 1971).
The list of modeling activities is summarized, for convenience, in Table II-1. The table serves to define the words *conceptualization*, *formulation*, and *evaluation*, which in this report are seen as summary terms for the indicated groups of activities.
--- Familiarization with the general problem area

--- Definition of the question to be addressed

--- Exploration of real-world behavior and structure relevant to the question

--- Description of the dynamic behavior of interest

--- Development of organizing concepts

--- Definition of system boundary through verbal description of system feedback loops

--- Representation of feedback loops in causal diagram form

--- Identification of system descriptors

--- Postulation of detailed model structure

--- Specification of a parametrization

--- Evaluation of model assumptions

--- Simulation to evaluate model behavior and test sensitivity to perturbations

--- Experimentation with different policies

--- Table II-1: The Activities in Generic System Dynamics Modeling.
CHAPTER III

THE CHRONOLOGICAL HISTORY OF ONE MODELING EFFORT

Chapter III describes an actual effort by a six-man work group to develop a generic system dynamics model based on their own knowledge. As will be made clear in this chapter, the specific focus of the study varied a great deal throughout the year. At any one time, however, the study was related to the same general area: social change resulting from attempts of a group to spread an idea in society. The overall objective remained what is normal for generic modeling: to generate system insights of potential use in improving policies, especially the policies of leaders in groups promoting a particular idea.

The chronology in this chapter and much of the analysis in the following chapters are based on the following "historical documents," generated during the project:

-- the work notes of the author (540 dated, handwritten pages) discussing real-world processes and ways of representing them, tentative organizing concepts, the formulation of models and model segments, and reflections on study topic and purpose.

-- the author's list of ideas (30 dated, handwritten pages) concerning real-world processes and formulation problems to be considered later in the ongoing study.

-- notes from the work group meetings (80 dated, handwritten pages, plus 40 flipover sheets).

-- seven running computer models and five models in causal diagram form, all focusing on different aspects of social change.

-- four formal project proposals/progress reports (double-
spaced, typewritten, 10, 5, 35, and 48 pages respectively).

Two perspectives on the chronological process are given below: one after-the-fact description of the actual sequence of activities and one subjective account of the study's progress, as recorded in the author's diary during the project.

The Modeling Process in Retrospect: The Actual Sequence of Activities

The retrospective chronology is written in terms of "I," the author, and "we," the work group, to stress that is an account of one historical process having no normative significance. In fact, conclusions were drawn during the project that seem to be wrong. The account focuses on our activities, goals, and plans for achieving those goals as they existed at various points. The development is described as it occurred, not as it ideally should have occurred. The chronology is used normatively in later chapters where it forms the basis for tentative guidelines for more effective model construction. Figure III-1 is an attempt at visual presentation of the overall sequence of activities.

The retrospective chronology is divided into twelve segments, one for each of the different made sequentially during the project. The twelve models are listed in Table III-1, with descriptions of model focus and degree of completion. For purposes of simplification, the models have been given names consisting of a mnemonic (suggestive of model focus) succeeded by a numeral between 1 and 12 (giving the sequential number of the model: for example, ACCEPTANCE#1, MOVEMENT#3).
<table>
<thead>
<tr>
<th>Model name: (date abandoned)</th>
<th>Main question addressed:</th>
<th>Model descriptions finished</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Causal loop diagram</td>
</tr>
<tr>
<td>ACCEPTANCE#1 (8/31)</td>
<td>What are the positive and negative societal forces affecting acceptance of an idea?</td>
<td>X</td>
</tr>
<tr>
<td>GROUP ACTIVITIES#2 (10/24)</td>
<td>How is a group strategy formed and what are its effects?</td>
<td>X</td>
</tr>
<tr>
<td>MOVEMENT#3 (12/14)</td>
<td>What determines QME and QAE (the milieu) and hence the growth of a movement?</td>
<td>X</td>
</tr>
<tr>
<td>LIFECYCLE#4 (12/27)</td>
<td>How do milieu and strategy formation in a movement interact to determine its lifecycle?</td>
<td>X</td>
</tr>
<tr>
<td>HELPORG#5 (2/2)</td>
<td>How do quality of service and strategy formation interact to determine the growth of a helping organization?</td>
<td>X</td>
</tr>
<tr>
<td>No new work was done during 1/73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CICO#6 (2/14)</td>
<td>What basic mechanisms generate the observed behavior of the Corporate Information Center?</td>
<td>X</td>
</tr>
<tr>
<td>MORALE#7 (2/21)</td>
<td>What determines movement morale and how can it be maintained in adversity?</td>
<td>X</td>
</tr>
<tr>
<td>COMMITMENT#8 (3/29)</td>
<td>How do the commitments of group to its cause (the new idea) and society to its behavior affect the widespread adoption of a new behavior?</td>
<td>X</td>
</tr>
<tr>
<td>ATTRACTIVENESS#9 (4/17)</td>
<td>How do group effort and societal satisfaction affect the perceived attractiveness of a new idea?</td>
<td>X</td>
</tr>
<tr>
<td>ADOPTION#10 (4/22)</td>
<td>How do promotion of, resistance against, and experience with an idea determine its adoption?</td>
<td>X</td>
</tr>
<tr>
<td>PROHIBITION#11 (5/5)</td>
<td>What were the major forces causing adoption of prohibition in the U.S., 1920-1933?</td>
<td>X</td>
</tr>
<tr>
<td>NEMIDEA#12 (not yet)</td>
<td>How do available information, group perseverance and societal institutionalization determine acceptance and stabilization of new views in society?</td>
<td>X</td>
</tr>
</tbody>
</table>

Table III-1: The Models Made During the Project.
MODELING ACTIVITY
(cfr. list in Table II-1)

Familiarization
Question
Exploration
Behavior of Interest
Organizing Concepts
Describe System
Causal Diagram
System Descriptors
Detailed Structure
Parametrization
Evaluation
Simulation
Policy Experiments

Improvement

Improvement is a summary description of further iteration used to avoid complication of the figure.

Figure III-1: The Sequence of Activities During the Project

No new work was done during January 1973.

The differently shaped symbols indicate duration (horizontal extent) and intensity (vertical width) of activities, very approximately. The continuous line indicates the general shift of emphasis.
The models are described in Chapter IV.

The Origins of the Project

The project arose out of interest in societal value change shared by the Planning and Research Department of the National Council of Churches of Christ (NCC) in New York, the staff of the foundation-funded INSEARCH Project on the Future of Religion in America, and the MIT System Dynamics Group, as represented by the "World Group," which had just completed the global modeling studies reported in The Limits to Growth (Meadows, D.H. et. al. 1972) and World Dynamics (Forrester 1971). The initial contacts were made during the spring of 1972; they focused on the feasibility of a study of value change using system dynamics. It was hoped that the study would be useful: for the National Council as a planning tool, for INSEARCH as a theoretical framework for their ongoing study of 50 trend-setting contemporary religious groups, and for the world group as an exploration of ways to include value change endogenously in the world models. The parties held in common a worldview that large scale change in societal attitudes and values (with respect to consumption, the environment, justice, and desired lifestyle) is desirable and necessary to insure a sustainable global society in earth's finite environment. Such change appeared, at the time, to be starting, as manifested by various small groups practicing different and often materially frugal lifestyles and attitudes. One question which arose, was, how could such tendencies be strengthened?
The discussions -- lasting perhaps three days in total -- culminated in a draft proposal (Randers June 1972) to the National Council of Churches, entitled, "The Diffusion of New Ideas and Values -- A Dynamic Model of the General Process," which stated in part:

"With respect to the global problems mentioned above, there seems to be little doubt that the necessary changes in values -- or in "life styles" -- will be suggested. Certainly the new ideas will also be accepted by small groups of people dedicated to their widespread dissemination. The critical problem is thus not the formulation of the proper ideas, but rather how to succeed in quickly diffusing the new values and gaining their acceptance by many people in a relatively short time. It does not seem obvious that this transmission of new values will occur spontaneously and smoothly in a society faced with some major threat, and it seems imprudent to rely on this relatively unknown process to solve major problems. Responsible statements about the likelihood that value change will relieve rising global problems can only be made on the basis of thorough understanding of the factors which govern the process of diffusion and acceptance of new ideas and values. Only when such increased understanding of the process is obtained will it be possible to model society's probable response to adversity, and to include this additional response in a formal structure like the existing world model in order to study what the likely consequences of non-static societal values are.

"It is the overall purpose of the proposed project to make the first step in this procedure aimed at including value change in the world model: We propose to seek increased understanding of the basic process of diffusion of new ideas by formulating a dynamic simulation model of this particular process.

"The Process of Diffusion and Acceptance of New Ideas and Values

"The first section outlined the general problem area for the proposed project. In this section we will describe in a little more detail the specific dynamic process which we intend to model, namely the process by which a specific idea spreads in society. We proceed by listing potentially important variables and indicating the empirically observed behavior we will attempt to explain.

"Obviously a very large number of factors interact to determine the ultimate fate of a new idea introduced in society. Very superficially one may say that success of an idea or value depends on its
relevance and whether it appears at the "right" time. But what makes an idea relevant and what defines the "right" time? The interesting problem is to localize and interrelate the factors which answer the questions. Examples of such factors are the societal conditions under which the idea is promoted, the power with which the new idea is transmitted, the felt need for the new point of view, the strength of the value which the new idea attempts to replace, the behavior of the group dedicated to the dissemination of the new idea, the degree to which the idea does not remain dogmatically rigid, but is able to evolve in response to relevant pressures.

"Although the factors may seem independent and also largely determined by the specific idea or value of concern, the basic belief underlying the proposed project is that the process of value diffusion can be described by a set of factors which are indeed causally interrelated and also common to all situations regardless of the specific idea or value being transmitted.

"One indication that this is in fact so, is the fact that there are only three fundamentally different categories of factors influencing the process: the characteristics of the new idea, the characteristics of the promoting group and the characteristics of the rest of society. It is the dynamic interaction of these elements which ultimately determines the fate of the new idea. A second indication is that although the detailed processes are complicated, there are only a few essentially different outcomes.

i) the new idea spreads successfully and becomes accepted by a large majority of the target population. (ex. Christianity in the West, communism in China)

ii) the new idea at the beginning spreads successfully, but reaches a level of penetration which seems unsurpassable (ex. the platforms of many political parties in typical European nations, the teachings of any Christian denomination within the United States). That level may be very close to zero acceptance.

iii) the new idea spreads vigorously during the initial phase, only to suffer a severe collapse at a later point in time (ex. the ideal among college youth that becoming rich is the proper goal of life). Some people are afraid that the current rise in environmental concern will suffer a fate of this type.
The time it takes for the idea to diffuse seems to vary significantly from case to case – from days to thousands of years. However, we still believe that the underlying structure governing the process is the same in all cases.

"The Proposal: To Construct a Formal Model of Value Change"

"We believe that greatly increased understanding of the process of diffusion and acceptance of new ideas will result from collecting the various relevant factors in a formal model of that process. There exists extensive knowledge about many of the detailed interactions that constitute the complex system which can demonstrate the different behavior modes outlined above. What does not exist, what we propose to construct, is a general theoretical framework into which all these pieces of detailed information fit. This framework (or model of the system) can be used for studying the simultaneous dynamic interaction of the many important variables.

"We plan to construct this general model or theory by incorporating into one causal structure – consisting of a set of interrelated feedback loops – all the individual detailed interrelations which are often described in the social science literature. In short we propose to make a formal model of the general process by which a new idea spreads in society through time – a model of value change.

"Apart from being useful as the necessary first part in work aimed at including value change in the world model, the construction of a model of the diffusion of new ideas is of interest because

i) it will give an overview and increased understanding of the processes by which new ideas spread in society

ii) it will give increased insights into what is needed for a successful incorporation of a new value, and as such be of use to people dedicated to social change.

iii) it will demonstrate how an abstract problem can be analyzed using formal modeling techniques."

An informal agreement was made to go ahead, and the modeling effort was started in late August 1972 with the gathering of a small work group of representatives for the three parties
in addition to a few outside people with particular expertise.¹

Description of the Work Group Process

We decided to construct the model, not by building primarily on the existing literature in the field, but by using the expertise, experience, and intuition of the work group. The group had expertise in sociology, management, theology, and planning; the members had experience with several groups promoting new ideas, notably the National Council of Churches, the City of New York, and the Jesus-movement.

We typically met once or twice a week for a three-hour session. The time was spent criticizing tentative model structures, identifying important variables I had omitted and insignificant ones I had included, and talking loosely about experiences related to social change. Between meetings I attempted to hypothesize a system structure embracing all the criticisms, new variables, and effects which were brought up at the session. I also incorporated my impressions gained from reflection or the literature. The goal was to synthesize the material into an illuminating, compact causal structure representing the system.

¹The following persons participated significantly in the work group meetings (in addition to the author):
   John Biersdorf, Director, INSEARCH project
   Neiland Douglas, Associate General Secretary, The National Council of Churches
   Herbert Dordick, Director of Telecommunications, New York City Government
   Poikail George, Staff Associate, Action-Education Task Force, NCC
   Everett Perry, Board of National Mission, United Presbyterian Church
   Frank White, Director, Corporate Information Center, NCC
Instant feedback from the work group acted as a harsh and immediate correction mechanism, invaluable in a field where there is little hard data and hypothesizing can result very quickly in beautiful, intellectually pleasing structures with little relation to reality. The feedback also solved my problem of becoming attached to and strongly defensive about an intellectually elegant model, since my constructions were torn down every third day or so.

ACCEPTANCE#1 (8/25, 1972)

It was implicitly assumed from the outset that the value under investigation was fixed and given, and so we immediately focused on the question of why certain values are accepted once they have appeared. During the first couple of meetings we decided to focus on the external, sociological determinants of acceptance rather than on the internal psychological forces affecting the individual's decision to accept a societal value.

Influenced by the three behavior modes described in the draft proposal, we searched for positive and negative feedback loops involving acceptance, together capable of generating S-shaped growth. In a week's time, the exploration resulted in ACCEPTANCE#1, which we viewed as a trivial aggregate description needing additional processes (feedback loops) before it was worthy of running on the machine.

The work group participated in a meeting of about 100 church administrators. We had the opportunity to split the meeting into small groups and have each group speculate on factors that enhance and impede the acceptance of a value. A large number of written
suggestions resulted, with much emphasis on characteristics of the
group promoting the value. ACCEPTANCE\#1 was presented after the experi-
ment, and was well received.

GROUPACTIVITIES\#2 (9/1-10/24, 1972)

Recurring semantic confusion in discussion made it necessary
to define the term "acceptance" more clearly. In the process we came
to emphasize the observable consequences of acceptance: behavior change
and implementation of new policies. It then appeared that a "value"
was too ambiguous and non-operational to be a fruitful first object
of study, so we agreed to start by studying more concrete "ideas."
Soon the topic was narrowed down to ideas involving behavior change,
however slight, upon acceptance. Rather unconsciously, we had been
been treating the group of people with changed behavior as a natural
unit. Further discussion led to a focus on the individuals actively
promoting the new behavior and consideration of internal processes in
that promoting group. We identified a large number of variables, causal
relationships and loops considered essential, relating to group
efficiency, cohesion, motivation, leadership, and the like. The
discussions culminated in a causal diagram which simply combined into one
structure most of the variables and interrelationships we could think
of.

We then realized that the group strategy formation process
was missing in the collection of causal relationships. The omission
was judged to be serious and we proceeded to try to understand
why some groups proselytize while others remain passive, and how
goals and strategies are formed. After much searching for a perspective
on the strategy formation process, we ended up defining a set of generic
group "activities." The set was intended to encompass all actions on
which group members spend time. We distinguished among effort spent
on increasing societal awareness; on group visibility; on group size;
on group cohesion; on the quality of the idea; and on reducing the
difficulties of conversion to the group point of view. We further thought
it reasonable to assume that the group has definite perceptions about the
marginal utility of each of these activities: impressions formed on the
basis of experience and changing through time. A rational group
strategy would be to allocate the total group effort (manpower) among
the activities so as to maximize perceived utility, and this was our
final assumption. Our formulation made it unnecessary to specify group
goals explicitly; it was sufficient to indicate the group's judgement of
the marginal utility of each of the various activities. From our
perspective, a group having success in promoting its cause was one with
a "correct" perception of the utility of the various activities at any
one time: a perception resulting in a time-varying allocation of effort
among activities conducive to growth. The dynamic strategy formation
was added to the causal diagram.

GROUPACTIVITIES#2 was further expanded by including a societal
sector. The sector represented the impact of group activities in
making people shift along a dimension describing involvement with the
idea. The expansion of the structure took the form of the accidental
mention and subsequent inclusion of factors that were "obviously" important, no other selection process being possible since the dynamic behavior of interest was still unspecified.

Our views on the idea diffusion process, after four weeks of exploratory discussions without too much direction, are well summarized in the formal proposal submitted to the National Council of Churches on September 25, 1972, entitled "Behavior Change Induced by Diffusion of New Ideas - A Dynamic Model of the General Process" (Randers September 1972):

"Project Description"

"The widespread diffusion of some ideas -- like a deeper concern for the environment or alternative interpretations of what constitutes religious activity -- results in changes in behavior when internalized by society. Many factors affect the fate of such an idea and the extent to which it induces behavior change. Examples of such factors are the perceived immediate and future gain in self-interest from accepting, the awareness of need to change behavior, the pressure to conform, the exposure to arguments pro or con, the perceived practicability of a change, the novelty of the idea, etc. If a group of people is promoting the change, the behavior of the group seems to be of considerable importance.

Depending on the total effect of these many factors, the new idea may be internalized by a (large or small) segment of the population and lead to changes in behavior. Or it may be rejected without any apparent change in societal behavior. Other alternatives exist, e.g., acceptance of the idea with significant change in behavior -- but only for a short period of time.

The purpose of the project is to construct a formal system dynamics model to simulate the interplay of the many factors which results in such diverse behavior modes. Special emphasis will be put on the interaction between the group that promotes the new idea/behavior (e.g., the church, an avant garde religious group) and the resulting societal change. The model will be tentative to the extent that concentration on the promoting group will lead to less thorough investigation of the other
factors that affect behavioral change (e.g., conformity pressure, the response of social groups opposed to change). The aim is to produce a generic model, capable of reproducing realistic behavior modes; it is not to arrive at a model capable of detailed prediction of future events. The overall goal is to achieve increased understanding of the dynamic processes at work when a new idea is introduced in society.

After several more weeks, it became harder for us to think of factors that were not already included in the causal diagram, and some effort was allocated to drawing DYNAMO flow diagrams of selected sectors. At this time we were satisfied with GROUPACTIVITIES#2; we saw it as a good representation of our mental models of both violent and peaceful change brought about by action groups. Our satisfaction increased further upon replacing the original strategy formation process with an improved version. Deciding that marginal utility considerations are unrealistic for small groups of people, we substituted a strategy formation process where effort is allocated to the part of the organization perceived to be faced with the most serious crisis.

In October, however, we began to feel a growing uneasiness about the lack of direction of the study. We sensed, vaguely, the lack of a clearly formulated question, and we touched on the question of how our study of why a given idea spreads could be made more specific. However, we did not want to abandon the crisis mode of effort allocation, which to us appeared to be our major insight, and we could not identify a meaningful question related to dynamic strategy formation. We continued for some time our previous pattern, looking at random processes
and variables of "obvious" interest, trying to convince ourselves that some interesting lessons could come out of the model.

A focus was discovered unintentionally in the course of later discussions, with the realization that one can view the fate of an idea in terms of the growth and decline of a social movement. We decided, in essence, that all ideas are so closely connected with the promoting group that one can just as well study the lifecycle of a movement, a much more tangible entity than the life of the idea itself. We had finally arrived at a concrete question: "What processes can make a movement fail (i.e., stop growing) prematurely?" Our major "discovery," sub-optimal effort allocation, found its place as one of the several negative forces that may terminate the influx of members into a movement. The focus was now on intentional, expansive action groups and membership became the operational measure of acceptance of the idea.

While trying to list the factors that attract members and leaders to a movement, we accidentally discovered two concepts that proved powerful in describing the lifecycle of movements: the quality of the membership experience QME and the quality of the leadership experience QLE, describing the satisfaction attained by members and leaders through participation in the movement. The two organizing concepts structured our further exploration by suggesting that we identify the determinants of QME and QLE and then close the system by identifying the endogenous forces acting on these determinants. QME and QLE also served the purpose of imparting to our study a softer, more fluid image, more representative of the religious and idealistic movements we had in mind as the subject
of interest. We decided to start on a new causal diagram focusing on QME and QLE.

MOVEMENT#3 (10/25–12/14, 1973)

The list of generic group activities was combined with the general determinants of QME and QLE into one causal diagram, representing internal processes in a movement, and its interaction with society. The large number of detailed assumptions in the diagram had in common only their all being affected by, or affecting, QME and QAE. (QAE, not QLE, because we changed terminology from "Leaders" to "Actors" to describe persons actively working for the success of the movement.) The causal diagram formed the base for a progress report written during the first week of November, "The Lifecycle of a Movement" (Randers November 1972), outlining the direction of the project. The report presents our perspective on movements at that time:

"Introduction

"The term 'movement' is used here to describe a group of people who stay together to achieve some common goal. I choose to restrict my attention to groups with goals that are better achieved if the group is larger. Examples of such 'movements' are all types of political parties, religious groups with missionary zeal, and activist groups wanting to reform society. Other, perhaps less obvious examples of what I consider to be 'movements' of interest, are academic groups trying to gain acceptance for a certain way of viewing reality, the environmental conservation movement, the countercultural movement, the transcendental meditation movement, and so forth.

"All of these groups aspire to large memberships to increase their power and their ability to achieve their goals. They also share in common their attempt to obtain widespread
acceptance of a 'platform' -- that is, a body of teachings of some kind. The leaders of a movement take on this task because of their belief that the insights contained in their 'platform' are capable of improving the quality of life of their followers -- and the larger and stronger their group, the greater the benefits. In short, I consider movements to be myth-making groups trying to impart a sense of increased power and meaning to their members.

"Any movement may be considered to have a 'lifecycle.' As time progresses, the membership of the movement changes, growing steadily in successful movements, stagnating in less successful ones and perhaps decreasing catastrophically in collapsing movements. This change in membership, of course, is not the only change that occurs during a lifecycle. At different stages, there will be different levels of dedication among the movement leaders; different levels of membership satisfaction; different degrees of flexibility in the organization; different types and degrees of opposition to the movement in the rest of society; and so on. The relevance of the movement 'platform' will also vary depending on the effort allocated to its improvement, e.g., relating it to the most urgent societal issues, adjusting it to the needs of members, revising it in the light of current conditions, and on the organization's ability to adapt to changes in the social reality in which it is operating. Finally, the movement's 'strategy' also changes during its lifecycle. By a strategy, I mean a specific allocation of movement's finite resources among the many activities which seem appropriate; improving the platform; hiring and educating new leaders; maintaining group cohesion; increasing the visibility of the movement; et cetera. The change over time of the movement, and the other variables mentioned, constitute the evolving pattern which I call the 'lifecycle' of a movement.

"Potentially, a movement can trace out a multitude of qualitatively different lifecycle patterns during its existence. One characteristic possibility is the movement which starts out as a small, highly cohesive group of strongly dedicated persons. Initially they put their full effort into improving and diffusing the movement platform. The work is efficient and relevant to the goal -- efficient because little effort is needed to maintain group morale and subdue internal friction, and relevant because the strategy can easily be changed (a reallocation of resources can rapidly occur) when there is good reason to do so. The group atmosphere is exciting, and both leaders and members obtain great satisfaction from belonging to the movement. But as the successful movement grows, task specialization and departmentalization occur; more effort is allocated to keeping information channels open. Changes in strategy start to take more time and effort, simply because more people, habits and things are involved. At this stage the movement -- it should perhaps be called an institution now -- starts becoming irrelevant to the existing social situation, and its members start leaving. In a desperate attempt to find out 'what went wrong,' the organization
turns inward and spends most of its effort on self-study and reorganization. The consequent reduction in the amount of effort allocated to improving the platform further reduces its relevance, making the movement even less attractive. At this point the movement may simply 'die,' or it may continue a long shadow existence as an irrelevant monster because the huge investment of time and effort in its establishment makes 'killing' it unacceptable.

"This bureaucratization lifecycle is not the only one possible for those movements which survive the early growth period. Other movements may manage to avoid the decay phase of the aging process by institutionalizing better communication channels both within the organization and with the outside world, and may end up as a stable but viable unit. A very different situation exists for those movements which die because they succeeded in achieving their goal, thereby removing one of the important reasons for people to join the movement. It is of course possible for a movement to survive even such a crisis: if the group cohesion is high, people may keep joining just to experience a strong feeling of community and close friendship.

"Movements that never really manage to start growing trace out a very different set of lifestyles. One possibility is a movement which stagnates after a relatively brief period of growth. Such stagnation may be caused by external reasons, such as a very powerful opponent; but it may also come from internal reasons, such as a strategy which is changed so often that the goal is never attained. Stagnation can also result from spending too much effort on spreading the movement's message to more and more people. If no resources are left for the important task of maintaining a desirable milieu for the movement leadership, the leaders themselves may desert the cause shortly after their education period.

"Finally, there are movements which never grow beyond the original founders. One example is the movement which turns fanatical and becomes completely unreceptive to constructive criticism, perhaps because of an overdose of adversity experienced in the early days of the movement. Another is the movement which is so ahead of its time (or so behind it) that its platform is considered irrevocably irrelevant by society.

"Thus a bewildering number of different lifecycles are possible, and many variables are obviously at work to determine the fate of any new movement. The lifecycles may seem fundamentally different, and the determining variables may appear to be unique in each different situation; in fact, both lifecycle and variables may seem to be determined largely by the specific content of the movement's platform. It is my belief, however, that there is a common set of variables operating in all movement situations,
regardless of the specific platform being transmitted; that these variables are causally interrelated; and that all the different lifecycles can be generated by this one set of variables....

The Overall Point of View Chosen in Thinking About the System

"One may approach the study of the lifecycle of a movement from many different points of view. One may focus on the particulars of the platform, on the psychological processes by which people accept or reject a new concept, or on the detailed societal conditions at the time. One may emphasize the financial constraints, the psychological satisfactions experienced by joining the movement, or both. One may disaggregate the population in groups according to the degree of involvement in the movement, according to prior experience, or according to the amount of power.

"Having tried and judged as inferior several other approaches, I currently consider it useful to include in the model structure most of the concepts mentioned above on a rather high level of aggregation, and to represent in somewhat more detail the activity of the group leaders and the strategy formation process. In other words, I am emphasizing the effect of the movement leadership ('actors') behavior on the lifecycle of the movement.

"A rough description of my viewpoint in modeling the movement lifecycle follows. The actors of the movement work to increase the quality of the members' experience. Their purpose is to attract more non-members to become members of the movement. The strategy followed by the actor group is formed in response to crises in performance (as the actors perceive them). Part of the strategy is to allocate some effort to increasing the quality of the actor's experience as well, in order to obtain an ample supply of actors in the movement. It is also possible, however, that the combination of activities which the actors pursue under a certain strategy may have counter-productive effects both on society and on the movement."

The progress report ended with a description of our current causal structure, which contained a bewildering number of factors. The only "obviously" important mechanisms deliberately excluded were those causing the movement platform (i.e., the cause, or beliefs, of the movement) to change over time. There was a strong feeling in the work group that the platform had to be dynamic, but we agreed to postpone the compli-
cation since the current structure seemed sufficiently interesting to be worthy of running on the machine, granted inclusion of the time-varying crisis mode of effort allocation.

The next several weeks were spent converting the huge causal structure into DYNAMO flow diagrams and equations. The size of the model turned out to be uncomfortably large, even after my decision to keep the effort allocation static. Additional problems arose from the need to quantify the model variables, that were largely abstract and unmeasured. For several days, I tried in vain to develop absolute measures for the levels (for instance, group visibility measured in "number of times the group was mentioned in the media per month"). I then discovered the possibility of expressing the numerical value of each model variable as a multiple of its own value at some reference point in time (for instance, group credibility measured as "x times the credibility in 1950"). Given a verbal description of real-world conditions at a reference point in time, one can describe quantitatively the conditions at any other instant, if one is willing to make intuitive estimates of conditions at that instant expressed as multiples of the reference condition. The same type of intuitively meaningful, albeit relative measures can be used for all model variables.

Using the "reference value" of each variable as its unit of measure and having all reference values related to the same point in time, it became possible to parametrize the whole model structure by drawing dimensionless table functions and choosing one time constant for each rate and delay in the model. A few additional dimensionless numerical
factors determining "natural" constants and the relative importance of various influences had to be estimated. The possibility of parametrizing a generic structure in this way was seen as a great breakthrough because it eliminated the need to obtain absolute measures for the model variables. Further, the reference point method made it feasible for a non-modeler to parametrize the structure on his own, making the model represent the specific case of interest to him.

The project's progress was reported on at a meeting of some twenty-five administrators representing the study sponsors, and the opportunity was used to test the reference point method for parametrization. The administrators, who were not acquainted with the detailed model structure, were asked to draw dimensionless table functions describing relationships in their own familiar and rather similar denominations. Figure III-2 shows the results of two experiments; 20 estimates of the effect on $y$ of changes in $x$ (after a long period of time, with all other influences assumed constant) are superimposed on the form used to obtain the response. The current situation was chosen as the reference point (represented by the point $(1,1)$ in the graphs) and the curves describe the administrators' beliefs about the consequences of deviations from the status quo. The spread in the results decreased when the respondents all considered the same real-world case and clearly understood what each variable was intended to include.

We interpreted the experiment as demonstrating the feasibility of parametrizing the generic model for a particular case, using the insights of persons knowledgeable about that case. We decided that it was accept-
Figure III-2: Experimental Determination of Table Functions by Non-Modelers Using the Reference Point Method.
able to parametrize our models on the basis of our own intuitive knowledge, since a more objective parametrization could be achieved later by the above "Delphi" procedure. We concentrated most of our effort on the major task, finding a reasonable structure.

I tentatively parametrized the model at hand to approximately represent the protestant churches in the United States, viewed as a mature movement at a very late stage in its lifecycle. The 1972 situation was used as the reference point. When MOVEMENT#3 finally ran on the machine, it immediately became obvious that the model was too complicated to give any insights at all. The major mode of the model was a gradual decline of the movement over a 100-year period, and this behavior was highly insensitive to changes in movement strategy. MOVEMENT#3 was so unwieldy that I could not discover what caused the decline, or judge whether it was a realistic behavior.

LIFECYCLE#4 (12/15-27, 1972)

Our work was presented and discussed at a meeting of people connected with religious groups, who found the organizing concepts QME and QAE extremely useful in describing and analyzing real-world situations outside the model context. However, our inability to gain any insight from the dynamic behavior of MOVEMENT#3 resulted in new questions about the purpose of the modeling effort. We attempted to sharpen the focus of the study by limiting ourselves to the growth phase of the movement lifecycle. We also constrained the study to movements where members join to obtain some help or service from actors (e.g., a congregation), as
opposed to movements where even members get their main satisfaction from performing the same activities as the actors (e.g., a bridge club, an activist group).

With the complexity of MOVEMENT#3 fresh in our minds we decided to concentrate on the essentials in the simplest way possible. A very simple model was made to show how failure to allocate effort in a way insuring high QME and QAE both in the short and long run will limit the growth of the movement. The strategy formation process was made dynamic, with reallocation determined by crises in satisfaction of members and leaders. The large number of influences on QME in MOVEMENT#3 was replaced by a short-term and a long-term effect on what was now called member satisfaction. Leader satisfaction (formerly QAE) could be increased by effort allocated to that purpose.

The model was completed in a few days, but the runs were not particularly enlightening. In spite of LIFECYCLE#4 being 1/5 the size of MOVEMENT#3, its behavior showed the same bothersome insensitivity to most reasonable parameter changes, and extreme sensitivity to variations in a few others. The model had no richness of behavior; it behaved, essentially, like one positive and one negative loop. I concluded that the similarity was inherent to the basic common structure of both models: a conserved flow of persons from "non-members" via "members" to "leaders" (actors), with rates of flow determined by perceived member satisfaction and by perceived leader satisfaction.
HELPORG#5 (12/28, 1972-2/2, 1973)

We viewed the behavior of LIFECYCLE#4 as unrealistic and decided to attempt a completely different structure. At the same time, the project was made less generic by focusing on small helping organizations (of which we were familiar with three particular examples: the Corporate Information Center of NCC, New Community Projects in Cambridge, and the System Dynamics Group at M.I.T.) rather than on movements in general. In our view, these organizations have in common a desire to serve as many "users" as possible. The desire arises from the basic belief of the organization staff in the validity of its cause. The new model addressed a question similar to the one which implicitly guided our two prior attempts: What can go wrong in a growing organization, obstructing its ability to serve more users?

My thinking concerning the insights gained during the fall, that preferably should be represented in the new model, appears in the following list compiled on December 28, 1972:

"Points I Would Like to Make:

Analytical:

--The QAE, QME way of seeing movements is useful.
--All influences on QME, QAE can be split into long-term and short-term ones, or, in other ways.
--The crisis mode of operation is a useful perspective on movements.
--Strategy as allocation of effort among activities (slower reallocation for larger movements) is a useful description of strategy formation.
--Persons' decisions to join depend on more than QME; they are affected by group visibility, entry cost, motivation to join, counterforce (i.e.,
opposition against the movement).

Dynamic:

--A trade-off exists between long-term and short-term efforts to increase QME and QAE (the tendency in a crisis to overemphasize short-term efforts leading to medium-term collapse).

--Planning for the longest system time constant is desirable, or equivalently, a slower expansion than the maximum possible is desirable, if the goal is long-term movement survival.

--A trade-off exists between quantity of people helped and quality of service (the tendency in a situation of insufficient capacity to overemphasize quantity at the expense of quality).

--A trade-off exists between short delivery delay and high quality of service.

--A very narrow platform (few independent movement qualities attracting members) results in an unstable entity (diversification of services is desirable for the movement's survival).

--Rapid growth may lead to overshoot.

  i) Rapid growth may well occur in a highly specialized movement once its focus becomes popular, but such "faddish" groups also collapse easily. More broadly defined movements are less volatile.

  ii) Rapid intake of many semi-skilled leaders lowers the quality of service and hence the number of users in the longer run.

"First impressions are so important they may determine the fate of a movement."

HELPORG#5 was assembled very quickly. At this time, after four months of full-time effort, I had clear preconceptions about which mechanisms I wanted to include. The model runs did deviate from the earlier ones, but once again the model output did not generate obvious insights. It started to dawn on me that this was due to our having nothing to compare the output with. Consequently we concluded it would be useful to start by modeling one historical example and proceed to the generic model afterwards.
During the month of January no new work was done, but the project was presented and discussed in several fora of people representing social movements, religious groups and voluntary organizations. I gained new knowledge about real world movements, particularly about the strong feeling of devotion to the cause and of community with one's collaborators in such enterprises. There was significant interest in our effort, particularly in the feasibility of viewing a movement as an entity with a lifecycle and, again, in the concepts of QME and QAE. The support helped sustain the interest of the work group in continuing the effort.

CIC#6 (2/3-14, 1973)

In February we began construction of a model intended to reproduce the past history of the Corporate Information Center, chosen as our case study. An auxiliary objective became to help this small, dedicated group plan their further work toward having American churches invest solely in "socially responsible" firms. My impression from a superficial knowledge about the organization was that the CIC demonstrated clear over-extension tendencies, that is, it took on more work than the staff of six people could complete without reduction of quality. I quickly made a simple model reproducing the overextension mode. Subsequent discussions with the CIC director and staff uncovered their belief that overextension was not occurring in CIC and we proceeded to identify other dynamic behaviors actually prevalent in the organization. We had quick successes in making models reproducing the behavior modes once they were identified.
Most of these models centered on the level of enthusiasm and dedication of the group staff.

[Two months later, after the CIC study was discontinued, I was approached by CIC staff who reported that CIC at that time was experiencing a clear overextension crisis. Although I realized that the staff’s perception could well have been biased by its exposure to runs from CIC#6, I viewed the report as corroborating CIC#6.]

MORALE#7 (2/15-21, 1973)

Although CIC#6 behaved realistically and apparently was illuminating to CIC's members, I was displeased by the fact that our study had lost most of its broad sweep. Instead of addressing fundamental processes of societal value change, our study was now directed at very detailed policy issues of relevance to one movement-like organization. In order to increase the generality of our effort, we decided to focus on member enthusiasm and morale, not as one aspect of CIC, but as the characteristic distinguishing all idealistic organizations and movements from, for example, business firms and bureaucracies.

A new question was formulated: What are the determinants of group morale and how can morale be maintained through periods of adversity? We assumed that the group is trying to convert society to the group's point of view, and that success in this enterprise is the major determinant of group morale. Graphs were drawn describing time patterns of group morale; of societal point of view; and point of view espoused by the group, as we expected them to occur under various conditions.
The basic mechanisms thought responsible for these modes were identified and put together in a causal structure (MORALE#7). A major novelty was inclusion of processes causing the change through time of the group's point of view.

Everything went smoothly; my only worry was the preponderance of positive feedback loops in the structure. We developed a fruitful tool, the "commitment-position" graph, where society's and the group's positions regarding the new idea were represented as two points on a one-dimensional axis. The intensity of the parties' commitment to their positions was indicated along a "commitment" axis normal to the "position" axis. Our discussion could be portrayed by plotting the paths of group and society in the resulting two-dimensional space. The graph was highly conducive to thought and the effort became centered around determining the "equations" of motion" for a point in the graph.

On February 20, 1973, the simuland was described in the following terms:

"General overview of group morale-perceived progress model:

"A small group decides to change the position of society on an issue of the type where there is no obvious "truth." The societal awareness about the issue may be high or low, and rigidity of the current beliefs may also vary. The group tries to move society by advertising the value of the espoused group view. People who disagree strongly will change their views less than those who find the group position less deviant. There are limits to how quickly people change
their point of view, and change is slower when people are already conscious aware about their position. The group is seen as a movement attracting members mainly on the basis of the meaningfulness of the group task, and to a smaller extent, on the basis of the enthusiasm of the group. The meaningfulness (as perceived by group members) depends on how deviant the group view is from accepted establishment views. The morale depends on the group's success as perceived by the members themselves and relative to their level of aspirations. The assumption is that it is always possible to change society's point of view, but it may take a very long time if done in the wrong manner, often very much longer than the group is willing to spend.

"The dynamic points to be made:

"Too high aspirations may lead to unnecessary failure in changing society because

i) This may lead to less complete achievement of aspirations than the group can handle, resulting in lowering of goals or in complete withdrawal.

ii) It may lead to attempts at changing society too quickly, thereby increasing resistance to change and reducing possible group achievement."

COMMITMENT#8 (2/22-3/29, 1973)

A presentation of MORALE#7 to the M.I.T. System Dynamics Group led to the conclusion that the scope of the model was still much too narrow to usefully describe the adoption of new ideas. In response I undertook to widen the system boundary to include additional interactions between group and society. The goal was to arrive at a meaningful whole for studying acceptance of ideas. The model size was kept from exploding by increasing the level of aggregation. To insure that the necessary mechanisms were identified and included, highly aggregate, verbal descriptions of the historical adoption of ideas and the fate of the promoting groups were written, speculating on the processes at work in each case.
A growing feeling that the model was again becoming unmanageable was temporarily relieved when I discovered that the involved structure could be described in terms of two organizing concepts in a simple way. The fate of a new idea could be seen as the outcome of an encounter between "group commitment to the espoused behavior (the behavioral correlates of the promoted idea)" and "societal commitment to current societal behavior." The model, in principle, was nothing but a (large) collection of factors influencing the respective commitments. The ultimate computer runs would only show how the most committed sector changes the least.

The multitude of individual relations in the causal diagram were studied in great detail, verbally and in DYNAMO flow diagram form. I felt it was a waste of time to put a less than perfect model on the machine, and spent days on endless speculation about possible omissions or wrong formulations. Mental simulation was used to check whether the structure would be able to encompass the behavior modes described verbally. A large effort was expended to overcome the behavior modes described verbally. A large effort was expended to overcome very detailed formulation problems, which turned out to result from my failing to realize that instantaneous feeling of utility and instantaneous behavior are both rates rather than levels. Other problems arose from inclusion of variables that could be either positive or negative.
I never became fully satisfied with all details, and this kept me from testing the soundness of even the four major assumptions through computer simulation.

A project description written in mid-March included rather detailed descriptions of ten observed time patterns for societal adoption of new ideas. The adoption patterns were originally intended to orient the reader about the scope of topic studied. We gradually decided that whether a model could reproduce the several dynamic behaviors described would be the criterion of a successful model. By late March I was convinced that COMMITMENT's causal structure would pass this test once put on the machine, since it included all of the processes referred to in the verbal description of behavior modes (here reproduced from the third and final draft of the project description, entitled "The Dynamic Interaction Between an Action Group and Society" [Randers April 1973]):

"**Observed Adoption Patterns**

This section describes possible outcomes of the interaction between a pressure group and its target population. I will call each specific dynamic outcome an adoption pattern. Ten generic adoption patterns are described below; in each case the process by which they may arise is discussed and real life examples are given. A general model of directed change must be capable of reproducing the several dynamic behaviors described.

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1. See bottom of next page
"No Adoption

Figure 4 describes the case where there is no perceptible change in societal behavior.\(^2\) This one result may have many different causes.

1. In some of the examples it may be doubtful that the described processes were solely responsible for the historically observed outcome. It is probably impossible to find examples of directed change where no case-specific factors are affecting the adoption pattern; the goal must be to find instances where the special influences are small. My tentative examples are somewhat inadequate in this respect.

2. On the graphs picturing the adoption patterns, it is assumed that the group initiates its advocacy of the new behavior at the left end of the time axis, with an initial goal (the originally espoused behavior) as marked on the vertical axis describing societal behavior. That goal may change through time as a result of the interaction between group and society. The dashed line is included for reference purposes only.
Some are a matter of degrees: too small an effort by the group, too little group authority, too small a relative advantage in the new behavior, too strong a commitment on the part of society to its current behavior. On the other hand, societal perception of the new behavior as counter-utilitarian or overwhelming societal pressure to maintain the status quo may effectively reduce the rate of change to zero.

This pattern of no change is exemplified by the failure of Ford Motor Co. to induce people to buy the Edsel in the late fifties or the lack of success on the part of some senators in making the U.S. Senate adopt the practice of open voting in committee meetings in 1973.

Figure 5 depicts a partial change in societal behavior occurring in response to the promotion of the new behavior. The final stabilization of societal behavior at less than complete adoption of the change originally promoted can occur through many processes. The espoused behavior may only be attractive to a small segment of the target population. The seemingly stable situation may also be the result of a balance between group pressure and conservative opposition. Next, it is possible that a group encountering overwhelming adversity in its attempts at directing change may respond by reducing its goals, i.e., by espousing a behavior more compatible with current societal norms. The observed stable equilibrium may represent the point where slowly changing societal behavior finally coincides with the "lower" espoused behavior. Stabilization at partial adoption may also result if societal gains in utility early in the change process are judged so high that a further change is not dared because of possible reductions in these gains. The observed equilibrium may become self-sustaining even without continuation of group effort, if the group maintains its pressure for a sufficient duration so that society gets used to the new behavior; that is, until the new equilibrium becomes status quo and the opposition gradually ceases.

This pattern of partial change is exemplified by the partial successes of the Esperanto and One World movements after World War II; the partially effective economic blockade of Rhodesia over the last five years; the small but observable increases in student representation
in university decision-making bodies resulting from the student movement in the sixties.

Complete Adoption

\[ \text{Societal behavior} \]

\[ \text{originally espoused behavior} \]

\[ \text{Original societal behavior} \]

\[ \text{Time} \]

Figure 6 depicts the case of complete adoption of the behavior originally espoused by the group. Total conversion may result if the group is sufficiently powerful, influential or coercive. It may occur with virtually no pressure when society perceives the new behavior as highly advantageous. Such "self-propagation" of society towards a new behavior may occur more consistently if positive reinforcement from the change is strong, unambiguous, and immediate. If effects of the change are unobservable in the short run, the group may maintain favorable societal movement by disseminating its own (optimistic) views on the benefits accruing from the ongoing change. Complete conversion may be effected by a small, relatively powerless group, given that the new behavior has no immediate negative consequences. Such a group must have the intense commitment needed to sustain group activity over a long period of painstakingly slow change without lowering its aspirations. The task will become less arduous as the group gains credibility due to a dawning perception in society that it may be "right." Increased group authority magnifies group pressure on society resulting from a constant effort by the group members.

Complete behavior change is exemplified by the general adoption of inoculation against polio originally espoused by a small number of medical people, or the recent adoption of no-fault automobile insurance schemes in some states of the U.S. A final example is the widespread usage of mineral fertilizer in modern Western agriculture, which to a certain degree is a result of the work of agricultural extension workers.
Figure 7 illustrates the over-adoption mode. For a time the new behavior is more widespread than in the final equilibrium. Such temporary overshoot may result if the behavior espoused is uncritically interpreted as the solution to a pressing societal problem. The new behavior is eagerly adopted at face value (e.g., on the basis of group information) until experience later reveals that the new behavior was not the societal cure-all hoped for. Over-adoption may also result if initial adoption occurs quickly, before opposition gets time to organize counterpressure. Later, the increase in such opposition will counterbalance the group's net effect. More subtly, overshoot may result if the group reduces its pressure prematurely, before the new behavior is self-sustaining. Removal of group pressure tips the balance in favor of traditional forces. Finally, over-adoption will result if group credibility is reduced, for instance, through continuous excessive claims concerning the relative advantage of the espoused behavior.

Over-adoption is exemplified by the widespread "free" rearing of children in the years following World War II, the substitution of NTA for polluting detergent phosphates around 1970, and the willingness of the Administration to make decisions compatible with environmentalist's concerns over the last four years. In all of these cases "societal" behavior has reverted somewhat towards traditional behavior due to the disappearance of pressure groups or increased insights about real effects.

The Fad
Figure 8 depicts the fad, where new behavior spreads vigorously during an initial phase only to suffer severe collapse at a later point in time. The fad may occur in a situation of low commitment to current behavior where resistance to change is small. The introduction of any new behavior (assuming it has no obvious, immediate, aversive consequences) is viewed as an improvement - people are excited by the change itself, since it represents deviation from an undesirable past. Excitement associated with the new behavior leads people to press for its further adoption, either by talking others into changing, or by further personal change. Societal "self-propagation" here results in a stronger momentum for change, as does the increased group enthusiasm caused by the current promotional success. Extensive adoption by the target population results. Commitment to the new behavior grows throughout the period of change due to the excitement and novelty of the change itself. However, after a period of widespread adoption, commitment starts diminishing since the "new" behavior has become a familiar and monotonous pattern and novelty was its key appeal. Consequent reduction in self-propagation pressure and in group pressure (because lack of progress causes enthusiasm to wane) soon leads to a return to traditional behavior, which is again viewed as the most attractive alternative. Another possibility is the occurrence of a new fad catching society's attention.

Such "change for the sake of change" is exemplified by the hula-hoop mania in the fifties, and by any type of temporary craze in behavior: in anything from dancing style to agricultural practices. Possibly the recent introduction of "new math" in U.S. schools also belongs to this category. It is characteristic that the relative advantage of the new behavior is close to zero; society is not significantly better off (as judged in retrospect by its members) one way or the other.

Temporary Adoption

Temporary adoption (Figure 9) occurs when the perceived utility of the new behavior is high for a period of time before it diminishes. The rise and fall of perceived utility may be solely due to psychological factors connected with novelty and boredom. This is the fad discussed.

![Fig. 9](image-url)
above. Here I discuss the case where society's perception of the utility of a new behavior varies due to other causes. First, there may be objective differences between the short term and long term consequences of a given behavior. Second, perceived utility may change when more information about the situation is diffused in the population.

The detailed processes of the temporary adoption mode are fascinating. They describe how a behavior, which ultimately is judged by society to have low utility, becomes adopted in the first place. The detailed processes also explain how a behavior, which is deemed to have high utility by the adopters, is rejected after a period of partial adoption. Naturally, such results can be obtained through coercion, but I will concentrate on the more interesting cases where brute force is not employed.

The two cases are discussed in detail below. In both cases it appears that the temporary adoption occurs because society is unable to judge the utility of the new behavior immediately. This is of course the normal situation; it is impossible to know beforehand whether a change to revenue sharing or light whiskey is a good idea.

Society will reject a new behavior when it is no longer perceived as useful compared to an alternative. The initial temporary adoption of that new behavior may be a result of high group authority and miniscule societal awareness. Low awareness means that independent societal knowledge about the relevant issues is low. Consequently, popular opinion is essentially formed by the information and interpretations emanating from the group. Thus society will tend to agree that change is a good idea. Assume now that as time progresses, undesirable consequences of the partially implemented new behavior start appearing. At that time the group may be heavily committed to the espoused behavior due to the large effort it has spent promoting it. Typically, a tendency to bias the signals from the real world will result; the group will interpret an indisputably undesirable situation as an indication of insufficient implementation of the espoused behavior. Thus the group keeps pushing for adoption. Nevertheless, the ongoing group effort for change inevitably has the effect of increasing societal awareness about the issues involved, as people start obtaining independent information and start looking into alternatives to the espoused behavior. Society soon (unless the group actively opposes the process of growing awareness) has a more realistic picture of what is going on than the strongly committed and biased group. Society perceives declining utility and starts resisting group pressure; resistance becomes stronger with time as it becomes clearer that the espoused behavior is undesirable. Opposition slowly breaks down group morale until the group commitment is so lessened that the overall group goals are reduced. The group loses its more dedicated members. The level of general commitment falls even further. Finally, the group effort falls to zero. The societal excursion into an undesirable behavior pattern is over.

The above adoption pattern is exemplified by the temporary adoption of a "military solution" as the appropriate behavior of the U.S. in Indo-China over the last decade. McCarthyism in the fifties and the temperance movement in the twenties also serve as examples. The current extensive use of synthetic substances, in the form of pills or additives
to food, to achieve any type of purpose, may be another example of temporary adoption.

"There is another mode in which a behavior perceived as utilitarian by the adopters is rejected by society at large after a period of partial adoption. This mode typically results when it is difficult to observe the advantageous consequences of the new behavior, that is, when benefits stemming from altered behavior only become apparent and observable after some period of time. Under such conditions the group will not be assisted by societal self-propagation pressure tending to move society towards higher perceived self-interest. There may, in fact, be active opposition against the change if society is strongly committed to its current (sub-optimal) behavior. The group must rely solely on its own effort, and will succeed only if it can sustain its pressure long enough so that claimed advantages are perceived by society. This endurance strategy may easily overtax the dedication of group members and induce them to lower their goal (stop espousing the new behavior). Such frustration and consequent discontinuation of effort may happen faster if group aspirations are initially high concerning its ability to induce rapid societal change.

"Examples of this adoption pattern are hard to give, since it requires me to judge whether a behavior that was never adopted would have increased societal utility if implemented. I would suggest that the Civil Rights movement in the sixties promoted utility-increasing behavior that would have been recognized as such, if adopted; and that frustration effectively reduced the intensity of the movement.

"Cyclical Adoption

![Image of cyclical adoption graph]

Figure 10 depicts a pattern where the societal behavior oscillates between two extremes. Such cyclical adoption can result in at least two ways.

"First, "cyclical frustration-crisis" may occur in the promoting group. Societal adoption varies due to oscillating enthusiasm and effort on the part of the group. If the group expects to change society much faster than its capabilities allow - if group aspirations are too high - the accomplished rate of change will be viewed as unsatisfactory. Unless the aspirations
are lowered quickly enough, the continued perceived inferior performance will eventually induce an intolerable stress on the group. In other words, the group becomes frustrated because perceived adversity overwhelms commitment to the cause. The result, particularly when the group and its purpose are not firmly established or institutionalized, may be a reduction in group enthusiasm, effort and aspirations. With lowered ambitions slow societal change may seem less intolerable, and the resulting period of relative lack of adversity may boost the group's self-confidence to the point where ambitions are again raised above what is realistically feasible, laying the groundwork for a new period of frustration. The next cycle may well have to wait until the past is forgotten through renewal of the group membership. The cyclical tendency may be enhanced by changing societal awareness and consequent self-propagation resulting from varying group effort. The periods of intense student unrest that seem to recur cyclically may be symptomatic of such oscillatory behavior.

A second cyclical mode may be caused by societal oscillation between two equally attractive behaviors. Initially the promoting group successfully implements one of the behaviors in society. Having completed its task, the group effectively dissolves (e.g., by allocating its time to other activities). With time, society experiences desirable and undesirable aspects of the current behavior. As usual, undesirable consequences get most attention and the alternative behavior becomes increasingly attractive. Finally, the commitment to current behavior falls sufficiently low such that there is a tentative change back towards the alternative. The change is quickly amplified through the excitement of the change experience itself. The (uncommitted) promoting group will find it rewarding to promote the alternative behavior under such conditions and will revive itself and thus reinforce the trend. However, after a period of complete adoption of the alternative behavior, and practical contact with its less desirable aspects, the original behavior will again appear more desirable, and the cycle starts again.

Some examples of this behavior mode are the cyclical emphases on decentralization and centralization that seem to occur in organizations and the perpetual change in the length of women's dresses and the width of men's trouser legs.

Co-optation

![Figure 11](image-url)
"Figure 11 describes the adoption pattern which I will call co-optation. This stepwise pattern may occur when group goals always exceed societal behavior, and society yields to group pressure little by little. Although society yields here when the group pressure is sufficiently strong, the resulting change is not sustained, because strong, active opposition is induced by the change. Opposition comes both from organized counterpressure in favor of the status quo and from society at large (the self-propogation pressure). The next step change occurs when society has grown accustomed to the new behavior and the opposition no longer overwhelms the group's pressure for further change. A period of rapid change boosts rapid commitment and effort during that phase. However, accomplishment will also tend to increase the aspiration level of the group. Conflict between heightened ambitions and much reduced change-rate in the subsequent period of active opposition against change may well appear to the group as "repression." The result may be a temporary waning of group effort and enthusiasm which eliminates the gains made during the period of successful change. The overall goal is usually not affected in these cases; what varies is the group effort toward achieving that goal. In fact, the overall goals may continuously be heightened as the group succeeds little by little.

"The co-optation process is exemplified by the interaction between any continuing radical pressure group and established society (e.g., the Environmental Defense Fund or Cesar Chavez' grapepickers' union). On a longer time horizon it describes the way in which the labor parties in Norway have moved that country toward social democracy against the stop-and-go opposition of the conservatives."

Having decided to view a model as successful if it reproduced the above adoption patterns, another question arose: Why is it useful to have a structure capable of reproducing the described modes? From the perspective of final use, COMMITMENT#8 came to look suspiciously like a description for the sake of description, not complying with the desire that models shall be of use to some real-world decision maker. This shortcoming, coupled with my enduring inability to arrive at a structure that was reasonable in all detail, made me discontinue work on COMMITMENT#8. The decision was made to pursue a similar model, but one which would be more directly applicable for a decision maker

wanting to know the likely adoption pattern for an idea, when given its
relevant characteristics and those of the promoting group and society.
Such a model could be useful in deciding whether to promote an idea at
a given point in time.

ATTRACTIVENESS#9  (3/30-4/17, 1973)

The characteristics of group, idea, and societal conditions
were not clearly visible in the causal diagram representation of
COMMITMENT#8. The new model was to contain them explicitly, and otherwise
retain the essential dynamic processes from COMMITMENT#8. The modeling
started from a list of descriptors similar to the following (Randers
April 1973):

Descriptors of group:
Descriptors of society (target population):
Descriptors of idea (cause):

Credibility
Authority
Level of Expectations
Enthusiasm
Effort
Extrovertedness
Perserverance
Concern
Inertia
Acceptance
Adoption
Active Resistance
Experienced Satisfaction
Utility over time
(as judged by adopters)
Observability
Understandability
Compatibility
Complexity of Implementation

Some descriptors were chosen to be levels; others, parameters and slopes
of table functions. The levels were drawn on paper, their rates added and
linked to the levels assumed to determine them. Very rapid progress was
made toward a complete DYNAMO flow diagram.
However, we could not fit in some variables that seemed necessary for generation of certain adoption patterns (for instance, inertia, the difference between long-term and short-term effects of adoption, and experienced satisfaction). When the problems resisted fourteen days of full-time attack, I decided that the overall point of view in ATTRACTIVENESS\#9 was deficient in some unknown way. I also suspected that I lacked sufficient understanding of the general processes modeled.

ADOPTION\#10 (4/18-21, 1973)

The difficulties had been discussed extensively with the author's colleagues in the M.I.T. System Dynamics Group throughout the spring, with the result that everyone viewed the problem from the same perspective and was equally incapable of resolving the difficulties with ATTRACTIVENESS\#9. It was felt that it was necessary to get assistance from someone who had not yet internalized the approach embodied in ATTRACTIVENESS\#9.

An outside group of system dynamicists made a causal diagram and sketched a flow diagram (ADOPTION\#10) solely on the basis of the ten adoption patterns described above. The result was a model very similar to ATTRACTIVENESS\#9 and COMMITMENT\#8, except that some simplifying assumptions were made. The simplifications made the model unable to generate some of the ten patterns, but it was argued that additional structure could be added, once the basic model was running.. I completed the model and chose a parametrization intended to represent the
prohibition period in the U.S. of the twenties. ADOPTION\#10 was our first running model since CIC\#6 ran two months earlier, but we still remembered the utility of parametrizing the structure for one historical case. In trying to adjust the model to fit historical data it became clear that even the ten loops of the simple ADOPTION\#10 model exceeded my intuitive grasp; simplification was unavoidable if I wanted to be in control.


An extremely simple model was made which included only the most fundamental and stable relationships involved in the previous three models. Since I specifically intended the model to describe the adoption and repeal of nationwide prohibition between 1919 and 1932, this was the seemed important for that case. A parametrization was chosen to quantitatively approximate historical descriptions of the period. The historical pattern was easily reproduced, increasing my confidence in the model.

Further corroboration was accidentally obtained as follows: The model generated prohibitions periodically, with a period of about 30 years. As I was trying to find the "mistakes" in the model responsible for this "anomalous" behavior, further reading on the history of prohibition revealed that the 1919-32 prohibition was actually the third in a series of "prohibition-waves" (Sinclair 1963). Thus the phenomenon first observed in PROHIBITION\#11 apparently was a real-life character-
istic. The discovery intensified the belief that PROHIBITION#11 was a useful basis for further improvement.

NEWIDEA#12

I proceeded by adding a few additional mechanisms to the basic structure, representing real-world processes considered absolutely essential for describing the stabilization of new ideas. In addition to internalization and institutionalization, a more detailed description of group enthusiasm was added. The extensions were made directly in the DYNAMO diagram of PROHIBITION#11, thereby creating NEWIDEA#12, capable of producing more varied dynamic behavior.

I decided to focus on one of the possible modes: fadlike acceptance and rejection of an idea whose growing attractiveness only reaches sustainable levels later on. The model was adjusted to produce the fad, and policies were tested that might conceivably have been tried by a group promoting the idea and wanting to avoid the collapse phase of the fad. The model and runs are discussed extensively in Chapter V.
A Subjective Account of the Modeling Process:
A Diary

This section presents a diary written by the author during the project period. The diary was originally intended to record selected lessons from the work group meetings that might prove useful in future work of the same type. The diary quickly developed into a subjective account, usually recorded once a week, of the study's progress.

To minimize distortion of the information contained in the diary, editorial changes have been made only where necessary to make the entries meaningful to the reader. Thus the language is quite rough, the diary being recorded originally for the author's own use. To avoid ambiguity the term "work group" is used consistently when referring to the author's collaborators. The term "group" refers to the topic under study: the movement or action group promoting an idea.

The sequence "3. meeting (9/12/73, MPFJHE)" identifies a work group meeting as the third in the series, taking place on 9/12/73 with Neil Douglas (N), Poikail George (P), Frank White (F), John Biersdorf (J), Herbert Dordick (H) and Everett Perry (E), present in addition to the author. (See footnote on page 69 for details on group members.) A total of 19 work group meetings were held representing 310 man-hours.
The Diary

1. meeting (8/25/72, NPFH) Everyone excited about opportunity to speculate freely. They also found it useful. Some initial trouble with meaning of words, they were not used to the system dynamics tendency to aggregate many phenomena into a comprehensive, loose term. High spirits; they wanted to go on. I kept back and did not show what I had already done, in order not to force them to see things my way.

2. meeting (8/30/72, NPFH and guest) Somewhat less excitement when we did not reach some result after 2 hours. I then showed my latest causal diagram, and they did not become too snowed and rigid and agreeing with my thoughts simply because they had seen the diagram. Discussion and interest picked up appreciably.

3. meeting (9/12/72, NPFJ) Some friction because I and Jack tried to make the whole thing more goal conscious - less freewheeling. This was obviously too early and opposition resulted. A few basic decisions were made about type of model, boundary etc.- which could not have been made until after the participants had some feeling about how a system dynamicist approaches a problem.

9/13, 1972 Presented the causal loop diagram to the American Baptist Home Mission Society's annual planning meeting in Valley Forge, Penna. after having had the 100 people try making their own diagrams about what causes acceptance of ideas.

4. meeting (9/17/72, NPJ) Given the new goal, centering on a group promoting an idea, the discussion went smoothly with much new insight. The concretizing to a model of behavior change occurred - probably because participants have started to operationalize abstract concepts in the way system dynamicists do. Free hypothesizing is again working - because all accept that we can control/evaluate model afterwards.

Informal discussion with System Dynamics Group in Dartmouth 9/17/72 after weekend in Vermont clarified group processes related to motivation and cohesion.
5. meeting (9/19/72, NPFJ) I had made breakthrough in describing causal relations in a group. Used most of time to explain it and get praise - until they all discovered that the goal formation process was lacking. We struggled hard with that for a while without apparent progress. However, although I was not happy with the help the group gave at the time, the notes and the discussion was of great importance in the breakthrough in modeling goal formation the next day. The causal diagram did boost work group morale some.

9/20-21, 1972 Informal discussions with Bill Behrens and John Miller (of MIT SD group) helped me not getting stuck in blind alley. It is very useful to talk with someone else when one is stuck, rather than keep banging one's head against the wall.

6. meeting (9/22/72, HNF) My progress over last days, mainly in describing goal formation process, was much too large and all of meeting was used to explain what I had done. This is useful in that it forces me to retrace and verbalize my thinking. I also discover what is difficult for others to understand, and often work group questions point to omissions or illogical conclusions. Not much useful output from them today, except in cooking up long lists of different aspects which I have to aggregate. This reduces chance of omission.

7. meeting (9/25/72, NP) I brought relatively complete causal diagrams of the group-, goal formation-, and society- sectors of the model. That helped the discussion a lot, because now every idea they think of ought to be somewhere in the model. Present mode of operation: they think of a real-life process, I try to explain it in terms of the causal loops already in model. By now the work group members have become accustom to inclusive use of vague words and to utility in looking for feedback loops. Some have even started wondering about the dynamic consequences of the assumptions we make. I think it was very useful to get a complete causal structure so they can see the system boundary and more or less where we are going.

8. meeting (9/28/72, JP) Everyone was tired, not much results. Poikail is still very excited after last meeting, where he discovered model could be used to describe revolutions. Jack seems to think we need more psychological variables. Never have meeting after 3 p.m.; conceptualization is much too hard work. It is very useful to have to explain many times what I have done, hopefully it will simplify writing the final report.
9. meeting (10/3/72, NPJ) I had tried the first "formal" presentation in hope of getting from problem statement, angle of attack to causal diagram. Did not work because we got hung up in semantics and real lack of understanding of goal setting process. I got impatient, they got offended - I learned a lot about how to present things, particularly that it is important to show people explicitly how a practical policy can be simulated in the model by changing some set of parameters when the policy variables do not occur explicitly. General lesson: important to define terms very explicitly (in fact the work group ought to have a written list of definitions), to tell what each causal link is supposed to represent (again a list should be prepared), and most of all to make everyone have the same perspective on and understanding of the question addressed and why it is important. Verbal confusion (semantics) will arise. It would have been useful for work group to know a little more about system dynamics. (They know nothing and I'll give them my paper on solid waste.) But basic problem again was that I did not get substantial help from meeting, only practice in presentation.

10/3-10, 1972 It became clear to me that it is unrealistic to expect to develop a meaningful model in a couple of months, and I decided to stop pressing for finishing by Christmas. Conceptualization of models obviously takes time! It was relieving to release the pressure of urgency, since my tense stressed condition as of late has made it difficult to behave sufficiently relaxed at the work group meetings to avoid counterproductive irritation of its members by me being too pushy and impatient. The decision to slow down occurred simultaneously with (because of?) confusion about what the goal of the study is. The first Special Projects Group (in the MIT SD group) meeting made me doubt the utility to anyone of the question I was addressing. Certain flaws in my description of the effort allocation mechanism was what started it all. Read The Life Cycle of Economic Development (Forrester, N.B. 1972), A Model of Corporate Growth (Forrester 1962), "A Cybernetic Model of Human Change and Growth" (Kolb 1971) and Industrial Dynamics (Forrester 1961) to get some guidance - giving in on my initial desire not to read others' work until after my model was completed. Found nothing of use, but realized that the structure of my current model is just like the Corporate Growth model. (I told Forrester "I had reinvented the wheel" - he did not think that it mattered.) I also decided it is more realistic to assume that an individual's behavior is guided by an operational goal, equal to a weighted sum of a fixed goal and the individual's traditional performance, than by marginal utility considerations. I evolved towards believing the question, "What distinguishes a movement from a stable, non-expansionist group?" might be useful to study.
10. meeting (10/10/72, NPHJ) Presented the "lifecycle of a movement" thought in an unclear way - because it was not yet clear in my own mind. They accepted it. We then talked a lot about goals and about characteristics of movements without getting anywhere. We discussed what leaders look at to decide whether a crisis is developing somewhere in the organization. Decided that we should concentrate on a myth-making group giving power and meaning to its members (religious or political movements). It is helpful to get the topic of study narrowed down.

10/11-29, 1972 At Special Projects Group meeting 10/11/72 I drew the first causal diagram indicating the positive growth loop of the movement - including size and ability to attract additional staff as major elements - as the essential loop. The lifecycle idea became more concrete. In Norway for 10 days. The following week I discovered the importance of QME and QSE (the quality of member and staff experiences) and progressed enormously. It is amazing how useful good concepts can be for one's thinking! The crisis mode of leadership became a concrete assumption (i.e., equalization of pressures in different parts of the movement as the guideline for allocation of effort).

11. meeting (10/29/72, NPFHJE) I presented the new model (2 1/2 hours) with success. First feeling that we are onto something good. For the first time everyone was on top of the current model and able to make constructive suggestions about new things to include - or to understand why I did not think they ought to be included. Long meetings are useful since one can both present current model and get criticism, but tiring. Some discussion about proper variable names. We also thought of the idea of having many people draw table functions and management strategy curves (i.e., the relations defining the leaders' response to varying crises) for a movement they know. (The notes from earlier meetings are really useful reading when I am stuck, need a new perspective on things, or when I want to know whether I have forgotten anything.

10/29 - 11/9, 1972 I wrote the first description (40 pp.) of the current stage of the movement model. Although a pain, writing is useful. It clarified several things to me; it also resulted in many good variable names. Talked to Morrison and Forrester who thought the document was interesting. Presented the project to some of the study sponsors in one hour with success. What I've got now seems to fit naturally into people's conceptions.

12. meeting 11/10/72, NFJE) The work group accepted my way of describing a movement's potential deviation form the original cause as useful and sufficient. They all now see that this is just a model that is useful, not true, and can be parametrized to represent the real-world situation of interest. We discussed what specific case to choose as our application of the model. Useful discussion
-111-

about choice of names for the axes in the strategy graphs. I have learned
that proper choice of variable names is infinitely more important than I
ever recognized, in fact, it determines whether people will understand
what the model is talking about.

11/12-20, 1972 I started making a DYNAMO flow diagram of the model and
slowly came to realize the fantastic fact that the model can be paramet-
ized simply by choosing a reference point, drawing dimensionless table
functions relating variables measured in terms of their reference values,
and choosing some time constants! Eliminates need for absolute units of
measure and complicated assessment of numerical values. I presented the
project to the sponsors in the National Council (11/20/72 20 min. - 3 hours).
I had them draw some table functions and found it a feasible way of obtaining
parameters - as long as those drawing know exactly how the variables are
defined and think about the same movement. Lots of positive comments
about the work. Some problems with variable names - they had diffi-
culties getting used to my including in "members" - people who behave
according to the movement norm although not formal members of the move-
ment.

12/2-12, 1972 I worked nights and slept during days and got a very compli-
cated model (MOVEMENT #3) running on the machine in five days. Concluded
that its dynamic behavior was not worth its complexity (close to that of the
Urban Dynamics model). At the planning meeting of INSEARCH in Chicago
12/9/72 I decided to drop the end of January as deadline for finishing, and
quite relieved I started on a simpler model that is only going to make some
few points. Participation and communication problem in movements are
central to my thinking now, as is the difference between short-term and long-
term efforts on member satisfaction. I am turned off by complicated models,
it is going to be simpler ones from now on.

12/12-20, 1972 Made LIFECYCLE #4, which shows the tradeoffs between allocat-
ing effort to satisfying members or leaders, in the short or the long run.
The model was a semidisappointment, because it did not behave in an interesting
and reasonable way, but I was incredibly happy having suddenly discovered
(by help of Forrester's Corporate Growth model overview) the utility of split-
ing all effects on QAE and QME into short-term and long-term effects. That
makes for simplification and insight.

13. meeting (12/20/72, NJ) In New York it became clear that Jack and Neil
want the study continued beyond the end of the first proposal period next
June. Neil wanted us to spend the spring making a specific study of the
Corporate Information Center. I was initially unhappy about both ideas - but changed my mind over a couple of days when realizing that CIC is like a possible system dynamics group in Norway (and hence a useful group to spend time on) and that Dale Runge (of the MIT SD group) might be interested in taking over the project (and keeping in touch with me) when I leave in January 1974.

12/20-31, 1972 I made a model of the major staff and service provision processes in a typical helping organization. Starting with this more concrete project is relieving, things go much quicker and ideas start to appear in my mind again. I decided that we ought to model the lifecycle of three specific movements and perhaps then proceed to a general model. I chose a future Norwegian system dynamics group, New Community Projects (a counterculture service organization), and the Corporate Information Center in NCC. I think I learned from this whole frustrating fall

i) one must have a very concrete question to answer (in fact even a clear picture of the dynamic behavior the model should generate, if one wants rapid progress).

ii) one should always think in terms of a specific case because otherwise whenever one thinks A→B, one can also think of another special case where A⇒B. Inability to choose among the two reduces progress.

iii) one has to start with a small model and then add things as one learns to understand the behavior of the earlier parts.

1/3-7, 1973 At the INSEARCH conference I presented some ideas on the negative forces that can stop the growth of a movement, and the presentation was received with great interest. Very interesting to talk to people involved in all types of movements (Jesus movement, Pentecostals, the mature, major bureaucratic major denominations, inner city helping organizations, etc.) with my own model in the back of my mind. Amazingly the extensive contact with all these people who "believe" over the last months has made me conclude that human peak experiences are a reality, maybe important. I doubt they can be modeled.

1/7-30, 1973 I lectured all over the U.S. about Limits, being very frustrated about the situation of the current project. I feel we have come nowhere. It seems that we have talked about everything, but not been able to collect it
all in a model. I did not read much during the month, but something, enough to tell me there is little help in the literature. It has finally begun to dawn on me that the problem is that we have never decided on a very specific question, posed clearly and put together with the expected answer. We have essentially tried to make a model of a movement, rather than modeling (to explain) a specific phenomenon connected with movements.

14. **meeting (2/6/73, JNFE)** Finally I went to N.Y. — after having suddenly realized how much more productive I am when subject to frequent criticism. It was several months since last subject meeting. To concretize the project even more, I made a model of simple overcommitment of resources (which I believe is a characteristic of CIC) — the first successful model in this project. It ran quickly and showed what I expected it to show. CIC was excited to have themselves modeled and promised help. I talked to Frank White (director of the six-man CIC) and he brought up at least two interesting dynamic processes: (1) the periodic motivational crises in CIC solved by a day of staff discussion of their goals (2) the expansion of the staff occurring only after long periods of incredible overload, with the result that the new staff was surprisingly able to cover its own costs. People were happy about the idea of making a specific model of CIC and about trying then to generalize. I feel good about having a firm, concrete, experiential basis for my model.

2/7-16, 1973 I made models of (1) and (2) above, only to become aware that the broad original question of value change is now narrowed down to purely organizational aspects of one specific movement. Also I can see no clear reason for why I should consider (3) and (4). I dislike the extent of restriction of topic and have started to wonder about study topic and purpose again. One serious problem in trying to define a problem in "client-less" tasks like this one is that the work group has no ability to see what is a fruitful problem to attack with system dynamics. That decision is left to the project leader himself. The choice is particularly difficult now, since I need a problem which is: do-able in 3 months, interesting from a system dynamics point of view, interesting to the sponsor, and includes most of the interesting thoughts we have come up with during project (e.g., QAE, QME, the allocation of effort).

15. **meeting (2/16/73, JNFE)** I suddenly solved the problem when it dawned on me that we should leave organizational aspects and study what distinguishes a movement from any other organization — namely member dedication. I now see the movement-specific problem of interest to be the dynamic interaction between perceived group progress and group morale. The idea might have come from reading "System Simulation of Program-Patient Interaction" (Kligler et. al. 1972) and reinforcement came from Frank White who had many things to say about dedication and morale in NCC.
2/17-20, 1973  It went well - after some struggle - to model the new system, even though I do not yet have a real hypothesis. But I do have clearer thoughts ("it may be that insufficient perseverance is what: causes lack of success") about what the model should show, and also the system is smaller. I plan to make other small models to study other interesting phenomena.

16. meeting (2/20/73, JNHE) They liked the causal diagram for the interaction of group morale and group progress and especially the awareness/position graph which Lennart (of the MIT SD group) and I had developed. Herb Dordick was all for making a relatively simple model this time - he found it interesting that "even I" had made the mistake last fall of making a model as complex, and incomprehensible, as reality. The others still tended a little toward believing that the model would have to be quite complicated in order to be useful - "there are so many processes at work!".

2/21/73 I presented to Forrester my plans about writing a Ph.D. thesis containing three models: one describing the external forces acting to constrain the growth of a movement, one describing the internal forces and one detailed model of the morale/progress interaction. He rejected the plans completely, considering the models too reductionist, calling for a general model of how some ideas in the "rain of new ideas" become accepted - even when they are "bad." He thus pushed me up on a higher level of aggregation; a "10 level, 14 days model" of the general filtering of new ideas by society or any other social group is to be the goal. Forrester thinks purpose of a model is to develop "better policies," in which he seems to include "obtain better understanding." He thinks verbal description of the lifecycles of ten real ideas (military solution of Vietnam problem, a low-ranking manager's idea concerning a new product, student disgust with establishment, etc.) will be useful.

2/21-26, 1973 I felt depressed about starting from scratch again. But it turned out that I can use much of the earlier insights. Discussions with Lennart and Bill (of the MIT SD group) and day-and-night hard work resulted in a really interesting model, possibly capable of satisfying my four (!) clients: myself, Forrester, the study sponsors, and the Ph.D. committee. Not unlikely that is quite stupid to have that many people to satisfy with one product.

2/27/73 Saw Rosabeth Kanter for an hour or so with INSEARCH staff and three hours on NYC-Boston plane. She turns out to have documented
my own speculations on commitment – different types and effects – in her book *Commitment and Community*. It is interesting that intuitive reasoning using system dynamics tools made it possible for me to create in a few days the same structure that she synthesized over several years by reading six million books and documents. The reason must be that in system dynamics one is forced to be consistent and complete. We always ask about the cause of everything and require that the answer shall lie within the system boundary. We do not get away with saying that "the determinants lie outside the scope of this study."

2/27-3/6, 1973 Made progress on a model of the commitments of group and society, the resulting actions and the interaction between the two parties. It was real fun when one day the group commitment representation, that had formerly been a mess with the same concepts appearing at several places in the same model, finally came together in a simple, sufficiently aggregated structure. I really feel I have a starting point now, seeing the filtering of new ideas as a struggle between two parties – having different biases on and perceptions of reality. The Special Projects Group was helpful in revising the awareness/behavior diagram. It did have flaws! Best of all: Forrester liked what I had done in the allocated two weeks and said go ahead (on Friday March 1). But then it all stagnated. I have become bogged down in trying to represent social utility, planning horizon, overall societal satisfaction, reinforcement etc. Unlike the commitment sector, these areas do not crystallize. I am really fumbling around. I discuss much with Bill and Lennart (of the MIT SD group), it seems to help, although not at the moment. The insights appear afterwards.

18. meeting (3/7/73, JNE) Presentation of "commitment/behavior" diagram and of what relative advantage means in terms of the relative "predicted utility x risk" for two alternatives, without any insights being added by that. Amazingly enough the workgroup is not completely exhausted yet, although we have been beating around the bush for six months. They realize that we are attacking a complex and very diffuse problem. There also exist psychological pressures on them to maintain belief in the project: they have spent a lot of time on it!

3/7-16, 1973 The last half a year has taught me much about model conceptualization. I can now solve other's modeling problems relatively easily (Kjell's [of MIT SD group] transportation-model, the model of our Norwegian group). Through a sudden realization of what "natural" levels are (a "natural" level is directly observable while its time derivate is unobservable and its integral over time does not have a clear intuitive meaning) I made a step forward in understanding utility: only the integral over time of perceived utility is observable. The discovery boosted my spirits, I am otherwise quite tired and bored of the whole
thing now. Interesting how a written diagram fixes thinking so it becomes
difficult to view a problem from other perspectives. One needs external
inputs to keep flexible. I do tend to spend enormous amount of time
trying to include detailed real-life phenomena (e.g., details in authority,
short-term vs. long-term effects of adoption) at a point where the overall
structure is still fluid. This is ok and gives much peace of mind per
hour of work if it can be done by changing the form of a table function,
but I think it is better to simply write down the detailed effects and
return to them later while proceeding with the essentials at a higher
level of aggregation until satisfied. But on the other hand pursuing
apparent problems with the model is the only way to improve it. I wrote
a 56 pp. proposal - useful since I had to describe possible system modes
and hypothesize about the causes of the modes I developed. Very useful
to think out an overall perspective - this time "commitments in conflict."
Amazing that finding the overall perspective comes late in the modeling
process (like the QAE, QME concepts last fall). Clearly an iterative process
is at work. Forced presentations are useful. Bothersome that I am not yet
able to answer people's question: What is your thesis about? My tentative
answers along the lines of "new ideas, movements, groups, societal behavior"
does make me feel I do not know what I am doing. I wish there were a few
words that accurately described the topic.

19. meeting (3/16/73, NJF) Talked generally about whether people like
or oppose change and why (with special case: that the U.S. lower class
probably does not do anything because TV keeps them quiet and with access to
sensation). Not very useful, but the work group has become very good at
and fond of rambling, highly speculative discussions over the last months.

3/17-24, 1973 Got back criticism of proposal saying it was badly organized and
that it is impossible to understand what I want to do, how, and why. Use-
ful to get feedback, so one does not freeze into accepting one's first
written draft. I scanned books more or less at random (in the general area
of movements and mathematical models) over the last two days. One insight:
what I want to do is obviously to study what is treated under the headings
"planned or directed change" in the literature. That made it possible to
invent a purpose for the study and to define more clearly what I want
to study. I rewrote and rewrote the proposal without much productivity.
I have started to think that the difficulty in explaining general insights,
feedback phenomena, dynamic behavior modes and simultaneous occurrences
in ordinary sequential language may ultimately hamper the development
and acceptance of system dynamics. (cfr. Perelman sensing a need for
his thesis that simply tries to get kids accustomed to systems thinking
and language). Fortunately The Special Projects Group members appear
interested in helping me; probably they realize that the model is un-
finished, that their advice is being needed and that our study apparently
is the first conceptualization not done by Roberts or Forrester. Had
difficulties in trying to change the formulation so that model
rates rely more on information that is actually available to the decision-maker being modeled. Found it useful to describe a specific case verbally and try to generalize on the basis of that one case, finally testing if the generalization worked in other cases also.

3/25-31, 1973 Rewrote the proposal. It is very useful to have to express one's thoughts in writing; they do become clearer in every draft. Hence it is not wasted time to write, although a horrible strain. Discovered that my problem is that I cannot find a formally acceptable reason why I am doing a study of the interaction between a group and society. My personal reasons are clear: I want to know the overall structure of the system that generates the observed behavior modes. But Forrester and system dynamics "ethics" appear to say that a study must be "useful". The new introduction I have toileted with for the last 6 days at least tells me what it is that I do. That realization arose from browsing in the literature on planned change and from an attempt at proving how useful the work will be. The two inputs made clear that the study focus ought to be guidelines for an action group's strategy, but the purpose is still artificial. Nathan (of the MIT SD group) discovered what is funny: the adoption modes I try to reproduce are situation-determined (determined by the given characteristics of the idea, group, and society) rather than group policy-determined (the system does not change from one mode to another simply through a change in group decision rules). Thus it seems that the model is not especially interesting for obtaining policy insights. I got depressed but Forrester said i) model is still useful since it indicates which ideas to back, and ii) it is unlikely that the parameters are completely situation-determined - they'll be indirectly affected by policy. Also he said I should use the "level" approach to modeling rather than causal diagrams. Nathan and I tried to model by i) list descriptors ii) put up levels iii) inter-relate levels and rates. It worked much better than drawing causal diagrams, but probably only because I have thought so much about the dynamics of the system before. Conclusion: with simple (e.g. two-level) models of one dynamic phenomenon, causal loops may be a good beginning; for a bigger model the "levels first" approach is better, but only if you know the system. After a 15 hour marathon toward a simple model, we bogged down. But the new outlook and experience made it simpler to rewrite the proposal - it helps to know what one wants to say! Now I concentrate on the dynamic interaction between an action group and society.

4/1-7, 1973 Informal thesis proposal seminar with Kolb and Forrester brought out the "value of idea" versus absolute and relative time as interesting concepts. Implicit agreement that the proposal was acceptable. In talking with Dale Runge (of the MIT SD group) on our several trips to NCC to set up next year's project, I came to verbalize and believe in the following insights:
i) Model formulation should proceed from causal loop diagramming to the "levels first" approach before the causal loop diagram is perfect—the role of the diagram is just to increase awareness about essential structure.

ii) Levels should be independent, exhaustive, not instantaneously changeable, and commonly used descriptors of the system.

iii) The elegant, wide stroke way of modeling is better than the rigid accounting way I have used, that is: avoid "DYNAMO models" of the brute force type. For example, my solid waste model is of the brute force category in that pollution comes flowing directly from natural resources and its origins are specified in detail. The contrast is the World model where pollution and natural resources are independent levels, for each of which one asks: what are the important determinants?

iv) Think in terms of "pressures" when formulating rates.

v) Social science concepts should be defined sharply but that is not the same as narrowly. Look for inclusive concepts that simplify talking about a system.

vi) Variable names in system dynamics models should be general (e.g., "pollution"). One can later show how they actually represent a specific variable in a specific case. (e.g., "SO₂ content")

vii) The behavior of my model depends more on situational parameters than on policy parameters. Usually in system dynamics studies one chooses one behavior mode by defining the situational parameters. Then one studies the effect of changes in policy parameters. Little sense in this approach when the model is so approximate that one cannot be sure that the overall mode is significant for the real world situation studied. It would then seem that one can do nothing more than to point out that the one structure can generate many different modes.

Worked hard to complete Nathan's and my attempt at a model by including satisfaction and institutionalization which I consider to both be important. Infinite problems with average length of adoption (needed to distinguish short-term and long-term effects), and with the fact that one concept seems to appear in two variables in the model (how pleased people are with the new idea—perceived attractiveness and in societal satisfaction). I was convinced that I was constrained by methodological limitations, but everyone else and common sense indicate that I am up against a knowledge constraint (regarding my knowledge about the real world).

4/8-17, 1973 Tried to the utmost of my ability to arrive at a complete DYNAMO diagram, without success and with total collapse of mental stability as a result. I called Dennis and Co. (the Dartmouth SD group) for a brainstorming and confidence boosting session next week and quit completely for 6 full days, doing all sorts of things except modeling social
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change. I think it is useful having worked now for 70 days without a
day off. I am in the vicious circle where I cannot take the time off
needed to regain innovativeness and productivity, due to pressure from
the approaching deadline. I cannot think clearly, I have no good ideas,
I am really down. A very dangerous situation that must be avoided.
The following insights appear to be true:

- all model relations must be obvious, clear and clean

- one should model quickly and defend one's result as an improvement,
not perfection. (Otherwise you'll get bored, discontinue and obtain
no result.)

- try to explain special cases after a model is made, instead of post-
poning running and writeup until all detail is in. Model may, in fact,
turn out to explain special cases even if it was not intuitively clear
that it would.

- model what you have got and then stop - one cannot go further than
one's understanding. (I have probably been limited by understanding,
not by methodological constraints as I believed. Another factor might
have been excessive fear of complexity after the experience with the
overly complex models last fall.)

4/18-25, 1973 Made a model of the processes described in my proposal with
Dennis and Co. Managed to make one and get it on machine - enormous boost
for my morale although its behavior was not very good. I am not sure
why we managed this time what I have not managed before; maybe because
of elimination of both inertia (commitment, societal satisfaction) and
variable cause. These two factors, especially the first, were so engrained
in my way of thinking about movements that I could not get them out.
Some discussion with Andy (of the Dartmouth SD group) made me aware of
the utility of a specific example - found a good book on Prohibition and
proceeded to attempt an application of my model to this case. Back at MIT
I discovered that even the "simple" Dartmouth model was too complex and
made a simpler one specifically addressing Prohibition. I had a clear
image of desired behavior mode and hypotheses about causes and succeeded
very quickly. Discovered in model first, then in book, that prohibi-
tions come in waves. A good boost for my confidence again. Wrote outline
of a three part thesis: 1/3 on conceptualization, 1/3 on social change
model, and 1/3 on how model can be parametrized by non-experts. I am in
a good mood, my goal is now solely to finish by July 8 (Copenhagen conference)
after having taken my name off degree list twice now. Goals have eroded!

4/25/73 The thesis proposal seminar was destroying. The committee members
thought the thesis was too inclusive and that I claimed too much for my
"general theory of social change." They tended to argue for a treatise
on conceptualization. I am crushed since that means one quality unit of content on conceptualization, which I am afraid I will not manage to produce, in spite of the invaluable insights I feel the last year has generated.

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4/26-5/3, 1973  It is clearer that I am not going to give up, but attempt to write a report on conceptualization, describing the process of model construction with our modeling effort as a specific case. As I started thinking about guidelines (or lessons I have learned) for the process it became clearer that my trouble over the last year was mainly due to lack of clearly defined problem (e.g., in terms of a behavior mode and underlying causes). I tried to expand the model somewhat to represent an ecology movement, without much luck. I only proved to myself (by running the model on the machine), for the millionth time, how counter-intuitive the result of a set of assumptions is (the set never gives the behavior I expect) and how incredibly insensitive models are to parameter changes (it is impossible to get rid of the behavior I do not like without changing the structure of the model). Forrester said I should stop working and start writing, probably a good idea. In fact it is quite interesting to ponder about my amazing meandering over the last year. For the first time in a month I did have some ideas, which helped my depression a lot.

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CHAPTER IV

TOWARD A MODEL OF SOCIAL CHANGE

Upgrading Models Through Generalized Evaluation

Like most other modeling efforts, this study ended up with a model (NEWIDEA#12). Like all other models, NEWIDEA#12 will be subject to criticism and questioning. Is this a good model? Why was this variable excluded? Where is the important XYZ effect? Why isn't the level of aggregation higher? lower? A model is defended by showing that it passes generally accepted credibility tests, for instance, compatibility with most published material on the topic, or capability of giving good statistical fit in some regression procedure. NEWIDEA#12 has passed another type of test. It is the result of (or rather the current stage in) a long process where several other formulations were rejected because they did not satisfy the criteria used in the generalized evaluation procedure, described in Chapter II. The purpose of this chapter is to demonstrate the working of the generalized evaluation procedure, showing how non-qualitative evaluation of tentative structures gradually changes the characteristics and topical content of a model.

The chapter describes the sequence of eleven models that led to NEWIDEA#12, a rather simple model that was never evaluated using statistical tests. Each of the models consists of one selected group of variables and relationships which was finally rejected on the basis of generalized evaluation, making room for a new and presumably better structure. The
sequence of models is described to correct three misconceptions. First, the rigor of generalized evaluation, as indicated by the large changes it forced in the proposed models, seems generally underestimated. The variety within the sequence of the twelve models demonstrates the power of generalized evaluation. Second, the sheer amount of experimentation and evaluation behind a seemingly trivial system dynamics model is largely underestimated by the inexperienced. It may be surprising that eleven distinct models preceded the rather simple NEWIDEA#12. Third, the ensuing description should correct the mistaken assumption that model size, variables, and relationships are chosen in one burst of conceptualization. Ten months of continuously changing choices led to the final selection embodied in NEWIDEA#12. The chapter should not, however, be construed as a defense of NEWIDEA#12 as an indisputable representation of the simuland.

The next section contains a description of NEWIDEA#12. It is written in the usual arrogant, after-the-fact manner, which gives the impression that model characteristics and content were obvious to the modeler upon first contact with the problem area and immediately crystallized in his mind. The following two sections present summary descriptions of the models that preceded NEWIDEA#12 and trace the evolution of model characteristics (order, nonlinearity, loop multiplicity, aggregation) and of model content (level names) as it occurred through a fumbling sequence of choice and rejection, guided by the criteria for satisfactory models that were listed in Chapter II.
The Current Model: NEWIDEA#12

Introduction

An action group is a group of persons undertaking deliberate action to institute change in the attitudes and consequent behavior of a target population of individuals by introducing new ideas. Contemporary examples are provided by groups working for women's liberation, a healthy environment, peace, and consumer protection. Group effort normally causes some change in the target population over time; the group itself is also changed by the encounter, as illustrated in Figure IV-1.

The system dynamics simulation model NEWIDEA#12 examines the overall dynamic interaction between an action group and its target population. The model structure emphasizes the variables and relations common to most situations where a group is promoting a new idea. Through changes in model parameters, NEWIDEA#12 can be used to study various dynamic patterns of acceptance and rejection resulting under different circumstances. Here NEWIDEA#12 is parametrized to represent a group pressing for early acceptance of an idea that is becoming increasingly advantageous with time due to exogenous forces. It is assumed that the idea's merits would slowly grow substantial enough to cause widespread acceptance even without group promotion. The group's self-imposed purpose is to advance the date of general acceptance.

NEWIDEA#12 focuses primarily on the (normal) situation where the "true" utility of the new idea cannot be known until after its full-scale implementation. Cases where the benefits of adoption are well established
Figure IV-1: The Interaction between Group and Society.
can also be simulated, but are less interesting, in addition to being uncommon in societal contexts.

The subsequent parametrization and simulations are intended to be relevant to the contemporary conservationist movement promoting "environmental concern," that is, an ecologically sound relationship between industrialized man and the biosphere. Consideration of environmental impact will grow increasingly necessary with time, as human affluence and numbers come to place heavier loads on the supporting ecosystem, and will one day become mandatory to insure survival. In short, the idea of environmental concern is becoming increasingly advantageous with time. What is disputed is the exact time when societal behavior should be adapted to the constraints of the biosphere. Environmentalists hold that action must be taken now, while their opponents argue that it can be delayed until the advantages of "environmental concern" grow more conspicuous. The objective validity of either view can be assessed only through future accumulation of practical experience. The simulations below present possible consequences of the formation of environmentalist pressure groups.

Major Variables and Relations

This section describes the conceptual framework underlying the structure of NEWIDEA#12. The framework is applicable in analyses of the fate of various ideas introduced in society. In each case the idea is assumed to be fixed throughout the analysis and to have observable behavioral correlates. An idea is defined as having behavioral implications if acceptance of the idea leads to changed behavior, except when
such behavior is illegal or impossible. For example, an individual who accepts the idea of pot-smoking may postpone this behavior until it is legalized; an individual who accepts the idea of a pollution tax cannot as an individual pass a bill imposing such a tax. Although the idea is assumed to be constant, it is recognized in the model that the real advantage of adoption generally varies through time (for example, environmental concern makes little sense when human activity amounts to an imperceptible perturbation of the natural equilibrium). It is also assumed that initially one has no certain knowledge about the actual advantage of adoption. Prior to large scale adoption, such information can only be inferred from cases of limited trial implementation.

The model distinguishes four degrees of societal involvement with the idea: society can accept the idea, adopt the behavior implied by the idea, institutionalize the idea, and internalize the idea. Societal acceptance is defined as a consensus to not fight the idea and willingness to adopt behavior compatible with the idea if it is legal and possible. Societal adoption is defined as adherence to behavior consistent with the idea (for example, abstinence from drinking when the idea under study is prohibition). Adoption does not presuppose acceptance; one may be forced to behave in an unacceptable way (for example, by a majority in favor of adoption). Societal institutionalization of the idea is defined as adaptation of society's institutions so that conduct compatible with the idea will be legal, feasible, and simplified (as in changed laws, attitudes, and educational and job opportunities making equal rights for women operational). Institutionalization of an idea may force adoption
of behavior at odds with what is accepted (traditional all-male dormitories, for instance, may thwart a widely accepted desire for coed college student housing). Internalization of the idea, by those who have accepted it, implies commitment to the idea and a correspondingly lesser tendency to revert. (For example, the idea that everyone is able to obtain wealth and status through hard work apparently remains cherished by large segments of Western populations in spite of increasing evidence to the contrary; this strong internalization may be due to past positive experience and habit.)

The model variables of acceptance, adoption, institutionalization, and internalization indicate the degree to which society has accepted, adopted, institutionalized, and internalized the idea. They can all either grow or decline. In the model, increased societal acceptance results when more people become concerned about the issue and perceive the idea as advantageous relative to the beliefs it will replace. Widespread and enduring societal acceptance is assumed to give rise to the idea's institutionalization. Extent of adoption depends, in the model, on the degree of acceptance of the idea and on institutional pressures. Internalization results from extended adoption of the new behavior; it occurs more rapidly when adoption coincides with a perception of the new idea as advantageous.

The perceived advantage of the new idea is the average view of the idea's merits, held by people concerned about the issue. Perceived advantage is assumed to be formed on the basis of available information about the idea and its practical implications, as well as on the basis of such factors as novelty and conformity pressure. People lacking
awareness about the issue are assumed to be indifferent to its possible advantage.

**Advantage** is seen as a dimensionless concept, defined relative to a situation of no involvement with the new idea. For example:

\[
\text{perceived advantage} = \frac{\text{perceived total utility of adoption}}{\text{perceived total utility of non-adoption}}
\]

Thus perceived advantage equal to one implies indifference.

The model distinguishes among three components involved in the activity surrounding the new idea: **group**, **active resistance**, and **practical experience**. All act to influence society's perception of the idea's advantage. The group promotes acceptance by claiming that the idea is advantageous; the active resistance, composed of those elements that oppose the idea, publicizes negative views of the idea. Public opinion is affected by reports on practical implementation of the idea: the body of practical experience induces acceptance if there is real advantage to the idea, and if not, experience supports the view of the critics.

**Total current activity** represents the sum of information related to the new idea impacting on the target population at one point in time. Influence emanates from the group, from its opponents, and from diffusion of reports on practical implementations. Influence from interested parties and spreading information leads to more widespread awareness and concern. The new idea looks particularly attractive when the issue is novel; however in the longer run excessive activity is assumed to produce indifference, boredom, even hostility in aware persons, resulting in a reduction in perceived advantage.
The three sources usually disagree on the advantage of the idea and disseminate their own discrete judgements. The average publicized advantage, weighted by the influence of the sources, forms the reported advantage:

\[
\text{reported advantage} = \frac{(\text{advantage claimed by group } \times \text{ group influence} + \text{advantage claimed by resistance } \times \text{ resistance influence} + \text{experienced advantage } \times \text{ experience influence})}{\text{total influence}}
\]

It is assumed that the action group desires full acceptance of the new idea. The amount of group effort expended toward converting society depends on how much motivation exists in the group for further work, as determined by: the group's belief regarding societal gain from further acceptance; the availability of support for the group (determined by the current level of acceptance); the intensity of individual group members' efforts (determined by the group enthusiasm in general and by short-term accomplishment aspirations). The group has aspirations which change in response to experience; the aspirations indicate what the group currently considers an acceptable rate of progress toward full acceptance. Failure to satisfy group aspirations is assumed to result in reduction of group enthusiasm and effort, but not in change of the idea itself, or change in the self-imposed goal of full acceptance. The group's influence on society is assumed to be a function of both expended effort and group credibility. Group credibility is assumed to be determined by how reliable the group has been in its past claims for the idea's advantage. Claimed advantage is assumed to be an upwardly biased version of the experimentally established merits of the idea; the bias lessens when the pool of available
practical experience is larger and more convincing. Once motivations and support disappear, in the model, the group will decay and disappear. Disintegration is a much slower process for larger groups (this is a representation of the persistence of large bureaucracies and the lingering commitment to goals toward which great effort has already been expended).

In the model, support for active resistance against the group originates from the segment of the population that has not accepted the idea. Intensity of resistance is assumed to depend on rate of conversions (signifying the rate of growth of the "threat" to opponents of the idea) and on the total level of acceptance in the population (giving another indication of how urgently needed countermeasures are). Resistance does not necessarily disappear as readily as it is generated.

Experienced advantage is the current estimate of the idea's advantage, based on available information about instances of practical implementation. Experienced advantage would be equal to real advantage (the unknowable "true" benefits that will accrue over time upon adoption) only if there were 100 percent adoption of the idea and all information about current and future consequences of adoption were instantaneously available in processed form. In typical situations there is a time lag before experienced advantage catches up to real advantage, due to the time-consuming nature of gathering and assessing information about a situation. (For example, there is a time lag between experienced and real advantage of global population control, because all global population estimates are at least one year old.) Experience delay may be lengthened simply because the consequences of adopting a new behavior do not become apparent
until years have passed by (for example, it took a decade before experienced advantage of persistent pesticides approached a truer value, real advantage, which incorporated side effects like accumulation in fish, birds, and humans). It is assumed in the model that experienced advantage is continuously changing toward the instantaneous real advantage; the process being more rapid when adoption -- and therefore sources of experimental information -- are more widespread.

The impact of experienced advantage in effecting change in society depends on the available volume of practical experience concerning the consequences of adoption. Practical experience is obtainable from cases of limited adoption. The rate at which experience is accumulated is assumed to depend on the extent of adoption. Furthermore it is assumed that a higher (constant) level of adoption will make a higher final level of experience possible because more side effects and externalities will be exposed.

Causal Diagram and DYNAMO Flow Diagram

Elements of the structure of NEWIDEA#12 appear in the causal diagram in Figure IV-2. Several loops are omitted and the apparently exogenous variables (included only to show their place in the structure) are actually elements in feedback loops.

Causal diagrams are useful only when they can be made sufficiently simple to increase intuitive understanding of the basic loop structure. When describing NEWIDEA#12 no representative, yet meaningful causal diagram can be drawn because the polarity of most loops varies with the
Figure IV-2: Partial Causal Structure for NEWIDEA#12.
chosen parametrization and with operating region, and the structure is such that distinction between levels and rates becomes critical for obtaining insight. Using the DYNAMO flow diagram solves both problems (Figure IV-3).

DYNAMO Equations

A listing of detailed model assumptions appears below. The structural assumptions are intended to be a valid generic description of the adoption of any new idea in a target population. The specific parameters and initial values chosen are intended to approximate very roughly the environmental movement in the United States, with the late 1950's as the starting point of the simulation. At that time, it is assumed, the movement was still small, but growing uniformly at a rate of 15% a year. The specific example was selected only as a focus for thought about the model; neither the structure nor the parametrization are sufficiently accurate to point-predict future real-world events in the conservationist movement. The model is intended solely as an insight-generator about possible dynamic behavior of the simuland.

The "new idea" in this case is the "necessity of environmental concern when planning human activity": the realization that man is part of the biosphere and must consider his impact on the fragile web of life that sustains mankind. The new idea will be interchangeably referred to as "conservationist attitude," "ecologically sound behavior," and "environmental concern."

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Figure IV-3: DYNAMO flow diagram for NEWIDEA#12
A.K = A.J + (DT)(CON.JK - VER.JK)  
A = A1  
A1 = .01  
A - ACCEPTANCE (D'LESS)  
CON - CONVERSIONS (1/YEAR)  
VER - REVERSIONS (1/YEAR)  
A1 - A INITIALLY (D'LESS)

Acceptance A is measured as the fraction of the population generally agreeing with the environmentalist's view, and is assumed to be one percent initially.

CON.KL = CLIP((IA.K - A.K)/CT, .0, (IA.K - A.K)/CT, 0)  
CT = 5  
CON - CONVERSIONS (1/YEAR)  
IA - INDICATED ACCEPTANCE (D'LESS)  
A - ACCEPTANCE (D'LESS)  
CT - CONVERSION TIME (YEARS)

Rate of conversions CON closes the gap between the current level of acceptance A and the equilibrium level IA (for given system conditions) within five years CT -- representing delays in information diffusion and changing one's mind.

IA.K = FC.K * IAMPAD.K  
IA - INDICATED ACCEPTANCE (D'LESS)  
FC - FRACTION CONCERNED (D'LESS)  
IAMPAD - INDICATED ACCEPTANCE MULTIPLIER FROM PERCEIVED ADVANTAGE (D'LESS)

Equilibrium acceptance IA constitutes a certain fraction IAMPAD of the part of the population FC that is aware of the environmental issue.
Awake segment of the population FC increases with the amount of activity CA related to the environmental issue. An activity level—in media, literature and public debate—thirty times larger than the initial group effort is assumed sufficient to make everyone aware of the existence of the environment problem.
Information related to environmental issues CA arises from environmentalists themselves GIN, their opponents ARIN and reports on practical implementations of ecologically sound behavior EXIN. One influence unit arbitrarily equals the initial influence of the group.

\[ \text{IAMPAD} \times K = \text{TABUL}(\text{IAMPAT}, \text{PEAD} \times K / \text{RPEAD}, 0, 3, .5) \]
\[ \text{IAMPAT} = .001/ .01/ .02/ .18/ .6/ .8/ .95 \]
\[ \text{RPEAD} = .8 \]

IAMPAD = INDICATED ACCEPTANCE MULTIPLIER FROM PERCEIVED ADVANTAGE (D'LESS)
IAMPAT = IAMPAP TABLE (D'LESS)
PEAD = PERCEIVED ADVANTAGE (D'LESS)
RPEAD = REFERENCE PEAD (D'LESS)

Acceptance among those aware IAMPAD increases strongly when they perceive the new idea as superior to current beliefs, i.e. when perceived advantage PEAD > 1. Some will always accept the necessity of environmental concern, others never will.
VER.KL = CLIP((A.K - IA.K)/VT.K, 0, (A.K - IA.K)/VT.K, 0) 7, R
VER  - REVERSIONS (1/YEAR)
A    - ACCEPTANCE (D'LESS)
IA   - INDICATED ACCEPTANCE (D'LESS)
VT   - REVERSION TIME (YEARS)

Rate of reversions VER reduces acceptance A to its equilibrium value within the reversion time VT.

\[ VT.K = RVT \times \text{TABHL}(VTT, \text{IN.K}/\text{RIN}, 0, 5, 1) \]
\[ VTT = 1/1/1/2/4/10 \]
\[ RVT = 5 \]
\[ \text{RIN} = .15 \]
VT  - REVERSION TIME (YEARS)
RVT - REFERENCE VT (YEARS)
VTT - VT TABLE (D'LESS)
IN  - INTERNALIZATION (D'LESS)
RIN - REFERENCE IN (D'LESS)

Reversion time VT represents delays in obtaining information and changing one's mind, and increases in length from five years upwards to a lifetime as the new idea becomes more internalized.
IN, K = IN, J + (DT/INAT)(CS, J - IN, J)

\text{IN} = \text{INI}
\text{INI} = 0
\text{INAT} = 10

IN - INTERNALIZATION (D'LESS)
INAT - INTERNALIZATION AVERAGING TIME (YEARS)
CS - CURRENT SATISFACTION (D'LESS)
INI - IN INITIALLY (D'LESS)

Extent of internalization IN of the idea in the population is assumed to depend on accumulated satisfaction obtained from societal adoption of the idea over the past decade. Thus increased internalization results when there is more widespread adoption, more enduring adoption (i.e. habit) and a stronger conviction that the idea is beneficial. Institutionalization IN is dimensionless, starts out equal to zero, and is computed as the past average of current satisfaction CS.

CS, K = PEAD, K \times D, K

CS - CURRENT SATISFACTION (D'LESS)
PEAD - PERCEIVED ADVANTAGE (D'LESS)
D - ADOPTION (D'LESS)

Current satisfaction CS with the idea is defined as the product of adoption D (the fraction of the population experiencing satisfaction) and perceived advantage PEAD (the intensity of satisfaction); both are dimensionless quantities.

PEAD, K = PACO \times RPAD, K \times PAPA, K \times PANC, K

PEAD - PERCEIVED ADVANTAGE (D'LESS)
PACO - PERCEIVED ADVANTAGE COERCION/COMPLEXITY MULTIPLIER (D'LESS)
RPAD - REPORTED ADVANTAGE (D'LESS)
PAPA - PERCEIVED ADVANTAGE MULTIPLIER FROM PAST ACTIVITY (D'LESS)
PANC - PERCEIVED ADVANTAGE CONFORMITY MULTIPLIER (D'LESS)
The idea is judged to be more desirable, by those aware, when available information reports the idea to be advantageous RPAD, when the idea is novel and exciting PAMPA and when most other people have already accepted PAMC.

\[ \text{RPAD}_k = \frac{(\text{CLAD}_k \times \text{GIN}_k + \text{EXAD}_k \times \text{EXIN}_k + \text{RCAD} \times \text{ARIN}_k)}{\text{GIN}_k + \text{EXIN}_k + \text{ARIN}_k} \]

RPAD - REPORTED ADVANTAGE (D'NESS)
CLAD - CLAIMED ADVANTAGE (D'NESS)
GIN - GROUP INFLUENCE (INFLUENCE UNITS)
EXAD - EXPERIENCED ADVANTAGE (D'NESS)
EXIN - EXPERIENCE INFLUENCE (INFLUENCE UNITS)
RCAD - ADVANTAGE CLAIMED BY RESISTANCE (D'NESS)
ARIN - ACTIVE RESISTANCE INFLUENCE (INFLUENCE UNITS)

Group, resistance, and reports on experience color publicly available information in proportion to the influence of the three activities.
Sustained activity PA close to saturation levels (≤30 influence units) is assumed to ultimately reduce attractiveness PAMPA of the new idea to one-fifth through loss of novelty, and through boredom resulting from endless repetition of facts and arguments.

Past activity PA is the average environmental flurry over the last five years.
The new idea is assumed to be considered more attractive when accepted by a larger fraction of society: there is a desire to conform.

In promoting environmental concern, environmentalists base their claims for superiority CLAD on available experience EXAD, adding a certain upward bias BIAS.
The bias BIAS is assumed to be reduced when more experimental proof EX makes the validity of the experienced advantage EXAD less disputable. In the late fifties scarcely any experience was available and it is assumed that an initial bias existed sufficient to make the claimed advantage high at that time.

Practically experienced advantage of caring for the environment EXAD is a delayed version of the "true" advantage READ due to the time needed to establish facts.
Delay \text{EXDE} \text{ in establishing the true advantage of the conservation ethic under current conditions, is assumed to fall from thirty to six years with increasingly widespread adoption of conservationist behavior.}
It is assumed that in the late fifties the true utility READ of ecologically sound human behavior was only one half the utility of disregarding environmental constraints altogether. The benefit of conservationism is further assumed to grow at six percent per year, making environmental concern truly advantageous (i.e., READ ≥ 1) around 1970.

The opposition is assumed to continue to assert an advantage of one-half (i.e., a disadvantage) for environmental concern.

\[ G_{IN,K} = R_{GIN} \times G_{INM,K} \times C_{K} \]

\[ R_{GIN} = 1 \]

\[ G_{IN} = \text{GROUP INFLUENCE (INFLUENCE UNITS)} \]

\[ R_{GIN} = \text{REFERENCE GIN (INFLUENCE UNITS)} \]

\[ G_{INM} = \text{GROUP INFLUENCE MULTIPLIER FROM GROUP EFFORT (D'LESS)} \]

\[ C = \text{GROUP CREDIBILITY (CREDIBILITY UNITS)} \]

Influence GIN of the environmentalist group on public opinion is assumed to depend on effort expended GINM, having a stronger impact when group credibility C is high.
Group promotion $E$ of conservationism some fifty times stronger than the initial effort is assumed to increase group influence on public opinion merely by a factor of twenty-three, since the most susceptible audience is affected first.

\[ C \cdot K = C \cdot J + (D \cdot T)(C \cdot J \cdot C M C \cdot J \cdot C M E \cdot J \cdot F C \cdot J) \]

\[ C = C I \]

\[ C I = 1 \]

- $C$ - Group Credibility (Credibility Units)
- $C M C$ - Credibility Change Multiplier from Credibility (D'less)
- $C M E$ - Credibility Change Multiplier from Exaggeration (D'less)
- $F C$ - Fraction Concerned (D'less)
- $C I$ - C Initially Concerned (Credibility Units)

Group credibility $C$ is a dimensionless measure of the extent to which people listen to the group. It is arbitrarily determined to be initially equal to one, with a possible range from one-eighth to four (constrained by $C M C$). Credibility falls when group claims are perceived as unfounded $C M E$; it falls faster when more people are aware of the issue $F C$. 
$CMC_K = \text{TABUL}(CMCT, 1.44 \times \log(C.K/RC), -3, 2, 1)$

$CMCT = C/0.25/1.55/1.75/0$

$RC = 1$

$CMC$ - CREDIBILITY CHANGE MULTIPLIER FROM CREDIBILITY ($D^I$LESS)

$CMCT$ - CINC TABLE ($D^I$LESS)

$C$ - GROUP CREDIBILITY (CREDIBILITY UNITS)

$RC$ - REFERENCE C (CREDIBILITY UNITS)

Credibility $C$ changes more slowly -- ceteris paribus -- when close to its extreme values.
CME,K=RCME*TAGHL(CMSET,CLAD.K/PEAD.K,0.3,.5)  25, A
CMSET=-.2/.0/.1/.08/0/-.2/-.4  25.1, T
RCME=1  25.2, C
CME - CREDIBILITY CHANGE MULTIPLIER FROM
      EXAGGERATION (D'LESS)
RCME - REFERENCE CME (1/YEAR)
CMET - CME TABLE (D'LESS)
CLAD - CLAIMED ADVANTAGE (D'LESS)
PEAD - PERCEIVED ADVANTAGE (D'LESS)

Credibility C falls quickly when group claims CLAD are highly
inconsistent with public perception of the utility of the idea PEAD, and
grows slowly when the two are more equal.

E.K=E.J+(DT)(ECR.JK)  26, L
E=E1  26.1, M
E1=1  26.2, C
E - GROUP EFFORT (EFFORT UNITS)
ECR - GROUP EFFORT CHANGE RATE (EFFORT UNITS/
      YEAR)
E1 - GROUP EFFORT INITIALLY (EFFORT UNITS)

Effort unit is defined as equal to the initial group effort
directed at convincing outsiders of the advantage of the new idea.

ECR.KL=(IE.K-E.K)/EDT.K  27, R
ECR - GROUP EFFORT CHANGE RATE (EFFORT UNITS/
      YEAR)
IE - INDICATED GROUP EFFORT (EFFORT UNITS)
E - GROUP EFFORT (EFFORT UNITS)
EDT - GROUP EFFORT CHANGE TIME (YEARS)

Group effort E moves toward equilibrium effort IE for the given
conditions within a period of time depending on group size.
Equilibrium group effort IE is basically assumed to be proportional to acceptance A of its cause, but is higher when there is a stronger motivation to promote the cause IEMXG, when group dedication is higher IEMEN and when the group has high aspirations regarding conversions IEMAS.
The group is assumed to reduce its effort when most people have already accepted the idea or when group members no longer view the idea as superior.

\[ XG_K = CLAD_K \times (1 - A_K) \]

\[ RXG = 1.98 \]

CLAD  - CLAIMED ADVANTAGE (D'LESS)
A    - ACCEPTANCE (D'LESS)
RXG  - REFERENCE XG (D'LESS)

In the group's view, possible societal gain from further acceptance equals obtainable advantage CLAD times number of people yet to convert \((1 - A)\).
It is assumed that the group effort $E$ can be increased or discontinued very rapidly when it is still small, but that larger groups are much more perseverant due to complexity of organization and accumulated commitment to the group itself.

It is assumed that the group can sustain a much higher effort $E$ when the group members are enthusiastic and dedicated to the cause.

\[
\text{IEMEN}_k = \text{RIEMEN} \times \text{TABHL}(\text{IEMENT}, \text{EN}_k/\text{REN}, 0.3, 0.5)
\]

\[
\text{IEMENT} = 0.5/0.7/1/1.5/1.9/1.95/2
\]

\[
\text{RIEMEN} = 1
\]

\[
\text{REN} = 1
\]

IEMEN - INDICATED GROUP EFFORT MULTIPLIER FROM ENTHUSIASM (D'LESS)
RIEMEN - REFERENCE IEMEN (D'LESS)
IEMENT - IEMEN TABLE (D'LESS)
EN - GROUP ENTHUSIASM (ENTHUSIASM UNITS)
REN - REFERENCE EN (ENTHUSIASM UNITS)
EN.K = EN.J + (DT)(ENC.N.K)

EN = EN.I

EN.I = 1

EN - GROUP ENTHUSIASM (ENTHUSIASM UNITS)
ENCN - GROUP ENTHUSIASM CHANGE RATE (ENTHUSIASM UNITS/YEAR)
ENI - GROUP ENTHUSIASM INITIALLY (ENTHUSIASM UNITS)

Group enthusiasm EN is defined as initially equal to one, representing the high morale of environmental pioneers.

ENCN.KL = EN.K * ENMP.K

ENCN - GROUP ENTHUSIASM CHANGE RATE (ENTHUSIASM UNITS/YEAR)
EN - GROUP ENTHUSIASM (ENTHUSIASM UNITS)
ENMP - ENTHUSIASM MULTIPLIER FROM PROGRESS (D'LESS)

ENMP.K = RENMP * TABHL(ENMP.T, CP.K/AS.K, 0.3, 0.5)

ENMP.T = -.1/-.07/.03/.045/.05/.05

RENMP = 1

ENMP - ENTHUSIASM MULTIPLIER FROM PROGRESS (D'LESS)
RENMP - REFERENCE ENMP (D'LESS)
ENMP.T - ENMP TABLE (D'LESS)
CP - CURRENT PROGRESS (1/YEAR)
AS - ASPIRATIONS (1/YEAR)
Group enthusiasm EN grows slowly when progress CP exceeds aspirations AS, and falls quickly when progress is less than what is considered reasonable AS.

\[ IEMAS = \text{RIEMAS} \times \text{TABHL}(IEMAST, AS \times K / \text{RAS}, 0, 5, 1) \]
\[ IEMAST = 0.5 / 1.2 / 1.35 / 1.45 / 1.5 \]
RIEMAS = 1
RAS = 1.5

\[ \begin{align*}
  IEMAS & \quad \text{INDICATED GROUP EFFORT MULTIPLIER FROM ASPIRATIONS (D'LESS)} \\
  \text{RIEMAS} & \quad \text{REFERENCE IEMAS (D'LESS)} \\
  \text{IEMAST} & \quad \text{IEMAS TABLE (D'LESS)} \\
  \text{AS} & \quad \text{ASPIRATIONS (1/YEAR)} \\
  \text{RAS} & \quad \text{REFERENCE AS (1/YEAR)}
\end{align*} \]

Increased aspirations AS are assumed to increase the intensity of the group members work output to some degree.

\[ \begin{align*}
  \text{AS} \times K & = TP \times K + FAS \times (1 - WX) \\
  WX & = 0.5 \\
  FAS & = 1
\end{align*} \]

\[ \begin{align*}
  \text{AS} & \quad \text{ASPIRATIONS (1/YEAR)} \\
  \text{TP} & \quad \text{TRADITIONAL PROGRESS (1/YEAR)} \\
  WX & \quad \text{WEIGHT ON EXPERIENCE (D'LESS)} \\
  FAS & \quad \text{FIXED ASPIRATIONS (1/YEAR)}
\end{align*} \]
Group aspirations AS are assumed to be formed from a fixed goal FAS of 10%/year growth in acceptance and the growth rate experienced recently; equal weight is given to both.

\[
TP_K = TP_J + (DT/TPAT)(CP_J - TP_J)
\]

TP = TP\_I
TP\_I = .15
TPAT = 4

TP - TRADITIONAL PROGRESS (1/YEAR)
TPAT - TRADITIONAL PROGRESS AVERAGING TIME (YEARS)
CP - CURRENT PROGRESS (1/YEAR)
TP\_I - TP INITIALLY (1/YEARS)

Average rate of conversions TP observed over the last four years is assumed to be what is viewed as normal achievement.

\[
ARIN_K = RARIN \times TABHL(ARINT, AR.K/RAR, 0, 30, 6)
\]

ARINT = 0/6/12/18/22/25
RARIN = 1
RAR = 1

ARIN - ACTIVE RESISTANCE INFLUENCE (INFLUENCE UNITS)
RARIN - REFERENCE RIN (INFLUENCE UNITS)
ARINT - ARIN TABLE (D'LESS)
AR - ACTIVE RESISTANCE (RESISTANCE UNITS)
RAR - REFERENCE RA (RESISTANCE UNITS)
It is assumed that the influence ARIN of opponents to ecologically sound behavior roughly equals the influence of proponents when both expend maximum effort. Each alone can effect full awareness about the issue involved and face similar decreasing returns to effort.

\[ \text{AR}, K = \text{AR}, J + (DT)(\text{ARCR}, JK) \]
\[ \text{AR} = \text{ARI} \]
\[ \text{ARI} = 1 \]
\[ \text{AR} \quad - \quad \text{ACTIVE RESISTANCE (RESISTANCE UNITS)} \]
\[ \text{ARCR} \quad - \quad \text{ACTIVE RESISTANCE CHANGE RATE (RESISTANCE UNITS/YEAR)} \]
\[ \text{ARI} \quad - \quad \text{AR INITIALLY (RESISTANCE UNITS)} \]

It is assumed that the opposition initially had the same influence on society as the environmentalists (both exerting one influence unit).

\[ \text{ARCR}, KL = \text{AR}, K \times \text{ARFC}, K \]
\[ \text{ARCR} \quad - \quad \text{ACTIVE RESISTANCE CHANGE RATE (RESISTANCE UNITS/YEAR)} \]
\[ \text{AR} \quad - \quad \text{ACTIVE RESISTANCE (RESISTANCE UNITS)} \]
\[ \text{ARFC} \quad - \quad \text{ACTIVE RESISTANCE FRACTIONAL CHANGE (1/YEAR)} \]
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$$ARFC.K = RARFC \times TABHL(ARFC, IAR.K/AR.K, 0, 3, 5)$$
$$ARFCT = -0.1/-0.06/0.3/0.7/0.9/1$$
$$RARFC = 1$$

ARFC - ACTIVE RESISTANCE FRACTIONAL CHANGE (1/YEAR)
RARFC - REFERENCE ARFC (1/YEAR)
ARFCT - ARFC TABLE (D'LESS)
IAR - INDICATED ACTIVE RESISTANCE (RESISTANCE UNITS)
AR - ACTIVE RESISTANCE (RESISTANCE UNITS)

Active resistance AR changes toward the equilibrium value

IAR indicated by the prevailing system conditions. Resistance is assumed
to grow fast (at a rate of up to 100%/year) and to decay more slowly
(at a maximal rate of 10%/year), representing the persistence of initial
impressions.

$$IAR.K = RIAR \times (1-A.K) \times IARMA.K \times IARMCP.K$$
$$RIAR = 1$$

IAR - INDICATED ACTIVE RESISTANCE (RESISTANCE UNITS)
RIAR - REFERENCE IAR (RESISTANCE UNITS)
A - ACCEPTANCE (D'LESS)
IARMA - INDICATED ACTIVE RESISTANCE MULTIPLIER FROM
ACCEPTANCE (D'LESS)
IARMCP - INDICATED ACTIVE RESISTANCE MULTIPLIER FROM
CURRENT PROGRESS (D'ESS)

Equilibrium resistance is basically assumed to be proportional
to the number of people that have not yet converted. However, opposition
per opponent becomes more intense when few are left to fight for the
old IARMA and when current growth in acceptance appears to be frighteningly
high IARMCP.
It is assumed that the last person left defending the old way of disregarding environmental constraints will put up a pressure which is 150 times stronger than that from the initial opponents: he remains in opposition only because he has a great deal more to lose from accepting.
It is assumed that a fivefold increase in growth of acceptance above the initial value of 15% per year will induce a tenfold increase in resistance.

\[ CP_2 = CP_1 + \frac{DT}{CPAT} (GR_1 - CP_1) \]

\( CP = CPI \)
\( CPI = 0.15 \)
\( CPAT = 2 \)

- **CP**  - CURRENT PROGRESS (1/YEAR)
- **CPAT**  - CURRENT PROGRESS AVERAGING TIME (YEARS)
- **GR**  - GROWTH RATE (1/YEAR)
- **CPI**  - CP INITIALLY (1/YEAR)

Both group and resistance are assumed to view average growth in acceptance over the previous two years as the indicator of current progress CP.

\[ GR_2 = CON_1 JK / A_1 K \]

- **GR**  - GROWTH RATE (1/YEAR)
- **CON**  - CONVERSIONS (1/YEAR)
- **A**  - ACCEPTANCE (D'LESS)
Fractional growth rate GR is calculated as conversions CON divided by acceptance A, mirroring a typical tendency to neglect less conspicuous reversions VER.

\[ \text{EXIN} \cdot K = \text{REXIN} \cdot \text{TABHL(EXINT, EX \cdot K/REX, 0, 1, .2)} \]
\[ \text{EXINT} = 0/14/26/33/38/40 \]
\[ \text{REXIN} = 1 \]
\[ \text{REX} = 1 \]

-EXIN - EXPERIENCE INFLUENCE (INFLUENCE UNITS)
-REXIN - REFERENCE EXIN (INFLUENCE UNITS)
-EXINT - EXIN TABLE (D'LESS)
-EX - PRACTICAL EXPERIENCE (EXPERIENCE UNITS)
-REX - REFERENCE EX (EXPERIENCE UNITS)

Influence EXIN on the public of collected practical experience with ecologically sound behavior is assumed to have been small initially (EX = .01 experience units \(\Rightarrow\) EXIN = .7 influence units), but with potential for overwhelming both group and resistance.
Practical knowledge $EX$ about the impact of ecologically sound behavior is measured on a scale from zero (representing no awareness) to one (representing full awareness) experience units. Practical knowledge $EX$ includes awareness of the effects of care for the environment on the economy, quality of life, health, and the like.

The gap between current knowledge $EX$ and maximum possible knowledge $MEX$ at current level of adoption is assumed to be filled within the period needed to establish facts $EXDE$.
Maximum possible knowledge MEX about effects and side effects of conservationist behavior is assumed to grow quickly with degree of adoption D of such behavior, revealing more consequences and externalities.

EXD.KL=EX.K/EXDT
EXDT=30

EXD - PRACTICAL EXPERIENCE DECAY (EXPERIENCE UNITS/YEAR)
EX - PRACTICAL EXPERIENCE (EXPERIENCE UNITS)
EXDT - PRACTICAL EXPERIENCE DECAY TIME (YEARS)

Experience gained is assumed to become outdated or forgotten over a thirty-year period, requiring new investigation which will be valid for contemporary existing conditions.

D.K=TABLE(DOT,PD.K/RPD,0,20,5)
DOT=0/.38/.6/.72/.8
RPD=1
D - ADOPTION (D'LESS)
DOT - D TABLE (D'LESS)
PD - PRESSURE FOR ADOPTION (PRESSURE UNITS)
RPD - REFERENCE PD (PRESSURE UNITS)
PDₖ = PDₐₖ + PDₐₐₖₖ
PDₐₖ = PRESSURE FOR ADOPTION (PRESSURE UNITS)
PDₐₐₖₖ = PRESSURE FOR ADOPTION MULTIPLIER FROM
ACCEPTANCE (D'LESS)
PDₐₐₖ = PRESSURE FOR ADOPTION MULTIPLIER FROM
INSTITUTIONALIZATION (D'LES)

Adoption D of conservationist behavior -- measured as a fraction of the population -- increases with the pressure for such behavior, arising from personal motivation (internalized acceptance PDₐₖ) and from legal and traditional rules (institutionalized conditioners PDₐₐₖₖ).
PDMA.K=RPDMA*TABLE(PDMAT,A.K,0,1,..)
PDMA=1/2.5/5/8/13/20
RPDMA=1

PDMA  - PRESSURE FOR ADOPTION MULTIPLIER FROM ACCEPTANCE (D'LESS)
RPDMA - REFERENCE PDMA (PRESSURE UNITS)
PDMAT - PDMA TABLE (D'LESS)
A    - ACCEPTANCE (D'LESS)

Desire or voluntary pressure PDMA for adoption grows with acceptance. The power people exert out of conviction is assumed to be twice that of any legislated or traditional pressure.

PDMII.K=RPDMII*INS.K
RPDMII=10
PDMII - PRESSURE FOR ADOPTION MULTIPLIER FROM INSTITUTIONALIZATION (D'LES)
RPDMII - REFERENCE PDMII (PRESSURE UNITS)
INS  - INSTITUTIONALIZATION (D'LESS)

Compulsory pressure PDMII for adoption grows with the extent to which society and its institutions have been adapted to perpetuate the conservation ethic (e.g., through anti-pollution laws).

INS.K=INS.J+(DT/INSAT)(IINS.J-INS.J)
INS=INSI
INSI=0
INSAT=10
INS  - INSTITUTIONALIZATION (D'LESS)
INSAT - INSTITUTIONALIZATION ADJUSTMENT TIME (YEARS)
IINS  - INDICATED INSTITUTIONALIZATION (D'LESS)
INSI - INS INITIALLY (D'LESS)
Institutionalization INS of ecological attitudes is assumed to approach the level indicated by current acceptance IINS over a ten-year period, needed for public debate and institution building. It is measured on a scale from zero to one, intended to represent institutionalization levels compatible with acceptance levels from zero to one.

The level of institutionalization hypothesized as resulting from different levels of acceptance has been given the "step-shaped" form, to mirror the need for a majority to effect major changes in a democracy.
Model Runs

Before turning to a study of the dynamic consequences of the full set of model assumptions, it is useful, for the purpose of comparison, to investigate the growth in acceptance when the group sector is eliminated by fixing the group effort at a value equal to zero throughout the model run. Figure IV-4 exhibits one such simulation of a situation where there is no group promoting environmental concern. Even without the aid of environmentalists, people finally perceive the advantage of the idea and accept it, although there is a lengthy perception delay. The low level of adoption and the consequent slow generation of experience cause the time lag; the perceived advantage reaches 1.5 only twenty years after the growing real advantage exceeds that value.

The situation is quite different in Figure IV-5, which illustrates the result of having a group pressing for an earlier acceptance of conservationism. In this simulation the group initially has success; public perception of the idea's advantage grows rapidly in response to group claims, and acceptance spreads. The group can make emphatic claims without losing credibility because little information is yet available about the practically experienced ("true") advantage of the idea. Claims attract people, giving additional momentum to the group, through direct support and through the increased group enthusiasm resulting from rapid growth in acceptance. Increased pressure for conformity follows a higher level of acceptance, which in turn further increases the perceived advantage of the environmentalist view. However, before long negative forces start to appear, and active resistance builds up in response to higher levels of acceptance and accelerated conversion
Figure IV-6: Higher Group Aspirations.
rates. More reports on practical experience appear, exerting an increasingly negative public influence; negative because the established real advantage has not yet reached the level of the group's positively biased assertions. The new, contradictory information begins to erode group credibility and lessens group impact. In the simulation the erosion occurs simultaneously with a loss of public interest in conservationism: the intense agitation of group, opposition, and media reports finally starts to bore the target population, which turns its attention to other topics. Because environmental concern is not yet internalized among those who have accepted, a decline in acceptance results. The multiplicity of negative forces transforms the emerging decline into a collapse of the conservationist cause, and the collapse is exacerbated by the fall in group enthusiasm (which is caused by the adversity).

Thus ends the brief period of glory for the movement. Later, a new wave of interest and acceptance occurs; this time less because of group effort than because of the now greater advantage of the conservationist idea, established through accumulated experience.

In summary: the group does achieve a degree of increased acceptance above that in Figure IV-4, but at a much later date than if the backlash following the initially swift growth in acceptance had been avoided. Given the objective of rapid acceptance, it would be useful to know whether such a collapse could be transformed (in the model) to a period of continuous growth through changed group policies.

A first suggestion might be to increase the group's aspiration level, in order to induce the members to work harder. Figure IV-6 shows that the only effect (in the model) of having the group aspire for
faster acceptance is a quick reduction in group morale and enthusiasm due to frustration over inability to satisfy aspirations. The minor short-run increase in work output caused by higher aspirations is rapidly counterbalanced by a reduction of effort due to declining enthusiasm. Enthusiasm declines because aspirations are assumed to fall more slowly than enthusiasm in the face of adversity.

A second possibility might be to aim for a quick, widespread acceptance by presenting exaggerated claims for the idea's advantage, in the hope that, the idea, once accepted (albeit on false premises), will remain so due to internalization, institutionalization, or practical experience obtained before the excessive claims are disproved. Figure IV-7 illustrates a short-run success for the policy (in the model) and a longer-run result of rapid and enduring reduction in group credibility and influence.

A third group policy might be to induce greater acceptance by actively trying to exert a stronger influence on public opinion (for example, through more talks, advertising, public meetings and publications). Figure IV-8 shows that the policy fails (in the model) after a short period of rapid growth in acceptance, because the growth leads to overwhelming active resistance. One undesirable side effect is that resistance lingers on long after the initial peak in acceptance, causing a lasting polarization of society. The intense activity of proponents and opponents results in the public's interest in the matter dwindling even further, making it difficult to generate any public enthusiasm about the issue for a long period of time.
Figure IV-7: Higher Group Claims.
Together, the remnants of the initial active resistance and
the public's lack of interest make the subsequent period one of extremely
low acceptance.

The above runs seem to indicate that (in the model) a very
energetic promotion of the cause at an early stage may be counter-
productive. Intense group activity tends to generate much debate, which
finally makes the public immune to the issues involved. This apparently
premature activity also creates adopters and generates practical
experience at a time when the idea is not sufficiently advantageous
to be self-sustaining.

An obvious suggestion would be introduction of the idea with
a more gentle approach. A series of runs (not shown) for various group
effort intensities revealed Figure IV-9 to be "optimal": lower intensities
fail to increase acceptance above the "natural" situation in Figure IV-4
and more intense efforts produce a more accentuated backlash.

Even the "optimal" case exhibits an undesirable backlash,
triggered by boredom with the issue. Such a faltering of interest
can be avoided (in the model) only by a closed-loop policy which maintains
group activity at the highest level possible without taxing public
patience (about 15 influence units); this is illustrated in Figure IV-10.
Such a policy is likely to be infeasible in the real world, particularly
if the opposition decides to limit acceptance by saturation tactics.

A final strategy might be to spend most of the available time
and energy on a few converts, to insure more thoroughly against their
reversion to old views. The strategy of thorough education is shown,
in Figure IV-11, to have good results.
Figure IV-9: "Optimal" Group Influence.
Figure IV-10: Closed Loop Policy Adjusting Group Effort so that total activity never exceeds 15 influence units.
Figure IV-11: More Thorough Education of Converts.
Conclusion

NEWIDEA#12 is a generic model incapable of making detailed predictions of what will actually happen in a given situation. The model runs should be used only to alert oneself to dynamic phenomena that may influence the effectiveness of a policy considered for use by an action group.
The Development of Model Characteristics and Content

Operational Measures for Model Attributes

Table IV-1 contains a summarized description of NEWIDEA#12. The table indicates important choices made with respect to model characteristics: the decision to describe the simuland using 12 levels, inter-related through 11 major loops, in a manner involving 24 table functions and 17 non-linear algebraic expressions and with time constants generally in the range of 4 to 16 years. Table IV-1 also shows the outcome of decision on model content. One may divide the description of the simuland into three categories, one for the descriptors of the promoting group (the group), one for the group's cause (the idea) and one for the target population (the society). Using this classification, 33% of NEWIDEA#12's levels represent aspects of the group, 17% represent the idea, and 50% represent different dimensions of society.

While realizing that NEWIDEA#12 is simply the current stage in a never-ending sequence of better models of the simuland, one may still legitimately ask: Why this particular choice of complexity, time horizon, and model emphasis? Why did we settle on 6 levels to describe society? Why is this model better than the others? While waiting for statistical tests that might prove the possible superiority of the model, one is in the meantime confined to justification of the choice on the grounds that it survived nearly a year of generalized evaluation. NEWIDEA#12 emerged through a long period of observation, pondering, questioning, and reading related to the simuland. It represents what was left
TABLE IV-1: Summary Description of NEWIDEA#12 (two pages)

**Model:** NEWIDEA#12

**Question addressed:** How do available information, group perseverance, and societal institutionalization determine acceptance and stabilization of new views in society?

**Levels:**

<table>
<thead>
<tr>
<th>GROUP:</th>
<th>IDEA:</th>
<th>SOCIETY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group effort</td>
<td>Experienced advantage</td>
<td>Acceptance</td>
</tr>
<tr>
<td>(The group effort toward societal acceptance of idea)</td>
<td>(Advantage of adoption proven through implementation)</td>
<td>(Fraction of society favorable to idea)</td>
</tr>
<tr>
<td>Group credibility</td>
<td>Past activity</td>
<td>Current progress</td>
</tr>
<tr>
<td>(Reliability as judged by society)</td>
<td>(Recent societal flurry related to idea)</td>
<td>(Observed percentage rate of conversions)</td>
</tr>
<tr>
<td>Group enthusiasm</td>
<td></td>
<td>Internalization</td>
</tr>
<tr>
<td>(Willingness to fight for cause)</td>
<td></td>
<td>(Intensity of acceptors' commitment to idea)</td>
</tr>
<tr>
<td>Traditional progress</td>
<td></td>
<td>Institutionalization</td>
</tr>
<tr>
<td>(Recent percentage rate of conversions)</td>
<td></td>
<td>(Extent of incorporation of idea into society's institutions)</td>
</tr>
</tbody>
</table>

**No. of levels:** 12

**No. of major loops:** 11

**Nonlinearities:** 24 table functions, 17 algebraic expressions

**Time constants:**

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>5</th>
<th>5</th>
<th>6</th>
<th>10</th>
<th>10</th>
<th>12</th>
<th>12</th>
<th>20</th>
<th>30</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>time constants occurring scale in years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Organizing concepts:** Reported advantage of adopting new behavior
Average societal perception of advantage
Basic mechanisms: Perceived advantage determined by the influences of group, resistance, and practical experience, each advancing different points of view. Group perseverance increased by success in gaining acceptance. Stabilization of new situation through internalization of new societal view resulting from experienced advantage.

Major change from previous model: Inclusion of group enthusiasm and societal internalization of idea, to increase model versatility.
after evaluation of a mass of suggestions from various sources about what to include, and selection among them. It is a refinement of models that were rejected due to criticism by the work group and outsiders. However, neither fact establishes the validity of NEWIDEA#12, nor its usefulness. It appears that the individual user must make his own judgement of model utility on the basis of how well NEWIDEA#12 matches his view of reality.

However, it is possible to answer the question: How did we arrive at the choices embedded in NEWIDEA#12? What other choices were considered and rejected in the process leading to the current model? This section attempts to answer the "how" question through description and comparison of the eleven discernable models that preceded NEWIDEA#12. The goal is to trace the gradual development of model characteristics and content.

In order to compare models, one must have operational measures for model characteristics and model content. Forrester (Forrester 1968) suggests one possible set of characteristics of feedback systems: order, polarity of feedback, nonlinearity, and loop multiciplicity. A fifth characteristic is the frequency distribution of time constants in the model. Table IV-2 displays the characteristics and measures used to compare models.

It is a less straightforward process to develop measures for model content. A complete description necessitates listing all model levels and the relationships among them. From such a list one could derive: model scope (that is, the position of the system boundary);
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Operational Quantitative Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order</td>
<td>Number of levels</td>
</tr>
<tr>
<td>Polarity of feedback</td>
<td>No simple measure possible when polarity shifts during a model run; hence not used here.</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>Number of table functions and non-linear algebraic expressions</td>
</tr>
<tr>
<td>Loop Multiplicity</td>
<td>Number of &quot;major&quot; causal loops</td>
</tr>
<tr>
<td>Frequency distribution of time constants</td>
<td>Number of time constants in each of a series of time intervals</td>
</tr>
</tbody>
</table>
relative emphasis on different aspects of the simuland; the social mechanisms or processes included; and all other content-related facts. However, the list would be large and unwieldy. To make analysis practicable, the discussion below is restricted to comparison of model levels.

Several aspects of the gradual development of model content can be described even from the short, unambiguously defined list of levels. Comparison of levels is sufficient to establish change among models in model scope and relative emphasis on different sectors. Next, given model scope and the number of descriptors used, one can infer the level of aggregation in the model. Further, knowledge about model levels often gives a good indication of what real-world processes are included in the model; thus analysis of levels will also give some indication about change in model relationships.

Summary descriptions of each model, given below, list the names of all levels, with a brief explanation of their definitions. Each level is assigned to one of three categories, depending on whether it is judged to be a descriptor of the promoting group, its cause, or its target. To assist inference of the scope of each model, the following information is also given: the question addressed, organizing concepts, basic mechanisms, and the major change from the previous model.

Models may be compared along other dimensions. Indices of model validity and predictive capability would be viewed as desirable by many, and much effort is spent to develop such indicators. They are not yet available, however, for high-order, non-linear, feedback models. It would be useful to have measures available for the insight-generating
Table IV-3: Content-related Model Attributes and Operational Measures.

<table>
<thead>
<tr>
<th>Model attribute</th>
<th>Can be inferred from</th>
<th>Operational quantitative measure used here</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope (System Boundary)</td>
<td>Question addressed by model.</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Names and descriptions of levels.</td>
<td></td>
</tr>
<tr>
<td>Relative emphasis on sectors.</td>
<td>Names and descriptions of levels.</td>
<td>Fraction of levels describing different topics</td>
</tr>
<tr>
<td>Aggregation</td>
<td>Questions addressed by model.</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Names and descriptions of levels.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aggregation can be thought of as scope divided by number of levels.</td>
<td></td>
</tr>
<tr>
<td>Other attributes possibly useful for comparison:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
capacity of social system models. One might conceive of a qualitative measure based on how generic the model is, how powerful its organizing concepts are, and how wide the scope of the model is per unit of complexity (i.e., how non-reductionist it is). Again, such measures are not currently available, and are not easily developed.

Summary Description of Eleven Models

Tables IV-4 through IV-14 present summary descriptions of the eleven models that preceded NEWIDEA#12. The measures of model characteristics and content discussed above are included. Each table is followed by a figure depicting the model description (causal diagram or flow diagram) on which the table is based, and, when available, a computer run showing the standard model behavior. Additional information about the models can be found in Appendix A, containing program listings and variable definitions for those models that actually were run on the computer (MOVEMENT#3, LIFE_CYCLE#4, HELPORG#5, CIC#6, ADOPTION#10, PROHIBITION#11, and NEWIDEA#12). Extensive verbal descriptions of MOVEMENT#3 and COMMITMENT#8 exist in two project reports, (Randers November 1972) and (Randers April 1973).

The following comments seem in order regarding the summary descriptions:

i) Subjective judgement was used to split the levels into the group, idea, and society categories.

ii) Delays were considered independent levels.

iii) When a flow diagram was unavailable, the system levels were selected on the basis of the causal diagram. The choice
is indicated by the rectangles added to the causal diagrams during the writing of this report. The rectangles represent the only changes made.

iv) The estimate of major loop multiplicity is not exact, due to definitional problems regarding what constitutes a separate, major loop.

v) The number of table functions and non-linear algebraic expressions is a rough measure of nonlinearity. Each rate and auxiliary involving a non-linear combination of variables was counted as a non-linear algebraic expression.

vi) The distribution of time constants is not constant through time because of common occurrences of variable time constants. The given distributions are approximations usable in the operating region covered in the standard model run. One time constant was included for each level and delay. For levels with multiple rates, an attempt to estimate the effective time constant was made, usually by choosing the smallest time constant.

vii) Nonlinearity and frequency distribution of time constants could not be assessed when flow diagrams were unavailable.

* * *
TABLE IV-4: Summary Description of ACCEPTANCE#1

Model: ACCEPTANCE#1

Question addressed: What are the positive and negative societal forces affecting acceptance of an idea?

Levels:

<table>
<thead>
<tr>
<th>GROUP: Propaganda (Current pro-idea information density in society)</th>
<th>IDEA: Perceived practicability (Feasibility of the idea in terms of improving conditions, as judged by society) Familiarity (Extent of societal exposure to idea)</th>
<th>SOCIETY: Acceptance of idea (Fracture not opposing idea) State of affairs (Societal condition to be improved by idea) Perceived system state (Conditions as perceived by society) Desired system state (Conditions seen as optimal) Implementation effort (Active effort to practical testing of the idea) Counter-propaganda (The active opposition against the idea)</th>
</tr>
</thead>
</table>

No. of levels: 9
No. of major loops: 7
Nonlinearities: Not available
Time constants: Not available

Organizing concepts: Acceptance of the idea in society, the perceived problem addressed by the idea.

Basic Mechanisms: The positive and negative societal feedback processes affecting acceptance: propaganda pro and con, conformity pressure, familiarity, proven reliability and perceived need for the new idea to improve conditions.

Major change from previous model: Does not apply.
Figure IV-12: ACCEPTANCE#1 as of 8/31, 1972.
TABLE IV-5: Summary Description of GROUPACTIVITIES#2 (two pages)

<table>
<thead>
<tr>
<th>Levels</th>
<th>GROUP</th>
<th>IDEA</th>
<th>SOCIETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model:</td>
<td>Promoting new behavior (no. of persons actively proselytizing)</td>
<td>Situation achievable by procedure (The result of implementing idea)</td>
<td>Actual situation (The condition to be improved by idea)</td>
</tr>
<tr>
<td>Question addressed:</td>
<td>Group cohesion (Smoothness of collaboration)</td>
<td>Transition cost of procedure (Psychological and other costs of behavioral change)</td>
<td>Awareness (Societal knowledge about relevant realities)</td>
</tr>
<tr>
<td>Levels:</td>
<td>Motivation (Group member dedication to cause)</td>
<td>Perceived transition cost (Society's perception of costs)</td>
<td>Visibility of procedure (Extent to which the new idea is commonly known)</td>
</tr>
<tr>
<td></td>
<td>Centralization of leadership (Extent of central authority in group)</td>
<td>Induced discussion (Current activity surrounding idea originating outside group)</td>
<td>Traditions (no. of persons behaving in old way)</td>
</tr>
<tr>
<td></td>
<td>Effort allocated to increasing cohesion</td>
<td></td>
<td>Behavers (no. of persons behaving consistent with new idea)</td>
</tr>
<tr>
<td></td>
<td>Effort allocated to increasing situation achievable by procedure</td>
<td></td>
<td>Recent progress (Recent change in no. of behavers)</td>
</tr>
<tr>
<td></td>
<td>Effort allocated to increasing awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effort allocated to increasing visibility of procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effort allocated to increasing sustainable effort</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effort allocated to decreasing transition cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of levels:</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of major loops:</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonlinearities:</td>
<td>Not available</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE IV-5 p.2

<table>
<thead>
<tr>
<th>Time constants:</th>
<th>Not available</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organizing concepts:</strong></td>
<td>Sustainable effort of the total manpower of the group. Group strategy as a specific allocation of effort among possible group activities.</td>
</tr>
<tr>
<td><strong>Behavioral mechanisms:</strong></td>
<td>People moving from traditionalists via behavers to promoters and back. Strategy formation aimed at maximization of perceived utility of group. Perceived marginal utility based on earlier experience. Change to new behavior entailing a time varying utility for converts of the general shape:</td>
</tr>
<tr>
<td>![Diagram of utility over time]</td>
<td>More detail in description of societal processes affecting acceptance, in order to achieve deeper understanding. Emphasis on the promoting group, its dynamic strategy formation process and the effect on the gains in the different loops of ACCEPTANCE#1.</td>
</tr>
</tbody>
</table>
Figure IV-13: GROUPACTIVITIES#2 as of 10/2, 1972
(page 1 of 3)
Figure IV-13: GROUPACTIVITIES#2 as of 10/2, 1972
(page 2 of 3)
**TABLE IV-6: Summary Description of MOVEMENT#3**

**Model:**

MOVEMENT#3

**Question addressed:** What determines QME and QAE (the milieu) and hence the growth of a movement?

**Levels:**

GROUP:
- Actors
  - (No. of persons actively promoting change)
  - Average actors entering
    - (Recently hired actors)
  - Actors finishing training
    - (Apprenticeship terminations)
- Actor suitability
  - (Ability and dedication of actors)
- Actor group cohesion
  - (Smoothness of collaboration)
- Centralization of decision power
  - (Extent of central authority in group)
- Performance standard
  - (Traditional actors' payoff per unit of expended effort)
- Experienced excess adversity
  - (Recent unusually small payoff from toil)
- Movement credibility
  - (Group reliability)

QAE observed
- (Actors' perception of satisfaction)

QAE reported
- (Others' impression of actors' satisfaction)

Perceived workload
- (Actors' impression of stress)

IDEA:
- Platform relevance
  - (Ability to improve situation)

Perceived platform relevance
- (Relevance as seen by non-members)

Perceived entry cost
- (Psychological and other costs of change)

QME observed
- (Members' perception of satisfaction)

QME reported
- (Others' impression of members' satisfaction)

Average discussion activity
- (Current activity surrounding idea originating outside group)

SOCIETY:
- Non-members
  - (No. of persons opposing or indifferent to idea)
- Members
  - (No. of persons having changed behavior but not proselytizing)

Perceived member fraction
- (Opponents' estimate of group support)

Average membership duration
- (Typical time between joining and retraction)

Average persons joining
- (Recent new members)

Average persons retracting
- (Recent member withdrawals)

Visibility
- (Extent to which idea is commonly known)
TABLE IV-6 p. 2

No. of levels: 25
No. of major loops: 920
Nonlinearities: 61 table functions, 32 algebraic expressions
Time constants: 0 1 2 3 3 3 3 5 5 5 5 10 12 16 30 45 75 occurring

Organizing Concepts: Quality of actor experience (QAE)
Quality of member experience (QME)
QAE and QME measure the satisfaction achieved from the movement by actors and members respectively.

Basic mechanisms: The determination of QAE from commitment to platform, work overload, peer dedication, feeling of accomplishment, perceived organizational flexibility, agreement on goals, group status, and perceived success. The determination of QME from perceived relevance of new behavior, satisfied expectations, perceived ability to affect change and satisfaction of wants.

Major change from previous model: A stronger emphasis on the feelings of those involved with the group, which was seen as a fruitful topic. The dynamic allocation of effort replaced by a fixed strategy, in order to temporarily simplify the model.
Figure IV-15: MOVEMENT#3 simulation runs.
(page 1 of 4)
Figure IV-15: MOVEMENT#3 simulation runs.
(page 3 of 4)
<table>
<thead>
<tr>
<th>Present</th>
<th>IA</th>
<th>IACO</th>
<th>IASU</th>
<th>IH</th>
<th>IHF</th>
<th>IV</th>
<th>IAE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000.T</td>
<td>1.250</td>
<td>1.250</td>
<td>1.800</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
</tr>
<tr>
<td>Original</td>
<td>1000.T</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
<td>2.000</td>
<td>5.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Present</th>
<th>6.000</th>
<th>51.50</th>
<th>1.400</th>
<th>2.100</th>
<th>1.700</th>
<th>-1.00</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>5.000</td>
<td>50.00</td>
<td>1.500</td>
<td>2.000</td>
<td>1.700</td>
<td>-1.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Present</th>
<th>TFE</th>
<th>FEFA</th>
<th>FAEE</th>
<th>FEE</th>
<th>FEE</th>
<th>0.00</th>
<th>0.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>6.000</td>
<td>9.000</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

PAGE 13

MOBMENT 3 6/26/73 MORE EFFORT TO SERVICE PRODUCTION

A=U, H=H, QAE=1, QME=2, SE=S, V=V, ASU=U, PF=F, ACO=U, PF=F

![Diagram](Image)
TABLE IV-7: Summary Description of LIFECYCLE4 (two pages)

Model: LIFECYCLE4

Question addressed: How do milieu and strategy formation in a movement interact to determine its lifecycle?

Levels:

GROUP:
- Leaders
  (No. of persons promoting the cause full-time)
- Perceived leader satisfaction
  (Leaders' evaluation of own situation)
- Fraction to satisfaction of leaders
- Fraction to short-term satisfaction of members
  (Fraction of total manpower allocated to serving leaders and members)
- Average effort to long-term satisfaction of members
- Average effort to satisfaction of leaders
  (Recent manpower allocated to serving leaders and members)

IDEA:
- Perceived member satisfaction
  (Members' evaluation of their own situation)
- Member satisfaction standard
  (Typical recent satisfaction)

SOCIETY:
- Non-members
  (No. of persons opposing indifferent to idea)
- Members
  (No. of persons who have joined movement but do not promote the cause full-time)

No. of levels: 10
No. of major loops: 8
Nonlinearities: 10 table functions, 9 algebraic expressions
Time constants: 0 1 1 1 1 2 4 4 5 6 15 32 *10^4 time constants occurring scale in years

Organizing concepts: Sustainable effort. Member satisfaction. Leader satisfaction.
TABLE IV-7 p.2

Basic Mechanisms: Flows of people from non-members via members to leaders and back.
Member satisfaction determined by short-term and long-term efforts by leaders
and by the size of the movement. Leader satisfaction determined by efforts
to training, development of platform etc. and by the size of the leadership
group.

Major change from previous model: Much higher level of aggregation, to achieve simplification. Dynamic strategy
formation reintroduced, to obtain interesting dynamics.
Figure IV-17: LIFECYCLE#4 standard run.
TABLE IV-8: Summary Description of HELPORG#5 (two pages)

Model: HELPORG#5

Question addressed: How do quality of service and strategy formation interact to determine the growth of a helping organization?

<table>
<thead>
<tr>
<th>Levels</th>
<th>GROUP:</th>
<th>IDEA:</th>
<th>SOCIETY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff</td>
<td>Perceived user satisfaction (Client satisfaction judged by potential clients)</td>
<td>Users waiting (Backlog of accepted clients)</td>
<td></td>
</tr>
<tr>
<td>(No. of trained persons in group)</td>
<td>Average waiting time (Delay between accepting and serving a client)</td>
<td>Relevance of platform (The quality of the group knowledge base)</td>
<td></td>
</tr>
<tr>
<td>Trainees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(No. of persons being trained)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average training duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Typical educational period)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff suitability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Quality of trained personnel)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived staff satisfaction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Staff satisfaction as judged by potential staff)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived utilization of staff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Management's perception of staff workload)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived indicated change in number of employees</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Change in staff size considered reasonable)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived budget surplus fraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Recent surplus to income ratio)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraction to user servicing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Fraction of staff time used to serve clients)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levels: (cont'd)</td>
<td>GROUP:</td>
<td>IDEA:</td>
<td>SOCIETY:</td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Fraction to staff development</td>
<td>(Fraction of staff time used to educate trainees)</td>
<td>Energy per user</td>
</tr>
<tr>
<td></td>
<td>(Staff time spent on each client)</td>
<td>Average users serviced (Client projects completed recently)</td>
<td></td>
</tr>
</tbody>
</table>

| No. of levels: | 16 |
| No. of major loops: | 15 |

| Nonlinearities: | 16 table functions, 18 algebraic expressions |
| Time constants: | \[0.25, 0.5, 0.5, 0.5\] |
| Organizing concepts: | Effort to staff development, user servicing, and long-term platform improvements. Waiting time. |
| Basic Mechanisms: | Dynamic allocation of effort to most critical activity. Staff growth determined by sufficient funds and satisfaction of staff. User satisfaction determined by quality of staff, platform, conformity pressure, and waiting time. |
| Major change from Previous model: | Elimination of people flows, to avoid an uninteresting mode. More emphasis on practical, concrete variables, to achieve connection with reality. |
Figure IV-19: HELPORG/5 standard run.
**TABLE IV-9: Summary Description of CIC#6**

<table>
<thead>
<tr>
<th>Model:</th>
<th>CIC#6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question address:</td>
<td>What basic mechanisms generate the observed behavior of the Corporate Information Center?</td>
</tr>
<tr>
<td>Levels:</td>
<td>GROUP: Energy per user (Man-days spent on each client)</td>
</tr>
<tr>
<td></td>
<td>IDEA: Perceived user satisfaction (Client satisfaction as judged by potential clients)</td>
</tr>
<tr>
<td></td>
<td>SOCIETY: Users waiting (Backlog of accepted clients)</td>
</tr>
<tr>
<td>No. of levels:</td>
<td>4</td>
</tr>
<tr>
<td>No. of major loops:</td>
<td>3</td>
</tr>
<tr>
<td>Nonlinearities:</td>
<td>4 table functions, 4 algebraic expressions</td>
</tr>
<tr>
<td>Time constants:</td>
<td>0            1   2   4   8   16   32 time constants occurring</td>
</tr>
<tr>
<td>Organizing concepts:</td>
<td>Attention given to each client.</td>
</tr>
<tr>
<td>Basic mechanisms:</td>
<td>Energy per user determining service capacity both through short-term and long-term effects.</td>
</tr>
<tr>
<td>Major change from previous model:</td>
<td>Focus on only one of the several processes included in HELPORG#5, to simplify interpretation</td>
</tr>
<tr>
<td>Model: MORALE#7</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>Question addressed: What determines movement morale and how can it be maintained in adversity?</td>
<td></td>
</tr>
<tr>
<td>Levels:</td>
<td></td>
</tr>
<tr>
<td>GROUP:</td>
<td></td>
</tr>
<tr>
<td>Work load per person</td>
<td></td>
</tr>
<tr>
<td>(Output per group member)</td>
<td></td>
</tr>
<tr>
<td>Group morale</td>
<td></td>
</tr>
<tr>
<td>(Enthusiasm of group members)</td>
<td></td>
</tr>
<tr>
<td>Group institutionalization</td>
<td></td>
</tr>
<tr>
<td>(Extent of formal organization)</td>
<td></td>
</tr>
<tr>
<td>Level of expectations</td>
<td></td>
</tr>
<tr>
<td>(Group aspirations regarding rate of societal change)</td>
<td></td>
</tr>
<tr>
<td>IDEA:</td>
<td></td>
</tr>
<tr>
<td>Group position</td>
<td></td>
</tr>
<tr>
<td>(The point of view espoused by the group)</td>
<td></td>
</tr>
<tr>
<td>SOCIETY:</td>
<td></td>
</tr>
<tr>
<td>Societal position</td>
<td></td>
</tr>
<tr>
<td>(Society's current point of view)</td>
<td></td>
</tr>
<tr>
<td>Commitment to current position</td>
<td></td>
</tr>
<tr>
<td>(Society's dedication to current views)</td>
<td></td>
</tr>
<tr>
<td>No. of levels: 7</td>
<td></td>
</tr>
<tr>
<td>No. of major loops: 210</td>
<td></td>
</tr>
<tr>
<td>Time constants: Not available</td>
<td></td>
</tr>
<tr>
<td>Organizing concepts: Group enthusiasm with respect to its cause</td>
<td></td>
</tr>
<tr>
<td>The gap between group's view and society's view</td>
<td></td>
</tr>
<tr>
<td>Basic mechanisms: Morale determined by progress in closing gaps relative to expected progress and by the quality of the group members. The dedication of those attracted to group dependent on the current characteristics of the cause. Adversity resulting in adjustment of group's view toward society's view.</td>
<td></td>
</tr>
<tr>
<td>Major change from previous model: Shift to emphasis on the determinants of group perseverance, in order to study what seemed the main attribute of any voluntary organization, viz. high dedication and morale.</td>
<td></td>
</tr>
</tbody>
</table>
Figure IV-22: MORALE#7 as of 2/21, 1973.
<table>
<thead>
<tr>
<th>Model: COMMITMENT#8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question addressed: How do the commitments of a group to its cause (the new idea) and society to its behavior affect the widespread adoption of a new behavior?</td>
</tr>
</tbody>
</table>

### Levels:

#### IDEA:
- **Group effort** (Effort expended by group members)
- **Accumulated effort** (Total effort over last years)
- **Group authority** (Credibility as judged by society)
- **Effective group pressure** (Influence of group in changing society)
- **Basic dedication** (Group members' belief in cause)
- **Group perception of recent improvement** (Group assessment of utility increase resulting from recent behavior change)
- **Perceived stress** (Recent failure in satisfying group aspirations)
- **Group aspirations** (Group expectations about time necessary to convert society)

#### SOCIETY:
- **Societal behavior** (Society's position on a one-dimensional scale of possible behaviors)
- **Recent behavior change** (Recent motion of society along scale of behaviors)
- **Counterculture** (Organized defense of status quo)
- **Self-propogation pressure** (Tendency of societal change toward increased utility)
- **Societal perception of recent improvement** (Society's assessment of utility increase resulting from recent behavior change)

<p>| No. of levels: | 15 |
| No. of major loops: | 38 |
| Nonlinearities: | Not available |</p>
<table>
<thead>
<tr>
<th>Time constants:</th>
<th>Not available</th>
</tr>
</thead>
</table>
| Organizing concepts: | Group's commitment to the espoused behavior.  
Society's commitment to its current behavior.  
Utility of behavior change as judged by group, society, and through experience.  
Societal behavior seen as a moving point in this graph: |
| Basic mechanisms: | The rate of change of societal behavior determined by the pressure arising from the promoting group, from the opposition and from society's tendency to move toward greater utility. Group commitment maintaining group effort. Commitment determined by members' dedication, by extent of recent adversity or success, and by group inertia due to size or age of group. Society's commitment to current behavior dependent on perceived recent improvements, formed on the basis of experience and group propaganda. |
| Major change from previous model: | Increased emphasis on distortion of information, to include the possibility of acceptance of ideas that do not actually solve problems although believed to do so. |
Figure IV-23: COMMITMENT#8 as of 3/29, 1973.
TABLE IV-12: Summary Description of ATTRACTIVENESS

<table>
<thead>
<tr>
<th>Model: ATTRACTIVENESS#9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question addressed: How do group and societal satisfaction affect the perceived attractiveness of a new idea?</td>
</tr>
<tr>
<td>Levels: GROUP: Group expectations (Aspirations regarding rate of acceptance) Group visibility (Extroverted group effort) Group credibility (Reliability as judged by society) IDEA: Adopter satisfaction (Adopters' perception of own utility) SOCIETY: Societal awareness (General knowledge about issue) Adoption (Extent of behavior change in society) Institutionalization (Institutional compatibility with idea) Non-adopter satisfaction (Non-adopters' perception of own utility) Societal conditions (The state of relevant aspects of the world)</td>
</tr>
<tr>
<td>No. of levels: 9</td>
</tr>
<tr>
<td>No. of major loops: 214</td>
</tr>
<tr>
<td>Nonlinearities: 28 table functions, 14 algebraic expressions</td>
</tr>
<tr>
<td>Time constants: Not available</td>
</tr>
<tr>
<td>Organizing concepts: Attractiveness of further adoption as judged by society. Societal inertia or momentum, due to satisfaction with or institutionalization of status quo.</td>
</tr>
<tr>
<td>Basic mechanisms: Change in adoption resulting from attractiveness overpowering inertia. The amount of group effort aimed at persons outside the group dependant on group morale, determined in turn by success in achieving goals.</td>
</tr>
<tr>
<td>Major change from previous model: No longer variable idea (i.e. the espoused behavior is assumed fixed), to simplify formulation. Replacement of the &quot;sum of forces&quot; description of social change with an &quot;attractiveness&quot; concept, to obtain a description in terms of variables more closely related to the information inputs used in real-world decision making.</td>
</tr>
<tr>
<td>Levels:</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>GROUP:</td>
</tr>
<tr>
<td>Visibility</td>
</tr>
<tr>
<td>(Extroverted group effort)</td>
</tr>
<tr>
<td>Credibility</td>
</tr>
<tr>
<td>(Group reliability judged by society)</td>
</tr>
<tr>
<td>Traditional accomplishment</td>
</tr>
<tr>
<td>(Recent rate of acceptance)</td>
</tr>
<tr>
<td>IDEA:</td>
</tr>
<tr>
<td>Experienced advantage</td>
</tr>
<tr>
<td>(Advantage proven in practical implementation)</td>
</tr>
<tr>
<td>SOCIETY:</td>
</tr>
<tr>
<td>Societal resistance</td>
</tr>
<tr>
<td>(Opposition against group)</td>
</tr>
<tr>
<td>Acceptance</td>
</tr>
<tr>
<td>(Fraction of society behaving in new way)</td>
</tr>
<tr>
<td>See organizing concepts below</td>
</tr>
<tr>
<td>Institutionalized behavior</td>
</tr>
<tr>
<td>(Extent of adaptation of society's institutions to idea)</td>
</tr>
<tr>
<td>Average activity</td>
</tr>
<tr>
<td>(Ongoing implementation of idea)</td>
</tr>
<tr>
<td>Recent change</td>
</tr>
<tr>
<td>(Observed rate of change of acceptance)</td>
</tr>
</tbody>
</table>

| No. of levels: | 9 |
| No. of major loops: | 11 |
| Nonlinearities: | 19 table functions, 8 algebraic expressions |
| Time constants: | 0 1 1 2 2 3 3 4 4 6 6 8 8 10 10 16 16 32 32 scale in years |

Organizing concepts: Acceptance (Note that "acceptance" in this model is defined to imply behavior change and hence is equivalent to what we called "adoption" in NEWIDEA#12). Perceived advantage of changing behavior. Reliance on experience as an information source.

Basic mechanisms: Society's perception of advantage formed on basis of practical societal experience with, and group promotion of idea. Group effort determined by progress in acceptance, by intensity of resistance and by expected societal gain from further acceptance.
Figure IV-25: ADOPTION#10 as of 4/22, 1973
### TABLE IV-14: Summary Description of PROHIBITION#11

**Model:** PROHIBITION#11

**Question addressed:** What were the major forces causing adoption of prohibition in the U.S., 1920-1933?

**Levels:**
- **GROUP:**
  - Group pressure
  - (Extroverted group effort)
  - Credibility
  - (Group reliability judged by society)
- **IDEA:**
  - Experienced advantage
  - (Advantage proven in practical implementation)
- **SOCIETY:**
  - Active resistance
  - (Opposition against idea)
  - Acceptance
  - (Fraction of society favoring idea)
  - Institutionalized behavior
  - (Extent of adaptation of society's institutions to idea)
  - Experience
  - (Recent practical implementation activity)

**No. of levels:** 7

**No. of major loops:** 6

**Nonlinearities:** 9 table functions, 3 algebraic expressions

**Time constants:**

<table>
<thead>
<tr>
<th>Time constants occurring</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>2</th>
<th>2</th>
<th>4</th>
<th>4</th>
<th>6</th>
<th>12</th>
<th>15</th>
<th>16</th>
<th>32</th>
<th>scale in years</th>
</tr>
</thead>
</table>

**Organizing concepts:** Acceptance of idea; acceptance defined as positive inclination toward adopting compatible behavior.

**Basic mechanisms:** Perceived advantage determined by the influences of group, resistance, and experience, each advancing a different point of view.

**Major change from previous level:** Omission of all factors unnecessary to generate a 13 year prohibition period, in order to simplify understanding. Distinction between acceptance of idea and adoption of behavior.
Figure IV-28: PROHIBITION#11 standard run.
Development Trends

A superficial review of the model summaries reveals the extent to which a system dynamics model changes throughout the initial modeling stage. The summaries demonstrate the wide variety of alternative formulations that were rejected through generalized evaluation before one formulation, a very early version of NEWIDEA#12, quite similar to PROHIBITION-#11, was found worthy of entry into the improvement stage. This does not mean that NEWIDEA#12 is a finished product; it can easily be improved through continued generalized evaluation and subsequent changes, without encountering decreasing returns and without resorting to statistical tests.

Plotting the information in Tables IV-4 through IV-14 versus time gives a better perspective on the gradual development of model characteristics over time. Because of the inherent inaccuracy in the underlying information one should not draw conclusions from detailed idiosyncracies of the plots. It is for the same reason that only gross indices are plotted.

Figure IV-29 shows the trends in several measures of model. Developments in number of levels, nonlinearities and major loops are similar, indicating an interesting constant proportionality among the entities (approximately one loop and two nonlinearities per level). The time pattern indicates how, starting from a simple model, the study developed through a phase of extreme complexity to increasingly simple models around the turn of the year. Another period of complex models was succeeded by several simple models, and NEWIDEA#12 appears in this graph as a third start toward more complex description of the simuland. The trend curve
Figure IV-29: Trends in Model Complexity
indicates the continuity in the generalized evaluation procedure that led to the choice of complexity incorporated in NEWIDEA#12. The graph might be interpreted as describing a process approaching a certain goal (the complexity represented by about ten levels) through damped oscillations.

Figure IV-30 depicts the time trends in the frequency distribution of time constants, demonstrating a continuing emphasis on processes with time constants between .5 and 5 years. The graph is ambiguous due to lack of data for those models that were not run on the computer, but seems to indicate a shortening of the time horizon around the turn of the year.

By dividing the number of levels in the group, idea, and society categories respectively by the total number of levels for each model, one can obtain Figure IV-31. Given the large variation in model complexity and the question addressed, the graph shows an astonishing continuity in the relative emphasis put on the three elements of the simuland. The figure shows that the current distribution of levels (33, 17, and 50 percent describing group, idea, and society respectively) is the end point of an evolution process in which an early emphasis on societal descriptors was followed by a period of focusing on internal group processes, before more balanced models again prevailed. At the peak (HELPORG#5) the study was almost solely centered on group processes; less than 10% of the levels were related to society. The dynamic description of the idea was always constrained to between 10 and 25 percent of the levels.

Turning to a more detailed description of model content, Figure
Figure IV-30: Trends in Frequency Distribution of Time Constants.
Figure IV-31: Trends in Model Emphasis.
IV-32 shows classification of model levels into finer categories of topics. On the basis of the classification scheme employed, it is seen that the early phases of the study exhibited a reductionist emphasis on specific internal process (Models #2 through #5). The majority of levels focused on a few issues pertaining to the group. The later models had a broader scope and were more balanced in the sense that their levels were distributed over most of the topic categories. The later models were also more aggregate: a few levels covered a wide range of topics. One might interpret the diagram as saying that the process of generalized evaluation filtered away most early levels and caused the introduction of several new ones, in a way which led to a model consisting of few, but essential, levels describing a wide scope at a high level of aggregation.

Figure IV-32 illustrates the dynamic process by which a subject entered the study (due to some reason), to stay in until it was decided through generalized evaluation to omit discussion of it. The process is apparently relatively continuous; once introduced, a topic usually lasted through several models. The continuity is even more visible when following individual level names from model to model. The reluctance to exclude variables and processes whose conception was laborious, and

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1. The categories are considered collectively exhaustive and mutually exclusive. The split of levels among topic categories was based on judgement. The reader can check that judgement by noticing that the levels in Tables IV-4 to 14 were allocated to topic categories sequentially from the top down, and the first letter in the level's name was entered in the box judged appropriate in Figure IV-7. For the second, third, etc. occurrence of that letter, an index 1, 2, etc., was added to the letter.
Figure IV-32: Distribution of Levels Over Topics through Time
which originally were viewed as breakthroughs in insight, was probably a factor in the graduality of changes between models.

There are several reasons for a topic's entrance into the process at some point in time. The topic may be judged to be "obviously" important. It may be needed for completeness, that is, in order to close a feedback loop, or to increase realism. It may be necessary to generate a desired behavior mode. The topic may also enter in response to a hint to the modeler originating from critics, the literature, or observation of the real world. A topic may be included to please some observer.

The topic may be dropped because a change in the question addressed makes it irrelevant, or because changes in level of aggregation make it too detailed. The topic may also disappear if intuition or computer experiments prove that the topic is unnecessary for generating the desired modes. Finally, a topic may disappear because the modeler does not manage to fit it into a new framework.

A topic may be rejected and then enter anew, if intervening experience forces the modeler to change his decision.

The expectation is that truthful use of the criteria for the generalized evaluation procedure (list in Ch. III) will make the continuing process of a topic's entry into and disappearance from a study, one of ultimate convergence toward a better model.
CHAPTER V

ANALYSIS OF THE CASE AND EMERGING GUIDELINES

The two preceding chapters have traced the development of one modeling effort which probably exhibited a typical mixture of confusion and progress. The ten month sequence of various modeling activities, of continuously shifting study focus, and of steadily evolving model characteristics and content has been described.

The effort remained in the initial modeling stage for nine of the ten months. During these nine months continuous attempts were made at creating an initial model worthy of advancement to the improvement stage. Each tentative model was subjected to generalized evaluation, using the criteria listed in Chapter II, to determine its suitability as a basis for elaboration and extension. The eleven models described in Chapter IV were among those that failed to pass this test. The quality of the tentative models increased as the work-group gained more experience, and finally the basic structure of NEWIDEA#12 was conceptualized and judged to be acceptable. The current version of NEWIDEA#12 is an elaboration and extension of the original basic structure, attained over a month of iterations in the improvement stage. The improvement was also guided by generalized evaluation of suggested alterations.

The effort embraced most of the modeling activities listed in Table II-1. Extensive efforts were spent on the exploration, verbal description, and causal diagramming activities, all part of the
conceptualization phase. Evaluation of tentative models was very time-consuming. Less time was spent on defining the question, or on describing the dynamic behavior of interest. Prior to the entry of NEWIDEA#12 into the improvement stage, little time was spent on formulation activities.

Looking back, it seems that nine months of continuous iteration, simply to achieve an acceptable initial model, is a waste of time (although experience indicates that few models are conceptualized in shorter periods of time). Can anything be done to speed up the process? Is it possible to reduce the number of iterations? Even a cursory glance at the chronology in Chapter III suggests that much of the iteration was due to lack of a well-defined question. Later, after failure with the overly complex MOVEMENT#3, excessive fear of complex models led to hopeless attempts at squeezing a myriad of social mechanisms into one simple model: more futile iterations resulted. It appears that a critical review of the chronology could lead to identification of additional dysfunctional tendencies related to the process and thereby to guidelines for more effective modeling behavior.\(^1\) The objective of this chapter is to present a two-stage analysis, first identifying undesirable

\(^1\)Another use of the descriptive material in Chapters III and IV would be an analysis with the focus on the organizational aspects of the chronology. The author can be seen as a consultant entering the client organization (the work group). Client and consultant each have their own share of expertise (system dynamics and social change) and hence ability to influence the other party (expert power). In this view, excessive iteration might be a result of shifts in leadership among two equally strong parties, who each have rather different goals for their participation in the modeling project. Much of the material in the author's diary would be suitable for organizational analysis of the effort.
tendencies and then suggesting remedies.

The two-stage analysis amounts to a study of a complex, non-linear social system, using mental models. The work group, attempting to construct a model of social change, is itself a social system. Over the ten-month project period the work-group system exhibited the dynamic behavior illustrated in Figure III-1. The depicted behavior can be viewed as the reference mode. Identifying the reasons for the observed behavior (that is, the tendencies at work) is equivalent to searching for the basic mechanisms assumed to underly the reference mode. Representation of these tendencies in a formal model of the group's model-building behavior would make possible a test of the dynamic hypothesis that the dysfunctional tendencies actually do reproduce the observed behavior. The model could also be used for policy experiments to determine guidelines for effective group behavior.

No model of the work group will be built, however, and so the dynamic hypothesis can be defended only by using verbal logic, while intuitive reasoning must form the basis for the proposed guidelines. The results derived in this chapter appear reasonable, but knowing all too well the risks involved in using linear reasoning in complex feedback systems, the author feels that the support of a formal model in the derivation procedure would have been comforting.

**Hypotheses on the Pressures Responsible for the Observed Chronology**

In Chapter III the modeling effort was described as one sequence of activities. The several transitions from one activity to the next
did not occur without a reason. The reason given in the account of the effort was the one which was perceived as critical at the time the transition occurred. However, the perceived rationales were not the only reasons for the actual chronology of the project. Other pressures affected the development although they were not consciously recognized as such at the time. This section describes pressures or tendencies that appear to have been operative. The pressure were inferred from the trends of the project, as summarized in the various time-plots in Chapters III and IV.

If the goal of a project is the quick achievement of a simple, productive model, focusing on the essentials of the simuland, the following list of tendencies serves as a warning about undesirable modeling behavior. In principle, the tendencies are specific to our modeling effort; the list is not exhaustive of problems a project may exhibit. Nevertheless the list may help other projects avoid at least one set of difficulties.

_Tendency to ramble due to lack of an explicit goal._ The first task of any modeling study is to define the goal of the effort.

Possible goals were explored during the first weeks of our effort and the question of purpose and topic was resolved to the work group's satisfaction. Apparently the goal discussions were terminated prematurely, without sufficiently explicit formulation or agreement. Consequently, the ensuing modeling process was troubled by frequent
changes in model focus; by difficulties in choosing alternative formulations; and by disagreement among work group members on whether the model was "finished." The rambling which resulted from the diffuse-ness of our goal is obvious in the account of the study process, particularly in the description of recurrent doubts about current objectives. The variety of questions addressed by the several models (listed in Table III-1) is another factor supporting this conclusion.

Tendency to make excessively complex models to avoid inadvertent omission of important elements. The simplest and safest response to uncertainty about whether a variable is important is to include it in the model. One thereby evades challenging one's ignorance in an attempt to select the few important factors; one avoids the easily formulated, and hence common, criticism of omission.

Our study exhibited strong and enduring tendencies toward extreme complexity, for the above reasons, which were aggravated by the lack of a clearly expressed goal. The mode of operation of the work group was "to see whether the effect is in the model," and if not, to include it. The resulting maze of detail is perhaps most obvious in GROUPACTIVITIES#2 (See Figure IV-13). The persistence of the tendency is evident from the complexity trends depicted in Figure IV-29; while few successful system dynamics models have had more than ten levels, our models often had fifteen levels.
Tendency to exclude too much detail subsequent to failures with overly complex models. In a field of inquiry devoid of guidelines one can learn only through the negative feedback of experience. In response to failures with excessive complexity, one makes simpler models. Lacking knowledge about what constitutes reasonable complexity, one may well overreact and thereby slow down progress toward flawless performance.

The "damped fluctuations" exhibited by the model complexity trend (Figure IV-29) portray an inefficient learning process where experience with overly complicated structures led to a focus on excessive-ly simple models, followed by another overshoot of the final level of complexity.

Tendency to contract the scope of the model to make a complete, respect-able analysis feasible. If one restricts attention to a narrowly de-fined system boundary, it is possible to include all elements of the system commonly viewed as relevant, without running into excessive complexity. No difficult choices among variables and relations need be faced, and the study attains an air of impresgnable completeness and respectability.

The first half of our study exhibited clear tendencies toward reductionist questioning. Starting from an interest in the broad sweep of societal value change, the effort focused increasingly on the promoting group (Figure IV-31), then on the even more limited subject of group strategy and milieu (Figure IV-32) which was at the end restricted to
one particular action group. The time horizon of the study was reduced as well (Figure IV-30). The evident driving force behind the trend was the work group's uneasiness about producing a model excluding apparently relevant, although not necessarily important, factors. There was a recurrent worry that the models did not have sufficient depth (i.e., incomprehensibility to outsiders) to warrant external acceptance. The models made during the last half of the effort were more aggregated due to peer pressure inside the M.I.T. System Dynamics Group to make them so.

Tendency to stick to earlier formulations to justify the effort put into their development. It is psychologically difficult to give up a line of approach on which one has spent much effort, particularly if the approach originally generated promising results. No doubt a certain persistence is needed in research, to insure that one does not prematurely discard an approach, but there is a danger that the commitment built up through the initial struggle keeps one from changing one's approach when this is necessary or preferable.

The tendency to cling to earlier insights increased the complexity of our early models. Attempts were made to collect, in each new model, all the bits and pieces of insight generated prior to that model (see, for instance, the list on page 85). More concretely, our fascination with the crisis mode of effort allocation led to the inclusion of that process in five consecutive models (GROUPACTIVITIES#2 through
CIC#6) in spite of its tenuous link to the process of value change.

Tendency to overemphasize causal diagramming, since causal diagrams constitute a tangible result without the finality of a completed model. Until something is put on paper one may feel that a study has gotten nowhere. The perception persists, although by rational standards the initial familiarization, exploration, and problem definition activities are worthy of extensive attention since they largely determine the outcome of the project. While one does want to see concrete results, one may have many reasons for wanting to postpone completion of a model. One hesitates to go through the time-consuming computer program specification for a model that is still unsatisfactory. A completed model tends to become "sacred" or unchangeable due to the commitment resulting from the effort and due to the impressive orderliness of a closed, consistent perspective on reality. Finally, a completed model is a conspicuous target for criticism. A causal diagram represents a convenient compromise. The diagram is visible proof that work has been done; it can be produced without much toil; and it is still clearly unfinished and therefore not so susceptible to criticism.

There was a strong tendency in our study to remain at the causal diagram level of description. It appears from Figure III-1 that about half of the project period was spent toying with causal diagrams: even more if one includes the exploration activity, which was also done in terms of causal diagrams.
Tendency to go stale in unending formulation problems actually resulting from lacking understanding of the simuland. It is impossible to make an accurate representation of an inadequately understood real-world system. Generic modeling, for example, requires thorough knowledge of the class of simulands studied; otherwise one cannot extract the few, powerful assumptions constituting a useful model. Such keen insight is not necessarily at hand. However, when encountering modeling problems, one is easily trapped into believing that the obstacle is the limited capability of the modeling tools to represent reality.

Unending, futile attempts at formulating some part of the model is symptomatic of a lack of knowledge of the real system; time could be better spent on obtaining a better understanding of the simuland. In extreme cases, apparent formulation problems may result in such frustration and disgust as to force discontinuation of the study. Knowledge constraints are more apparent when using powerful, versatile techniques.

During the latter part of our study, great effort was expended overcoming detailed formulation problems. Literally weeks were spent on simple equations describing utility, authority (COMMITMENT#8), and societal satisfaction (ATTRACTIVENESS#9). When satisfactory representations were finally obtained, it became apparent that the difficulties were caused by a lack of understanding of the real world rather than by DYNAMO restrictions. The alleged existence of knowledge constraints is corroborated by the rapid progress made when we focused on a well-
understood phenomenon, Prohibition.

**Tentative Guidelines for the Conceptualization of Dynamic Models**

A list of positive rules for how to go about obtaining a satisfactory model is more useful than a list of difficulties encountered in one specific modeling study. However, the induction of a positive list is a far more speculative undertaking. The utility of any rule rests on the assumption that there are common traits in all modeling situations. A rule is necessarily a generalization and may be misleading in a given case. A rule, if adhered to, can reduce flexibility, which is essential for successful modeling.

In spite of these and other dangers, ten modeling guidelines are listed below, focusing mainly on the conceptualization phase. They were derived from analysis of our modeling effort; some were "discovered" while the study was still in progress. The guidelines appear capable of counteracting the tendencies identified in the section above. They are consistent with the author's earlier experience. Discussions with system dynamics colleagues have not resulted in rejection of the guidelines. Notwithstanding, the heuristics should be viewed as hypotheses in need of testing in later studies of conceptualization. Such studies should try to exploit the rich, but rather inaccessible, source of modeling insights constituted by the community of professional modelers.

The ten guidelines, taken as a whole, advocate one strategy for completion of the initial modeling stage. The modeler should start
his study by actually drawing the time pattern(s) of the major variables of interest, that is, the reference mode. He should then identify the small collection of fundamental, real-world processes just sufficient to reproduce the reference mode, that is, the basic mechanisms. An initial model consisting of the few basic mechanisms should then be built and run to test the dynamic hypothesis, which asserts that, "The basic mechanisms can reproduce the reference mode." Only when the initial model does generate the behavior of interest, should one enter the improvement stage for elaboration or extension of the model structure, to make it more realistic or more versatile. The guidelines also present a few hints relevant for the improvement stage.

The modeling process will remain iterative; but the guidelines may reduce the number of futile iterations since it insures immediate compliance with several of the generalized evaluation criteria. Use of a reference mode forces the modeler to study a specific dynamic phenomenon rather than "describing a system." Inclusion of the full set of basic mechanisms in the initial model forces a "top-down" style of modeling where the model addresses a meaningful whole at all stages of refinement. In "top-down" modeling, the later models simply describe in more detail the fundamental processes that were already present in the initial model.

The individual guidelines are more meaningful when seen from the perspective of the above strategy. The guidelines appear most useful when the modeling task is difficult relative to the modeler's
ability. Intuitive flair may well lead to successful conceptualization of simple models, but conscious consideration of the heuristics may help if one gets stuck.

**Guideline 1:** Explicit description of the dynamic behavior of interest -- the reference mode -- and assumptions about its cause -- the assumed basic mechanisms -- are necessary prerequisites for successful model-building.

In other words, a model should initially be built to test the hypothesis that the assumed relationships actually do generate the expected dynamic behavior. A model should not be constructed by collecting a number of "obviously important" assumptions to see what behavior they generate when put together. A predetermined reference mode should determine which fundamental relationships should be included in the initial model. The reference mode is not necessarily a single dynamic behavior; the term is meant to describe the small family of behaviors of interest. The model may be simplified and slightly erroneous from the outset, evolving toward its perfect formulation only through the modeler's learning from the initial modeling experience. The basic mechanisms are the small set of fundamental real-world processes responsible for the dynamic behavior of interest. Awareness about which assumptions are most fundamental, and the ability to express them concisely, typically increases throughout the study process.
For example, in World2 (Forrester 1971), the generic model of growth on a finite planet, the reference mode is the various behaviors where rapid growth in population and capital is succeeded by a decline. The decline can have many causes: lack of food, lack of resources, excessive pollution. The basic mechanisms are growth in population and capital toward a finite carrying capacity which starts to erode when the load becomes too high, thereby reducing the further rate of growth of the load. It is also assumed that the erosion is not perceived and ameliorated until after a delay period, during which the carrying capacity may fall irreversibly.

One purpose of World2 was to demonstrate that a system growing toward constraints exhibits overshoot (growth and decline) when there are delays in the feedback about the limits' proximity. Contrary to apparently common belief, the overshoot mode of the world model was not the surprising result of a collection of "obviously important" assumptions. The collapse mode was the dynamic behavior expected from the assumed basic mechanisms, and the initial computer runs only served to prove that the set of assumed relationships actually does produce overshoot.

It may seem excessively structured to start a modeling project with predetermined model content and dynamic behavior. One may feel that there is nothing left for the modeling effort to reveal. While it is true that the basic mode of the model should not appear as a surprise, but rather as a verification that one's dynamic hypothesis is correct, this still leaves room for major surprises or revelations. First, it may turn out that the basic mechanisms, contrary to expectations, are not
capable of generating the reference mode. Additions or modifications may be needed to reproduce the dynamic behavior of interest. A second surprise may be that a remedial policy does not have to have the expected "obvious" effect when tried in the model. Policy experiments in the model system may reveal surprising side effects. Third, running the model with parameters outside the observed range may bring attention to new behavior modes which the modeler has not yet recognized and which are found to exist in the real world, once described by the model. Finally, expansion of the scope of the initial model through gradual addition of more structure may reveal unexpected change (or lack of change) in model behavior.

The need for a reference mode and basic mechanisms to guide a modeling effort is trite from the perspective of theoretical physics, a field not lacking in challenge. In theoretical physics, unexplained, experimental observations (falling apples, the constancy of the speed of light) serve as the "reference mode" to be reproduced from the new theory (Newton's law, the Lorentz transformation [i.e., Einstein's special theory of relativity]). The task of the theoretician is to select the set of elements, or "basic mechanisms," which together, form a theory capable of describing the observed phenomenon. The test is whether the theory does reproduce the observations, and no one is surprised (although they may be excited) if the theory matches the data it was built to explain. The unexpected insights come from the additional conclusions (the "new behaviors") one manages to derive from the theory. These conclusions may draw attention to real-world phenomena not noticed earlier,
and verified by new observations.

The necessity of a dynamic hypothesis is argued concisely in *Industrial Dynamics* (Forrester 1961, p.450).¹ The discussion may have been insufficient to create awareness about the origin of models. The more widely read, "Counterintuitive Behavior of Social Systems," (Forrester 1971) and similar papers by the same author appear to have been interpreted as stating that the basic behavior mode of the model comes as a surprise to the modeler; in other words, that one builds models without prior expectations about model behavior. This is a false interpretation. Forrester's point is that the effects of policies, in an established model, are "counterintuitive," not that its basic behavior is such. The point is intuitively correct, since the model is built to reproduce that behavior (just like theories in high energy physics are made to reproduce observed particle behavior).

The advantage of a reference mode is that it serves as a well-defined standard for the model, dictating the time horizon and indicating which variables and relations must be included.

The reference mode reduces divergent rambling and indicates a completion point; one would tend to keep adding new loops indefinitely

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¹The other passages in *Industrial Dynamics* of relevance to initial model conceptualization are pp.60-61 (on what to include); pp.137-141; and pp.208-213 (on choice of scope and factors -- page 209 describes a dynamic hypothesis). Due to their speculative character, the first twenty pages of Chapter 19 ("Broader Applications of Dynamic Models") give some insights into the problem definition process.
unless reproduction of the reference mode served as a criterion of sufficient completeness. Most important, however, the mode makes the study focus on a phenomenon rather than on a system. It defines the aspect of reality under study, namely those factors related to the dynamic behavior of interest. It precludes an attempt at including "everything" in a model, as though a one-facted social reality exists, capable of being subject to a one-to-one mapping into a model that is equally relevant to all phenomena exhibited by that reality. The mode makes one focus on a specific problem.

The reference mode serves all the above purposes much better than a verbal problem definition, but to be useful the mode must be chosen rather specifically. In our effort, only CIC#6 and PROHIBITION#11 were based on simple time patterns with clear dynamic characteristics. They were both judged to be successful and were quickly brought to the improvement stage. Our earlier models centered unsuccessfully around a reference mode that was too diffuse (S-shaped growth of movement memberships). The latter part of the study, on the other hand, was impeded by having excessive variation included in the reference mode (the ten adoption modes we never managed to contain in COMMITMENT#8).

The assertion that the assumed basic mechanisms together will generate the reference mode, is termed the dynamic hypothesis. The dynamic hypothesis thus consists of two parts: mechanisms and mode, both of which must be obtained by the modeler from his knowledge of the simuland. The origin of the dynamic hypothesis varies with the type of model. The reference mode may be a dynamic phenomenon observed by the modeler. If the
behavior is recurring: for example, an annual phenomenon in a company or a school, the basic mechanisms may be obtained through study of an existing system. In a client study the reference mode typically describes the problem perceived by the client; he may also have opinions on basic mechanisms. The dynamic hypothesis of the client should not be adopted at face value; however, it may be a useful lead. In generic studies of existing systems (e.g., our effort) the dynamic hypothesis is achieved through generalizations based on observed histories. A different approach is necessary when the reference mode has not yet been observed (e.g., the World models). In that case, the modeler must develop basic mechanisms and reference modes simultaneously, in interactive fashion. His worldview may lead him to foresee a specific future which, in turn, may make him look for mechanisms possibly affecting that future. Ultimately a choice is made as to which real-world processes and possible behaviors will be studies; an attempt should be made to indicate why the choice is worthwhile.

One does not automatically fall into the habit of using dynamic hypothesis, because one tends to think in static terms (e.g. "I have enough money," "The U.S. birthrate is at replacement levels"). The following rules may help:

--Make it a firm habit to sketch the expected model output beforehand.

--In generic modeling, consider a concrete case that provides one behavior mode and one set of basic mechanisms for the initial modeling.
Guideline 1a: A reference mode does not lead to a useful model unless accompanied by assumptions about underlying basic mechanisms.

Guidelines 1a and 1b are reformulations of Guideline 1. They are included to emphasize the two mistakes one can make in not completing the dynamic hypothesis: neglecting to select a reference mode or neglecting to identify basic mechanisms.

System dynamics studies are performed with the belief that there is a comparatively stable structure operating to create the observed behavior. If one is unwilling or unable to select a few major relations from this structure as the major cause of the chosen reference mode, the initial model will be an unmanageable patchwork of relations. There are two disadvantages connected with a model structure lacking a clear focus: it is difficult to work with and it does not generate insights to the extent clear structures do. The patchwork resembles a mature model, which is characterized by having several elaborations and extensions superimposed on the simple basic structure that is necessary to generate the dynamic behavior. The problem is that it is very difficult, as a practical matter, to start out with a complex structure, parametrize it, and make it behave reasonably. In our study it was found impossible to adjust the parametrization of ADOPTION#10 (in itself a simple model) to reproduce the prohibition era. It was necessary to go back and conceptualize a simpler model, PROHIBITION#11, consisting only of fundamental mechanisms related in a
transparent manner, before reproduction of the 13-year dry period was achieved. (See Figures IV-26 and IV-28). Once a simple model is running, it can easily be enriched.

A clear structure is an advantage because of its insight-generating capacity. A system dynamics model of the patient dropout phenomenon in health care programs (Kligler et. al. 1972) illustrates this fact. The assumed basic mechanisms of the model is one in which the felt need for treatment, and the program's willingness to provide treatment, interact to reproduce the dropout mode as the result of a clearly understandable structure. Unexpectedly, the basic structure, once identified, proved capable of elucidating service receiver/service producer situations outside the health field.

A model need not be small to have a clear structure. As long as all model relationships represent elaborations of a few basic mechanisms, a large model is still transparent. The superficial complexity of World3 arises because the one basic mechanism of growth constrained by limits is described as it manifests itself in several dimensions of human activity; World3 is still basically simple.

GROUPACTIVITIES#2 exemplifies the unwieldy, diffuse result when relations are thrown together without prior selection of a few essential mechanisms to form the basic structure of the model. S-shaped growth and stagnation was selected as the reference mode, but no decisive selection of the major reasons for stagnation and growth was made at any time. The choice was evaded: because of our lack of knowledge, it
appeared safer to include everything that might be potentially important. This resulted in a model too large to be useful, with a structure incapable of generating insights about the one case it was meant to address.

Guideline 1b: A set of basic mechanisms does not lead to a useful model without the focus provided by a reference mode.

One can never capture all aspects of a real-world system in one model. A choice of one aspect must be made. It is feasible to select which mechanisms to include in a model when the objective is to reproduce the reference mode. Without a mode there is no basis on which to make a selection and modeling degenerates into an attempt to give a "true description of the system." Since no single description of "true reality" (if such a thing exists) is valid in all contexts, the attempt "to map reality" is doomed to fail.

HELPORG#5 constitutes a set of basic mechanisms which were collected without any reference mode in mind. The model shows the relationships between several elements in a helping organization. But why this selection of elements? The only reason for the choice was historical: the model includes mechanisms that had been discussed throughout the preceding months. Not surprisingly then, the model was unable to produce useful behavior, an inability which must result when model relations are chosen without conscious consideration of their contribution to total system behavior. A random network of interrelated variables would not be expected to generate intelligible behavior.
One might characterize HELPORG#5 as a "DYNAMO model," that is, simply one collection of mechanisms, as opposed to a "System Dynamics model," which is a parsimonious structure carefully put together to reproduce the interesting behavior. It is not sufficient to ask, as Simon did (Simon 1954, p.414), that modelers include "concepts and postulates that lie in the central core of existing social science theory." Dynamic models must be constructed with a certain problem (dynamic phenomenon) in mind. Lee (Lee 1973) attacks the tendency in recent large-scale urban modeling toward making "grand plans or big models," not specifically addressing "a particular policy problem," thereby supporting Guideline Ib.

Guideline 2: One should consciously look for organizing concepts that are powerful indicators of the basic mechanisms underlying the reference mode.

In explicating this guideline the author wishes to emphasize the existence of organizing concepts. It appears that the insight-generating capacity of generic models is linked to the clarity and power of their organizing concepts. Organizing concepts need not appear as model variables; they characteristically describe the simuland at a higher level of aggregation than that of the model. It has been mentioned that the world models are built around the organizing concepts "exponential growth," "physical limits," and "delays" (in perception and response to close limits). The organizing concepts of the Urban Dynamics (Forrester 1968)
model are "attractiveness" of the city to different population groups and "finite land" limiting the number of city structures. The Dynamics of Research and Development (Roberts 1964) model is based on the organizing concepts "value of new product" and "cost of developing a new product," both of which vary through time due to exogenous factors. Organizing concepts are useful in telescoping diverse phenomena into one concrete concept, making verbal description more effective.

Ideally, organizing concepts ought to be identified at the outset so they can be used for identification of basic mechanisms. Experience indicates that concepts evolve slowly, however, reaching clear expression only after extensive explorative modeling. The slow pace is not surprising in view of the amount of time and number of repetitions required to arrive at much simpler concepts; for example, in recognizing geometrical patterns under experimental conditions (cf. Simon 1969, Ch.2).

If the organizing concepts are not identified until late in the modeling effort, their major utility is in communicating the model content in a compact form. Our ten-month study developed two sets of successful organizing concepts, both appearing late in the process:

1) the quality of member experience (QME) and the quality of actor experience (QAE), making the overall description of MOVEMENT#3 shown in Figure V-1 possible.1

1'In the model QME depends on: the perceived personal significance the membership imparts to the individual member; individually perceived satisfaction of membership expectations; individually perceived ability to effect change in society; and the extent to which membership results in satisfaction of a member's wants.

QAE depends on: peer dedication; feeling of accomplishment; perceived relevance of the current strategy; agreement among the actors on goals affecting direction of the movement; status of the movement; perceived success relative to effort; actors commitment to the movement's platform; work overload.
Figure V-1: Aggregate Description of MOVEMENT#3 Demonstrating Use of the Organizing Concepts QME and QAE.
the group commitment to the espoused behavior and the societal commitment to current behavior, making the overall description of COMMITMENT#8 shown in Figure V-2 possible.\(^1\)

It is necessary to draw attention to the existence and utility of organizing concepts because they are hard to perceive through the clutter of real-world detail. Concept formation may be facilitated by employing analogies to existing organizing concepts when searching for new ones.

Guideline 2a: Organizing concepts are useful for guidance of modeling and description of models, but do not automatically lead to a successful model.

The discovery of powerful organizing concepts is an exciting experience. In the subsequent euphoria one may view the resulting insight as sufficient to support an interesting model, although obviously good concepts cannot serve as substitutes for a dynamic hypothesis. The dynamic hypothesis is indispensible; concepts can, at best, express it in more compact form. The conclusion is supported by experience with both MOVEMENT#3 and COMMITMENT#8, neither of which were successful models in spite of their core of insight-generating organizing concepts.

\(^1\) In the model group commitment depends on: perceived group performance relative to group aspirations; basic dedication of group members; total group effort expended recently.

The societal commitment to current behavior depends on recent improvement ascribed to that behavior, and on the extent to which the behavior is internalized in people's minds and society's institutions.
Figure V-2: Aggregate Description of CONSTRUCT-\textsuperscript{76}
Demonstrating Use of the Organizing Concepts Group Commitment and Societal Commitment.
Guideline 3: A dynamic hypothesis is obtained through exploratory combination of historical (or hypothetical) simuland behavior and simple structures with known behavior. Ideas for a productive perspective on reality can be obtained from familiar organizing concepts and existing models.

Problem definition is the least structured activity in scientific inquiry, taxing the creative abilities of the researcher. Few directions can be given for its successful completion. Similarly, conceptualization of the initial model is the major problem in dynamic modeling:

"In ... model construction, a key point is the formulation of an initial model. As far as we know, no one completely understand how a model is born. However, involved in the birth process are usually (1) hard work, accompanied by labor pains, to understand and relate results and findings in the literature, (2) several hard looks at the data, (3) synthesis of previous current ideas into an initial model, (4) consistency checks of the initial model, and (5) use of available data, insights, and whatever other information is available..." (Hamilton et. al. 1969, p.261)

Hamilton's description appears to be correct, but does not give much concrete advice. Guideline 3 represents an attempt at greater specificity. The process of initial model conceptualization is more involved and intuitive than routine addition of loops and investigation of policy effects in an existing model, which amounts to a rather simple exploration of the consequences of changes in a given structure. The distinction is analogous to the difference between problem-finding and problem-solving in the human problem solving process. Problem solving entails the use of existing programs or sets of mental rules (Newell and Simon 1972, Ch. 14), while problem finding is much less structured and implies detection of the need
for new programs (Mackworth 1965).

Using a dynamic hypothesis in fact a "new program" for coming up with an initial model. With a clearly expressed dynamic hypothesis at hand, the formulation of an initial model is straightforward. The difficult initial modeling problem is reduced to the relatively structured task of identifying the elements of the dynamic hypothesis: a reference mode and underlying basic mechanisms. This simplification is a major achievement of the modeling procedure proposed here.

How are reference modes and basic mechanisms identified? A reference mode rests on knowledge about simuland behavior over time. Extended time series, or verbal descriptions of historical behavior, must be found. Our effort suffered from a failure to investigate the time behavior of social movements. When speculating about possible basic mechanisms behind the observed time patterns, familiarity with the behavior of simple structures is useful in indicating what type of structure to look for:

"A person applying the industrial dynamics approach to corporate problems seems to do so by drawing heavily on his mental library of the systems which he has previously studied." (Forrester 1968, p.412)

One does not usually have available a structure that fits perfectly to the problem at hand, but if obvious basic mechanisms are insufficient to generate the behavior of interest, tentative causal diagrams may suggest new directions of search. The behavior of simple structures can be taught, and the speed with which basic mechanisms are identified can be increased through learning.
Turning to less structured ways of obtaining a dynamic hypothesis, (Morris 1967) argues for "writing down the obvious," a procedure that would seem particularly fruitful in the case where a good notation is available for doing so. "A good notation has a subtlety and suggestiveness which at times makes it seem almost like a live teacher." (Bertrand Russell) Kiviate (Kiviate 1972, p.88) accentuates the utility of a good language in shaping one's thoughts:

"If we can't tell people how to build good models, can we tell them how to build models at all? Fortunately, we can. While we have no simulation scheme that is based on a developed theory of systems, we do have specialized simulation languages that guide a modeler in thinking about systems and in expressing his thoughts. Since one of the great problems of modeling is articulating thoughts and relationships in a manner consistent with the aims of simulation, a language that directs, orders, and expresses a modeler's thoughts in an operationally meaningful way is a giant step in the right direction."

The DYNAMO notation and language is developed specifically to facilitate viewing the world as causal, continuous, and with ample feedback of information. Speculative DYNAMO flow diagram segments may therefore be suggestive of how to formulate the dynamic hypothesis.

To focus the search for a dynamic hypothesis, it is helpful to restrict oneself to one aspect of reality and attempt to keep attention from wandering from this aspect. Organizing concepts from the past may indicate which slice of reality will be productive. It appears that our modeling effort was severely hampered by inability to decide which facet of the introduction-of-new-ideas-in-society problem to approach. Our emphasis fluctuated between characteristics of the idea, individual psychological considerations behind a person's acceptance, internal
management decisions of the promoting group and so on. A past successful study could have helped in determining a perspective, as did our own organizing concepts when they were finally developed.

Morris (Morris 1967) views modeling as an evolutionary process and supports the conscious use of analogies in the initial phase:

"Analogies or association with previous well-developed logical structures plays an important role in the determination of the starting point of this process of elaboration or enrichment."

**Guideline 4:** The system boundary must be chosen to be wide enough to encompass feedback loops capable of generating endogenously non-trivial dynamic behavior over the time period studied.

This may seem trite, if the goal is to study dynamic behavior and one knows that a model free of exogenous driving functions exhibits no time-varying behavior without loops in the structure. Experience shows, however, that the novice tends to make models with "straight lined" computer runs. At first there is a tendency to focus on a slice of reality that misses important information feedbacks. An appreciation of this fact can be obtained by comparing the uninteresting runs of MOVEMENT#3 with the runs emanating from the much simpler World2 model (Forrester 1971). Beginners are also apt to lose the dynamics of a structure by running the model over time periods much shorter than the time constants in the major loops (as we did when MOVEMENT#3 was originally run for a decade only, while the dominant loops turned out to have time constants of around fifty
years.) In desperation, the inexperienced modeler often tries to obtain dynamic behavior by relying on exogenous driving functions.

It is not "wrong" to make models without loops and with important influences exogenous to the system boundary. Loops are only necessary if one is studying dynamic behavior; models without loops simply transform an input signal and are dynamically uninteresting. Guideline 4 further rest on the belief that more fundamental descriptions will result when the cause of all major influences are included in the model.

To insure an inclusive system boundary and dynamically exciting models, one should select a reference mode with clear time variation and reject models unable to generate the mode endogenously.

Guideline 5: The purpose of the initial model is not to predict, but to test the dynamic hypothesis.

Guideline 5 is included to reduce the common inhibition against starting with a simple model. A certain self-assurance on the modeler's part is necessary to exclude factors, and putting aside considerations germane to the realism or acceptability of the model, one may achieve the necessary confidence by remembering that the purpose of the initial model is to test the dynamic hypothesis. The objective is not to construct a predictive model, but rather a basis from which predictive models can be derived.

Boosting modeler courage would be superfluous if the model-using community heeded Solberg's advice:  A Model Should Not Be Pressed Beyond
The Limits Of Its Intended Use and A Model Should Not Be Criticized For Failing To Do What It Was Never Intended To Do (Solberg 1972, p.70).

Guideline 6: The initial model should only contain the basic mechanisms needed to generate the reference mode; additional complexity should then be gradually incorporated until a sufficiently realistic and versatile model is obtained.

Morris (Morris 1967, p.B-709) describes the iterative improvement stage in these words:

"The process of model development may be usefully viewed as a process of enrichment or elaboration. One begins with the very simple models, quite distinct from reality, and attempts to move in evolutionary fashion toward more elaborate models which more nearly reflect the complexity of the actual management situation...

"...The process of elaboration or enrichment involves at least two sorts of looping or alternation procedures.
1) The alternation between modification of the model and confrontation by the data. As each version of the model is tested, a new version is produced which leads in turn to a subsequent test.
2) The alternation between exploration of the deductive tractability of the model and the assumptions which characterize it. If a version of the model is tractable in the sense of permitting the attainment of the analyst's deductive objectives, he may seek further enrichment or complication of the assumptions. If the model is not tractable or cannot be "solved," he returns to purify and simplify his assumptions."

Urban and Karash (Urban and Karash 1970) defend the "evolutionary approach to model-building," because it makes it possible for the user to understand the final complex model through participation in its gradual evolution from a simple starting point. They present three versions of a product planning model as a concrete demonstration of the approach. In a beautiful series of analytical models Simon (Simon 1954) shows the
utility in making a model of human behavior gradually more realistic (and more complex) as the earlier model comes to be well understood and its limitations become objectionable. It appears reasonable to postpone enrichment until the earlier model seems obvious.

In spite of widespread recognition, the rule of initial simplicity appears to be violated by most modelers, the first half of our own effort being a prime example of unmanageability arising from excessive initial complexity. The strong tendency to violate a widely espoused heuristic is understandable only when one considers the irresistible pressures working against simple descriptions. Western technological culture perpetuates a view putting a premium on demonstrated knowledge of detail (see [Mitroff 1972] for an eloquent argument to this end). Education is geared toward reductionism and accentuation of detailed differences rather than overall similarities. General outlooks on reality do not count as "science":

"... Therefore those interested in gaining a measure of acceptance for a model often feel pressure to develop certain sectors far enough to please experts in subjects treated by those sectors regardless of whether such sophistication is needed from the point of view of the main research problem." (Hamilton et. al. 1969, p.286)

The cultural pressures toward achieving exhaustive detail in the first model are heightened by some technical considerations. The modeler often does not have sufficient dynamic insight to realize that a simple structure is sufficient to reproduce the reference mode. He may lack the inductive capability needed to extract the essential mechanisms from the welter of real-world detail. Finally, he may feel compelled to model
explicitly the full policy formation machinery of the simuland, instead of representing the influence of remedial policies (at least initially) as changes in existing model parameters.

It would appear that the technical pressures toward complex models could be reduced through formal training. For example, Table V-1 demonstrates how policy proposals for reducing the solid waste problem can be reduced to simple parameter changes.

Some rules may result in simpler initial models:

--Insist on having a running model shortly after completion of the problem definition process.

--Obtain the courage to make simplistic models by writing down all the simplifying/assumptions made, thereby proving to you and others that you know what you are doing.

**Guideline 7:** The model should be kept transparent subsequent to the initial modeling stage as well.

Lee (Lee 1973) presents a succinct rationale for Guideline 7:
Policy Proposal
Remove depletion allowances in mining industries
Remove deductions for cost of exploration
Remove capital-gains tax treatment in mining industries
Make freight rates as low for scrap as for virgin raw material
Remove federal government stipulations that prohibit use of anything but virgin material
Make people sort their own wastes in their homes
Prohibit nonreturnable containers
Reduce packaging

Equivalent Parameter Change
Increase extraction cost EC
Increase extraction cost EC
Increase extraction cost EC
Decrease recycling cost RCC
Decrease recycling cost RCC (through the economies of scale which larger demand makes possible)
Decrease recycling cost RCC
Increase product lifetime PLT (for the substitute returnable containers)
Reduce raw material per product RMPP.

Table V-1: A Variety of Measures for Solving the Solid Waste Problem can be Expressed in terms of Parameters in the Existing Model, without Inclusion of Additional Structure (Randers and Meadows 1972).
Guidelines 7a, b, and c represent elaborations on the content of Guideline 7.

**Guideline 7a:** A model relationship should only be included if it is necessary to generate a desired behavior mode or to test effects of a policy, and, in the case of external use, to achieve sufficient realism to gain credibility.

**Guideline 7b:** Each model link should represent a stable, meaningful real-world relationship in which the modeler has confidence.

**Guideline 7c:** The model must be kept simple relative to the user's level of intuitive understanding of the system.

Guidelines 7a, b, and c are all pleas for simplicity, at all stages of modeling. Parsimony is, of course, an accepted ideal in scientific inquiry; it is somewhat neglected in simulation studies, perhaps because it is so easy to enlarge computer models. Due to their deductive abilities, computers can derive consequences from masses of assumptions, exceeding by far the deductive power of the human brain. It is therefore possible for the modeler to build models he cannot understand and still obtain "results" (or model output, at any rate). Such undesirable behavior is common. Dutton and Starbuck (Dutton and Starbuck 1971, p.4) make the point this way:
"In the extreme case, simulation leads to 'Bonini's paradox.' A model is built in order to achieve understanding of an observed causal process, and the model is stated as a simulation program in order that the assumptions and functional relations may be as complex and realistic as possible. The resulting program produces outputs resembling those observed in the real world and inspires confidence that the real causal process has been accurately represented. However, because the assumptions incorporated in the model are complex and their mutual interdependencies are obscure, the simulation program is no easier to understand than the real process was. As Bonini concluded, "We cannot explain completely the reasons why the firm behaves in a specific fashion. Our model of the firm is highly complex, and it is not possible to trace out the behavior pattern throughout the firm... Therefore, we cannot pinpoint the explicit causal mechanism in the model." (Bonini 1963, p.136)

Forrester (Forrester 1968, p.407) calls for restraint in deciding what to include in a model:

"For an industrial system model, the boundary should include those aspects of the company, the market, the competitors, and the environment which are just sufficient to produce the behavior being investigated. Anything not essential to producing the mode of behavior under study should be left outside the system boundary."

Solberg states more cryptically, "Do Not Build A Complicated Model When A Simple One Will Do" (Solberg 1973, p.71). Lee exclaims, "Build Only Very Simple Models" (Lee 1973, p.176), while Reitman defends simpler models from the point of view of hardware constraints and model-builder's capacity to understand (Reitman 1970). Simple models are desirable because they are more likely to be under the control of the modeler; because they can be communicated and are transparent to the user; and because they are esthetically pleasing.

The common call for simple models has been ridiculed, perhaps because the advice, "Keep the model simple," is usually given without indications of how to simplify. Hamilton (Hamilton et. al. 1969, p.261) espouses the attractive, but not very helpful, concept of "sophisticated
simplicity in model construction." Morris (Morris 1967, P.B-715)

orims that intractable models should be simplified by making variables
into constants, eliminating variables, using linear relations, adding
stronger assumptions and restrictions, and suppressing randomness. The
criterion of analytical tractability appears arbitrary if the goal is to
describe the real world or to trigger policy change. It is not relevant
to simulation modeling.

Guidelines 7a, b, and c are intended to suggest operational
criteria that should be satisfied before including an additional relation.
First, one should have a specific reason for including the link; one should
not enlarge the model in response to a diffuse urge to include "apparently
important" relations.

Second, the model link must not be so aggregate that no stable,
meaningful real-world counterpart exists. Nor should one pursue the model
to such detail that one is outside the range of available, secure knowledge.
The latter advice may seem superfluous, but

"...simulation provides few safeguards against the model-builder's
human propensity for self-deception, and both the freedoms and constraints
of simulation facilitate self-deception. Sufficient assumptions and
temporal sequences must be specified even when the model-builder lacks
adequate information to justify them; output flexibility lures model-
builters into inventing a superficial realism; the mechanization of logic
permits a model-builder to disclaim his personal responsibility for logical
analysis; and the particularity of solutions adds ambiguity to the inter-
pretation of model properties." (Dutton and Starbuck 1971, p.589)

Those models which have buried within them assumptions that are not fully
acceptable to the modeler should not be built in the first place, since
the model conclusions tend to have impact even if the weaknesses of the
model are emphasized by the modeler. Furthermore, there is little point
in basing a dynamic model on controversial assumptions, since the dynamic
behavior of perfectly reasonable structures still constitutes a rich area
for inquiry.

Third, the modeler should recognize his limited ability to master
complex feedback systems, to prevent his drawing policy conclusions from a
model he does not fully understand. Apparently, one cannot control ten-
level systems even after three years of modeling experience (see Figure
IV-29). If an external user is to learn from the model, the allowable
complexity is further lessened. Formal models are of little use in
upgrading mental models if the gap in complexity is significant
(Gorry 1971).

Some practical rules, which may help in achieving adequate
complexity, are:

--Make frequent presentations to test the understandability
and general acceptability of the work.

--Model quickly; an extended formulation period will soon
make one include an amount of detail for which there is
little support.

--Write a verbal description of each assumed relationship to
insure its being a clear, uncontroversial statement about
the real world.

--Use a level of aggregation compatible with common discussion
of the topic.

--To achieve a simple, but dynamically sufficient formulation
of a model sector, it is useful to first make a very detailed
structure to clarify issues, and then aggregate.
Guideline 8: If it is necessary to reduce model complexity, reduce amount of detail (depth) rather than scope (breadth).

The "natural" tendency in scientific research is to study a contracting slice of reality in ever-increasing detail. In modeling, as in research in general, there is nothing fundamentally wrong about limiting scope instead of amount of detail. Guideline 8 is simply a warning that one thereby loses the major advantage of a system analysis, a meaningful, holistic point of view. The warning is necessary, for although it makes sense to start with an aggregate description of the whole simuland, rather than with the detailed study of one, possibly insignificant aspect of the picture, the latter is often easier and appears more scientifically responsible.

The reductionist tendency is counteracted by making it a rule to include the full set of basic mechanisms in the model at all stages of development. The model will then always include all factors relevant to the problem. The rule was violated in our study of social change; we buried ourselves in detailed investigation of one organization until the scope was expanded, by forces external to the work group, to a more meaningful boundary for study of the acceptance of ideas.

Splitting a model into modules or segments is another way of reducing complexity, but one risks losing the holistic perspective.

Guideline 9: Spend most time on what matters most: a balanced model structure. An elegant, concise formulation and a
reasonable parametrization can be obtained later.

Guideline 9 accentuates the utility of getting the overall facts straight before starting on the time-consuming, detailed work of model formulation and parametrization. Guideline 9 is necessitated by the common, but false, view that meticulous detail, when put together, will form a productive whole. The general features of the model must be outlined before it is meaningful to elaborate on the detailed assumptions. Just as in drawing a face, one starts by sketching the profile and the rough position of the eyes, nose, and mouth before proceeding to fill in more and more detail, down to the limit of one's anatomical knowledge.

In a study of dynamic behavior, the bulk of the initial effort should be concentrated on refining the causal feedback loop structure, since the configuration of closed loops is the major determinant of the time-varying behavior of the final model. The influence exerted by the exact parametrization is weaker; thus it is acceptable and efficient to rely on a rough, quickly achieved set of parameter values until a satisfactory structure has been obtained. At that stage, and only then, is it worthwhile striving for an elegant formulation and an accurate parametrization. The reference point method for parametrization by a group of knowledgeable persons may be productive at this stage.

The formulation of MOVEMENT\#3, which was built by sequential addition of very detailed descriptions of factors affecting QME and QAE (see Randers November 1972), is a case where no effort was spent on outlining
the general features of the structure before filling in the detail.
The unstructured, unwieldy result shows that the juxtaposition of reasonable details does not necessarily form a useful whole. During the construction of MOVEMENT#3 our effort was allocated to attaining a precise, multi-dimensional description of QAE and QME. All other considerations, for instance, those of overall structure, were subordinated to the objective of elegance and completeness in the representation of QAE and QME. More commonly, attention is deflected from essentials by a desire to obtain models that can be evaluated by existing data; that are mathematically elegant; that belong to one academic discipline; that are used by others; or, that "give high R-squares." Hamilton describes the ideal procedure (Hamilton et al. 1969, p.282):

"In a modeling study, the major responsibility of the program manager is to produce what may be termed a "balanced model." A balanced model may be defined as one in which the level of research effort devoted to developing each of the model's sectors and subsectors is commensurate with its importance to the overall problem being investigated. As a research program unfolds, it is necessary to review continually the goals of the over-all study and to assess the question of balance in light of the program's prior findings."

Guideline 10: Causal diagrams should be used only for exploration in the initial modeling stage and for communication of the "final" model; the modeling proper should be performed by choosing levels and linking them together.

In order to complete a DYNAMO flow diagram one must be internally consistent, decide what the system levels are, and distinguish between
levels and rates. The causal diagram is inferior in not imposing this rigorous discipline, so useful in unveiling blurred thought. Still, the causal diagram has a role in initial modeling, where it aids exploratory search for a basic loop structure sufficient to generate the reference mode. Rough sketches of the basic structure help visualize the boundary of the system to be described.

Once the system boundary is determined, one can select a set of levels capable of describing completely and unambiguously the state of the system. The levels are found among the meaningful descriptors of a system that is frozen at one instant of time.\(^4\) In addition, the set of levels must be sufficient to describe the simuland, in the sense that given the numerical value of all the levels, one can derive the values of all other system variables. The number of levels necessary indicates the dimensionality of the simuland. Finally, the levels must be independent, in the sense that given numerical values for all but one level, it is still impossible to derive the value of the last one through logical considerations alone.

Several feasible sets of levels will always exist and the selection of one set is largely an art for which only a few, diffuse guidelines can be given. One practical way of identifying the levels is to make a long, possibly redundant, but complete list of descriptors of the system.

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4. Thus the past average behavior of a person is a level (it could be seen, in the picture of the frozen system, as a diary of past activities) while his instantaneous behavior is not (he may appear in the picture as standing on one leg; it is, however, impossible to tell whether he is actually running or just posing as a runner).
By eliminating first, those descriptors that do not vary over the time horizon of the study and second, those that are dependent on other descriptors, the set of descriptors that is left will be close to a useful set of levels.

Having chosen the levels, one must identify the determinants of their rates. Lest the linking of rates to their determining levels (usually via auxiliaries) become another exercise in collecting "obviously important" relations, it should not be performed without prior decision on what (few) processes the model is to represent.

In those cases where the system boundary and levels are obvious from the outset (for instance, in models of physical flows), causal diagrams will not be of much help and model formulation should start directly with levels.

The simplicity of causal diagrams makes them an appropriate tool for communicating model assumptions to a wide audience. It should be the duty of all modelers to reveal their assumptions in a transparent manner.

A Recommended Sequence of Modeling Activities

This section summarizes the approach to dynamic modeling which is suggested in this report and represented graphically in Figure V-4. Some characteristics of the modeling process are likely to remain unchanged regardless of how well the modeler masters his art. These characteristics are the iterative evaluation to guide progress (the narrow curve in Figure V-4) and the partly parallel performance of all modeling activities. No set of guidelines will transform modeling into a once-through, sequential
Figure V-3: The Recommended Modeling Procedure
execution of a set of activities. The self-corrective mechanism of recurring invention and evaluation is desirable during problem definition, hypothesis testing and model improvement as long as the number of iterations remains reasonable. The purpose of the recommended scheme is to reduce the number of futile iterations by imposing some structure on the process (the broad band in Figure V-4).

It is useful to split the modeling process into an initial modeling stage and an improvement stage.

The goal of the initial modeling stage should be to arrive at a rough model capable of addressing a meaningful problem. One should identify a dynamic behavior of interest -- the reference mode -- and the related basic structure -- the basic mechanisms -- thereby determining in a precise way the aspect of reality to be studied. The reference mode serves to focus the modeler's attention on a problem, and helps him avoid attempting to make a model that is a mapping of reality made without special relevance to a dynamic phenomenon. Including the basic mechanisms from the outset insures that the model addresses a meaningful whole at all stages of development. The initial model should comprise the basic mechanisms and be capable of testing the dynamic hypothesis: "The basic mechanisms are capable of generating the reference mode."

The initial modeling stage embraces two processes: problem definition and testing the dynamic hypothesis. The final expression of the problem decisively influences the direction (and outcome) of the modeling. Identification of a meaningful, soluble problem at the outset will prevent much unnecessary iteration. Extended time should be spent on problem definition before any formulation of models is attempted. The
exception is very tentative exploratory sketching of feedback loop structures. The problem definition process should be strongly iterative and involve simultaneously the four activities of familiarization, questioning, exploration, and identification of dynamic behavior. The end result should be a problem described in terms of some few time patterns, that is, a reference mode (for example, patterns describing actual and desired behavior).

The process of testing the dynamic hypothesis must begin with verbalization of the hypothesis in terms of basic mechanisms and a reference mode. Given the reference mode, one proceeds with identification and verbal description of the main forces assumed to underly the mode. An attempt should be made to exclude all traces of less important details, retaining solely the basic mechanisms. Forcing oneself to express the assumptions in writing usually "trims off the fat" and should be done. A quick sketch of the mechanisms in causal diagram form may be useful for focusing thought and picturing the system boundary. The resulting structure should be very simple (few loops) and describe fundamental processes.

One should now start formulating the initial rough model by identifying the system levels. First a list of descriptors (factors, variables) sufficient to describe the state of the closed system should be made. A main goal is to attain a complete list. Possible redundancies are removed through the ensuing selection of the levels from among the descriptors. To extract the levels one should first eliminate remaining entries that are not independent. After putting the levels and the necessary
rates on paper, one should add the causal influences on the rates which are necessary for capturing the basic mechanisms. The DYNAMO flow diagram notation is a useful level of description at this stage. The process should be quite straightforward if sufficient time has been spent on verbal descriptions of the basic mechanisms.

Next, one should choose numerical values for table functions and time constants. Without belaboring the activity, one should subject the completed structure to a first evaluation with respect to consistency, completeness, and reasonableness in its individual assumptions. If found satisfactory, the model should be run to test whether it actually does reproduce the major characteristics of the reference mode. If the model fails in either test the flaws must be corrected in a new iteration, possibly redoing all the steps, starting with an altered problem definition. When the model passes both tests and addresses a problem of interest, one has at hand a model worthy of entry into the improvement stage.

The improvement stage consists of a never-ending series of extensions and elaborations made to increase model richness or realism through changes in system boundary, level of aggregation, or detailed formulation. In most cases, this means making the model more complex. Since all models should be transparent, care must be taken to include new relationships only when necessary for generalizing a desired behavior mode, testing the effect of a policy or attaining external credibility. The enrichment process must not be pursued to the point where the modeler can no longer grasp the connection between model assumptions and model output. At this late stage one may manage to identify powerful organizing
concepts that make it possible to reformulate the whole study in a simpler, more elegant form. Such concepts are a valuable spin-off of modeling and should be actively sought at all stages of the process.

The reference mode plays its essential role in a study as a catalyst in the transition from general speculation about some part of reality to a process of routine improvement of a given structure. This leap, manifested in the initial model, is the major creative step in modeling. Once the initial model is achieved, the value of the reference mode in guiding the progress diminishes. Later models will be obtained with behavior much richer than that contained in the original reference mode.

Finally, after extensive iteration in the improvement stage and attainment of a model structure and parametrization in which one has confidence, one can perform the policy experiments from which conclusions may be drawn. The conclusions should be presented along with the model premises on which they are based. An after-the-fact causal diagram is useful for communication of model assumptions because it is widely understood.
CHAPTER VI

SUMMARY AND FUTURE WORK

Summary

The topic of the report is the process by which models are created. More specifically the focus is on social system models that are descriptive, generic and dynamic. Emphasis is placed on the conceptualization phase, that is the early problem definition and initial modeling activities. Chapter I defines the topic in more detail and shows that there is a lack of literature describing the modeling process, both as it actually occurs and as it ideally should occur. The intent of the report is to help fill that gap.

Chapter II argues that point-prediction is not currently a feasible objective in social systems, because the simple models employed require an important stochastic element. Thus iterative improvement of models through point-prediction, observation and evaluation using statistical tests employed successfully in the physical sciences, will be less effective in social modeling. Instead one must use a much broader evaluation scheme in the iterative process, where most aspects of the model (its detailed assumptions, its consistency, its general behavior characteristics, and the like) are compared with all available knowledge about the real world (descriptive, non-quantitative information as well as numerical measurements). The scheme is referred to as generalized evaluation.
Chapter II also presents a framework for description and analysis of dynamic modeling efforts, a framework that is used in the subsequent chapters. The modeling process is seen as consisting of two stages, both iterative in nature and involving the same activities, although in varying proportions. The discernible activities are listed on Table II-1. In both stages progress is made toward more useful (as determined by the modeler's set of objectives) models by subjecting the current model to generalized evaluation, thereby locating weaknesses and opportunities for betterment. The first, "initial modeling," stage embraces problem definition and creation of the first rough model judged to be capable of addressing the question in a useful way. At minimum the initial model should include a set of important "basic mechanisms" capable of reproducing the major characteristics of the real-world dynamic behavior of interest. Many iterations are needed to arrive at an initial model; inferior models are eliminated through generalized evaluation. The major conceptualization effort takes place in the initial modeling stage. The second, "improvement," stage transforms the rough initial model into an increasingly acceptable, versatile and realistic model through an iterative series of elaboration and extensions. The improvement is guided by continuously ongoing generalized evaluation, including statistical tests, if feasible and productive.

Chapters III and IV describe an actual (six-man, ten month) effort to make a dynamic model of the consequences of introducing an idea in society. The chapters serve to make the inexperienced modeler aware of the unorderedly
progress of a real-life modeling study. The chronological activities of the work group are described in Chapter III, both in the form of a retrospective account and as a diary written during the project. The chronology is summarized in Figure III-1. Eleven tentative models were made before the study progressed from the initial modeling stage, all of which were rejected as unsatisfactory on the basis of generalized evaluation. Summary descriptions of the eleven models are given in Chapter IV. A twelfth model, NEWIDEA#12, satisfied the criteria used and was advanced to the improvement stage. The current version of NEWIDEA#12 is described in detail. Trends in model characteristics and content over the study period are plotted in Figures IV-29, 30, 31, and 32, illustrating the continuity in evolution of model characteristics and content that results from the iterative modeling procedure using generalized evaluation.

Chapter V presents an analysis of the modeling effort. The following pressures appear to have been operating and are considered capable of explaining the major characteristics of the experienced chronology:

- Tendency to ramble due to lack of an explicit goal.
- Tendency to make excessively complex models to avoid inadvertent omission of important elements.
- Tendency to exclude too much detail subsequent to failures with overly complex models.
- Tendency to contract the scope of the model to make feasible a complete, respectable analysis.
- Tendency to stick to earlier formulations to justify the effort put into their development.
- Tendency to overemphasize causal diagramming, since causal diagrams constitute a tangible result without the finality of a completed model.

- Tendency to go stale in unending formulation problems actually resulting from lacking understanding of the simuland.

Next, ten guidelines or heuristics are identified; they are useful in counteracting the above tendencies and in forcing the modeler to more explicit consideration of his own activities and to more effective working habits. Guidelines 1 through 3, focusing on the unstructured conceptualization phase of the initial modeling stage, appear to be most significant. Awareness and use of "reference modes" and "basic mechanisms," are important in forcing the modeler to model a specific problem rather than a system. The guidelines are the following:

**Guideline 1:** Explicit description of the dynamic behavior of interest - the reference mode - and assumptions about its cause - the assumed basic mechanisms - are necessary prerequisites for successful model-building.

**Guideline 1a:** A reference mode does not lead to a useful model unless accompanied by assumptions about underlying basic mechanisms.

**Guideline 1b:** A set of basic mechanisms does not lead to a useful model without the focus provided by a reference mode.

**Guideline 2:** One should consciously look for organizing concepts that are powerful indicators of the basic mechanisms underlying the reference mode.

**Guideline 2a:** Organizing concepts are useful for guidance of modeling and description of models, but do not automatically lead to a successful model.

**Guideline 3:** A dynamic hypothesis is obtained through exploratory combination of historical (or hypothetical) simuland behavior and simple structures with known behavior.
Ideas for a productive perspective on reality can be obtained from familiar organizing concepts and existing models.

**Guideline 4:** The system boundary must be chosen to be wide enough to encompass feedback loops capable of generating endogenously non-trivial dynamic behavior over the time period studied.

**Guideline 5:** The purpose of the initial model is not to predict, but to test the dynamic hypothesis.

**Guideline 6:** The initial model should only contain the basic mechanisms needed to generate the reference mode; additional complexity should then be gradually incorporated until a sufficiently realistic and versatile model is obtained.

**Guideline 7:** The model should be kept transparent also subsequent to the initial modeling stage.

**Guideline 7a:** A model relationship should only be included if it is necessary to generate a desired behavior mode or to test effects of a policy, and, in the case of external use, to achieve sufficient realism to gain credibility.

**Guideline 7b:** Each model link should represent a stable, meaningful, real-world relationship in which the modeler has confidence.

**Guideline 7c:** The model must be kept simple relative to the user's level of intuitive understanding of the system.

**Guideline 8:** Reduce amount of detail (depth) rather than scope (breadth) if it is necessary to reduce model complexity.

**Guideline 9:** Spend most time on what matters most: a balanced model structure. An elegant, concise formulation and a reasonable parametrization can be obtained later.

**Guideline 10:** Causal diagrams should only be used for exploration in the initial modeling stage and for communication of the "final" model; the modeling proper should be performed by choosing levels and linking them together.

Chapter V ends with a description of the recommended modeling procedure.
Future Work

The overall framework for model construction and the guidelines presented are tentative and should be confirmed or rejected by other modelers studying their own efforts. A concrete first step would be to create summary descriptions of activities and model trends (like those in Figures III-1 and IV-29, -30, -31, and -32) for other modeling projects. Along with reports on overall satisfaction with the outcome. Such data could be used to refine the recommendations made in this report.

A second step would be to undertake modeling efforts where the above rules are followed from the outset, in order to study what problems then arise. Such an attempt will be made by the author and his colleagues during the fall of 1972.
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APPENDIX A

PROGRAM AND VARIABLE LISTINGS

This Appendix contains DYNAMO program listings and variable descriptions for the models for which complete running versions were made: MOVEMENT#3, LIFECYCLE#4, HELPORG#5, CIC#6, ADOPTION#10, PROHIBITION#11 and NEWIDEA#12
* MOVEMENT 3

**NOTE**

*******PLATFORM RELEVANCE**

L 
PRE.K=PRE.J+(DT)(PRE.I JK-PRDFJK)
N 
PRE=1PRE
C 
IPRE=1
R 
PREI.KL=ER.K*PREP*PERM.K
C 
PREP= .92E-6
A 
PERM.K=TABHL(PERMT,PRE.K/RPRE,0,4,1)
T 
PERMT=3/1/6/4/3
C 
RPRE=1
R 
PRDF.KL=PRE.K/PRDF
C 
PRDF=3

**NOTE**

*******SATISFACTION OF WANTS**

A 
SW.K=RSW*SWMFLO.K*SWMSPM.K
C 
RSW=.8
A 
SWMFLO.K=TABHL(SWMFLO,FLO.K/RFLN,0,4,1)
T 
SWMFLO=.5/1/2/2.5/3
C 
FLON=1.5
A 
SWMSPM.K=TABHL(SWMSPM,SPM.K/RSPM,0,4,1)
T 
SWMSPM=0/1/1.9/3.9/4
C 
RSPM=1.4
A 
SPM.K=TSP.K/M.K
A 
TSP.K=ESP.K*PESP
C 
PESP=400

**NOTE**

*******VISIBILITY OF MOVEMENT**

L 
V.K=V.I+(DT)(VIR.JK-VDR.JK)
N 
V=IV
C 
IV=5
R 
VIR.KL=TEV.K+RVP*PEVM.K
A 
TEV.K=EV.K+IE.K+RIFF*IFEM.K
A 
IE.K=RIE4*IE4.K*IFEM.K
C 
RIE=0.936
A 
IFEM.K=TABHL(IFEMAT,ADA.K/RDA,0,4,5)
T 
IFEMAT=0/1/2/2.5/3.7/4.3/4.7/5
C 
RDA=4.95
A 
ADA.K=ADA.J+(DT)(ADRATE.JK)
N 
ADA=IADA
C 
IADA=5
R 
ADRATE.KL=(VIR.JK-ADA.K)/DRT
C 
DRT=6
A 
IFEMN.F.K=TABHL(IFEMNFT,NF.K/RNF,0,4,1)
T 
IFEMNFT=.2/1/1.5/1.8/2
C 
RNF=.4
C 
RIE=.13E6.
A 
IFEM.K=TABHL(IFEM,MF.K/RMF,0,4,1)
T 
IFEM=.0/1/1.5/1.75/1.8
C 
RMF=.6
C 
RVP=15E-6
A 
PEVM.K=TABHL(PEVMT,V.K/RV,0,2,5)
T 
PEVMT=4/2/1.4/0
C 
RV=5
R 
VDR.KL=V.K/ASP
C 
ASP=1

**NOTE**
NOTE *****************************PFRCieved ENTRY COST
A PFC.*K=SMOOTH(CIEC.*K,IFT.*K)
A CIEC.*K=EC.*K*ECMPF.*K
A EC.*K=CLIP(NEWEC,REC,TIMEF.*K,TFE)
C NEWEC*=.5
A ECMPF.*K=TABLE(ECMPFT,PF.*K/RPF,-4,4,1)
NOTE  RPF=RIF*PRA
C RPF=.003E6
NOTE ****************************CREDIBILITY
A CP.*K=SMOOTH(ICR.*K,IFT.*K)
A ICR.*K=PICR*ICRMMS.*K
C RICR=1
A ICRMMS.*K=TABLE(ICRMMT,SMF.*K/RSMF,0,.4,.5)
T ICRMMT=-.3/1/.4/1.5/1.5/1.5/1.5
C RSMF=.1
A IFT.*K=RIFT*IFTMV.*K
C RIFT=5
A IFTMV.*K=TABLE(IFTMVT,V.*K/RV,0,2,.5)
T IFTMVT=0/.7/1/1.2/1.25
NOTE ****************************POSITIVE FEEDBACK
A PF.*K=IF.*K*PRA*AMR.*K
C RRA=.1
A AMR.*K=TABLE(AMRT,PPRF.*K/RPPRE,0,4,1)
T AMRT=-4/-1/4/1.2/1.8
C RPPRE=.7
A PPRF.*K=SMOOTH(CIPRE.*K,IFT.*K)
A CIPRE.*K=PRF.*K*RPR*PBMCR.*K
C RPB=.7
A PBMCR.*K=TABLE(PBMCRT,CR.*K/RCR,0,4,.5)
T PBMCRT=0/.3/1/.4/1.5/1.5/1.5/1.5
C RCR=1
NOTE ****************************COUNTERFORCE APPLIED
A CFA.*K=RCF*CMPT.*K*CMNS.*K
C RCFS=.001E6
A CMPT.*K=TABLE(CMPTT,PT.*K/RPT,0,.4,10)
T CMPTT=0/10/19/26/30
NOTE  RPT=(RTG+RTS)/2
C RTG=.8
A RT.*K=(RTG*PTMG.*K+PTS*PTMS.*K)/2
C PTG=.1
A PTMG.*K=TABLE(PTMGT,NI.*K/RNI,-4,4,1)
T PTMGT=0/.1/5/1/2/5/11/16/20
C RNJ=1.2E6
C RTS=1.5
A PTMS.*K=TABLE(PTMST,PMF.*K/PPMF,0,2,.5)
T PTMST=0/.25/1/2/5/10
C RPMF=.6
A NI.*K=APJ.*K-APR.*K
N NI=INI
C INI=-1.2E6
A APJ.*K=SMOOTH(PJ.*K,KL,OP)
A APR.*K=SMOOTH(PR.*K,OP)
C OP=2
PMF.K=SMOOTH(MF.K,MPD)
MPD=2
CMNS.K=TABHL(CMNST,NF.K/RNF,0,4,1)
CMNST=0/1/2/2.5/2.7

NOTE

*****PERSON FLOWS

N.K=N.J+{DT}({PR.JK-PJJK})
N=IN
C IN=79E6
A NF.K=N.K/TP
C TP=200E6
L M*K=M.J+(DT)({PJJK+ALJK-PRJK-AFJK})
N=IM
C TM=120E6
A MF.K=M.K/TP
I. A.K=A.J+(DT)({AJJK-ALJK})
N=IA
C IA=1E6

NOTE

*****PERSONS JOINING

PJJK=NLK*N.K*TKJK
A TJJK=RTJK*ATJVK*ATMJJK*K*ATMCFJK*K*ATMSNK*K*ATMQMEJK
C RTJK=0.015
A ATJVK=TABHL(ATJVT,V.K/RV,0,2,5)
C ATJVT=0.7/1.1/1.5/1.2
A ATMJJK=TBHL(ATMJCT,PEC.K/RPEC,0,4,1)
C ATMJCT=1.5/1.6/3/1
A ATMCFJK=TBHL(ATMCFCT,CFJK/K/RCF,0,4,1)
C ATMCFCT=1.3/1.8/7.65
A ATMSNK=TBHL(ATMSNCT,PMF.K/RPMF,0,4,1)
C ATMSNCT=3/1/1.4/1.5/1.5
A ATMQMEJK=TABLE(ATMQMT,QMEREK.K/RQMEMK,0,6,1)
C ATMQMT=0/1/1.9/2.5/3/3.5/4
NOTE

RQMEMK=RQMED/RSME
C PQMEMK=2

NOTE

*****PERSONS RETRACTING

PRJK=NLK*N.K*TPJK
A TRJK=RTJK*MRTMCFJK*MRTMJJK*MRTMFJK*MRTMQMJJK
C RTJK=0.02
A MRTMCFJK=TABLE(MRTMCT,CFJK/K/RCF,0,4,1)
C MRTMCT=1/1/1.1/1.25/1.5
A MRTMJJK=TBHL(MRTMJCT,ECJK/K/REC,0,4,1)
C MRTMJCT=1.4/1.8/7.75/7.75
A MRTMFJK=TBHL(MRTMFT,AMD.K/RAMD,0,2,5)
C MRTMFT=3/1.4/1/1/1
A RAMD=50
A MRTMQMJJK=TBHL(MRTMQRT,QMEO.K/RQMOE,0,4,1)
C MRTMQRT=5/1.7/55/5
C RQMOE=2
L AMD.K=AMD,K+{DT}({AMRATE.K})
N AMD=IAMD
C IAMD=50
R AMRATE.KL={MD.K-AMD.K}/MAT
C MAT=5
**NOTE**

**QUALITY OF MEMBER EXPERIENCE**

A  QME.K=RME*K*QMPRE.K*QMEMSW.K*QMSME.K*QMEMMF.K
C  RQME=2
A  QMPRE.K=TABLE(QMPRT,PRE.K/RPRE,0,4,1)
T  QMPRT=0/1/1.72/2/2.5
A  QMEMSW.K=TABLE(QMEMST,SW.K/RSW,0,4,1)
T  QMEMST=0/1/2/2.9/3.6
A  QMSME.K=TABLE(QMSMT,SME.K/RSM,0,4,1)
T  QMSMT=.8/1/1.2/1.4/1.6
A  QMEMMF.K=QMEO.K/QMEREP.K
A  QMEREP.K=SMOOTH(CMEO.K,MRC)
C  MRD=3
L  QMEO.K=QMEO.J+(DT)(QMRATE.JK)
N  QMEO=QMEO
C  IQMEO=2
R  QMRATE.KL=(QME.K-QMEO.K)/MQPD
C  MQPD=1.5
A  QMEMMF.K=TABLE(QMEMMT,MM.K/RMM,0,4,1)
T  QMEMMT=0/1/1.3/1.5/1.5

**NOTE**

**ACTOR GROUP Cohesion**

L  ACO.K=ACO.J+(DT)(COG.JK-CCO.JK)
N  ACO=ACO
C  IACO=2
R  COG.KL=(EM.K/A.K)*RMP*PEMM.K
C  RMP=13.5
A  PEMM.K=TABLE(PEMMT,ACO.K/RACO,0,4,1)
T  PEMMT=4/1/3/1/0
C  RACO=2
R  COD.KL=ACO.K/COD.K
A  COD.K=RCODT*CODMS.K*CODSMU.K*CODMAT.K
C  RCODT=2
A  CODMS.K=TABLE(CODMS,ASU.K/RASU,0,4,5)
T  CODMS=.5/2/1.5/8.5/8/8/8/8/8/8
C  RASU=1E6
A  CODSMU.K=TABLE(CODSMU.RASU,0,4,1)
T  CODSMU=1/1/1.4/1.5/1.5
C  CODMAT=1/1/1.3/1.5/1.5
C  RAD=5

**NOTE**

**PERCEPTION OF ACCOMPLISHMENT**

A  PACC.K=(RSMACC*ACMSME.K*RFACC*ACCF.K+RGACC*ACMN1.K)/3
C  RSMACC=1
A  ACMSME.K=TABLE(ACMSMT,SME.K/RSM,0,4,1)
T  ACMSMT=0/1/1.9/2.5/3
C  RFACC=.9
A  ACCMKF.K=TABLE(ACCMPT,PF.K/RPF,-4,4,1)
T  ACCMKP=.2/2.5/1/1.5/2.4/2.4/2.4/6
C  RGACC=.5
A  ACMN1.K=TABLE(ACCMNT,NI.K/RN,4,4,1)
T  ACCMN=.9/.9/.95/1/1.4/2/2.8/3.8/5

**NOTE**

**ACTOR DEDICATION**
A  AD.K=RAD:ADMQAE.K
A  ADMQAE.K=TABHL(ADMQAT,QAEO.K/RQAEO,0,4,1)
T  ADMQAT=8/1/1,2/1,4/1,5
C  RQAEO=1,5
L  QAEO.K=QAEO.J*(DT)(QARATE.JK)
N  QAEO=IQAE0
C  IQAE0=1,5
R  QARATE.KL=(QAEO.K-QAEO.K)/AOPD
C  AOPD=1

NOTE

*******CENTRALIZATION OF DECISION POWER
A  CEDP.K=SMOOTH(ICEOP.K,CET)
A  ICEOP.K=RICE*CEMS.K*CEMSU.K
C  RICE=2
A  CEMS.K=TABLE(CEMST,A,K/RA,0,4,1)
T  CEMST=1/1/1,6/1,9/2
A  CEMSU.K=TABLE(CEMSUT,ASU.K/RASU,0,4,5)
T  CEMSUT=4,5/2/1,6/5/5/5/5/5
C  CET=10

NOTE

*******FLEXIBILITY OF ORGANIZATION
A  FLM.K=RFLO*FLMCE.K*FLMXAI.K
A  FLMXAI.K=TABLE(FLMXAT,XXA.K/RXCA,-5,5,1)
A  FLMAT=4/3/2,4/1,9/1,5/1,2/1,8/6/5/4
A  RXCA=25
C  XXA.K=SMOOTH(PXA.K,AET)
C  AET=3
A  PXA.K=RFT*FTMCO.K-PS.K
C  RFT=-25
A  FTMCO.K=TABLE(FTMCOT,ACO.K/RACO,0,4,1)
T  FTMCOT=9/1/1,6/1,9/2
A  PS.K=PFR.K-PERS.K
A  PFR.K=1-QAFN.K*(PEMWL.K*RSEPP*SEPPMD.K)
C  RSEPP=1,2
A  PEMWL.K=TABLE(PEMWLT,PWL.K/RPWL,0,2,5)
A  PEMWLT=1,7/8/1,2/1,7/4
A  RPWL=1
C  PWL.K=SMOOTH(WL.K,WLPT)
C  WLPT=6
A  SEPPMD.K=TABLE(SEPPMT,AD.K/RAD,0,4,1)
T  SEPPMT=7/1/1,5/1,6
L  PERS.K=PERS.J*(DT)(PERSAT.JK)
N  PERS=PFRS
C  IPERS=1,75
R  PERATE.KL=(PER.K-PERS.K)/SAT
C  SAT=5

NOTE

*******LEISURE TIME
A  WL.K=CF.K/SE.K
A  CE.K=EH.K+EI.K+EM.K+ER.K+RE.K+FS.K+ESP.K+EV.K
NOTE
RCE=(FEH+FEI+FEM+FFR+FES+FESP+FEV)*RSE
C  RCE=1,5E6
C  RSE=1,5E6
A  ILT.K=1-WL.K*NWT
**ACTORS ENTERING**

R: AFT,KL=DFLAY1(AF,KL,TD)

C: TD=2

R: AE,KL=EHL,K*RH*PFHM,K

C: RHP=2.3

A: PEFHM,K=TABHL(PFHTM,AC,K/RAC,0,4,1)

T: PFHTM=0/1/1.6/2/2.2

**ACTORS LEAVING**

R: AL,KL=A,K*(RTO*TMOAQAE,K)

C: RTO=0.3

A: TMOAQAE,K=TABHL(TMQT,K,AQEO.K/RQFO,0,4,1)

T: TMQT=5/1.4/0.7/1

**ACTOR SUITABILITY**

L: ASU,K=ASU,J+(OT)(SUIJK+SUHJK-SUDJK)

N: ASU=IASU

C: IASU=2

R: SUI,KL=(ES,K/A,K)*RSP*PESM,K

C: RSP=1

A: PESM,K=TABLE(PESTM,ASU,K/RASU,0,2,0.5)

T: PEMST=4/2/1/0/4/0

R: SUH,KL=(NASU,K-ASU,K)(AAF,K/A,K)

A: NASU,K=(RNASU*SUMC,K)*SUMC,K

C: RNASU=2

A: SUMC,K=TABLE(SUMCT,AC,K/RAC,0,4,1)

T: SUMCT=0/1/1.8/2/5/3

A: SUMC,K=TABLE(SUMCT,EC,K/REC,0,4,1)

T: SUMCT=9/1/1.2/1.4/1.9

R: SUD,KL=(ASU,K-MASU)/TNT

C: MASU=5

C: TNT=10

**QUALITY OF ACTOR EXPERIENCE**

A: QAF,K=RQAE*QAMPRE,K*QAEMLT,K*QAEMAD,K*QAMAC.K*

X: QAMFL.O,K*QAMASU,K*QAEMMF.K

C: PQAE=1.5

A: QAMPRE,K=TABLE(QAMPRT,PRE,K/RPRE,0,4,1)

T: QAMPRT=2/1/1.7/2/4/3

A: QAEMLT,K=TABLE(QAMLT,T,K/RLT,0,2,0.25)
U\textsuperscript{4}0036.10933.\textsc{movement.\textsc{data}}

T \quad QAMTLT=0/1*3/1/1/7*3/1/3
NOTE \quad RLT=1-RCEN((RA*RSEP+RSEI)*RSEI)*NWT
C \quad RLT=.715
A \quad QAEMAD.K=TABLE(QAMAT,AD.K/RAD,0,4,1)
T \quad QAMAT=.1/1/1.3/1.5/1.5
A \quad QAMACC.K=TABLE(QAMACT,PACC.K/RPACC,0,4,1)
T \quad QAMACT=.3/1/1.9/3/5
NOTE \quad RPACC=(RMSACC4RFACC+RGACC)/3
C \quad RPACC=8
A \quad QAMFLO.K=TABLE(QAMFLT,FLO.K/RFLO,0,4,1)
T \quad QAMFLT=.1/1/1.6/2.3
A \quad QAMASU.K=TABLE(QAMAST,ASU.K/RASU,0,4,1)
T \quad QAMAST=.2/1/1/1.4/1.5
A \quad QAEMMF.K=TABLE(QAEMMT,4F.K/RMF,0,2,5)
T \quad QAEMMT=0/8/1/1.1/1.15
NOTE
NOTE \quad \textbf{*SUSTAINABLE EFFORT}
A \quad SE.K=SUM(SE.K+RSEI*SEMI.K)*(RSE*OEMC*1.K)
C \quad RSEI=.06
A \quad SEMI.K=TABLE(SEMIT,1.K/RI,0,4,1)
T \quad SEMIT=0/1/1/9/2/7/32
C \quad RI=80006
A \quad I.K=RI*IMIR.K*IMM.K
T \quad IMIR.K=TABLE(IMIRT,ESI.K/REI,0,4,1)
A \quad IMIRT=.5/1/1.4/1.6/1.7
A \quad IMM.K=TABLE(IMMT,K*RM,0,4,1)
T \quad IMMT=0/1/2/3/4
NOTE \quad RM=RMF*TP
C \quad RM=12006
C \quad ROE=.75
A \quad OEMC.K=TABLE(OEMDAT,ACD.K/RACO,0,4,5)
T \quad OEMDAT=2/7/1/1.15/1.25/1.25/1.25/1.25
NOTE
NOTE \quad \textbf{STRATEGY}
A \quad EH.K=FEM.K*SE.K
A \quad FEH.K=TABLE(FETAB,1,1,7,1),RFEM,TIME.K,TFE)
C \quad RFEM=0.01
A \quad EFI.K=FEI.K*SMOTSE.K
A \quad FEI.K=TABLE(FETAB,2,1,7,1),RFEM,TIME.K,TFE)
C \quad RFEI=.20
A \quad SMOTSE.K=SMOTH(SE.K,1)
A \quad SMOTSE=ISE
C \quad ISE=1.5E6
C \quad REI=30E6
A \quad EM.K=FEM.K*SE.K
A \quad FEM.K=TABLE(FETAB,3,1,7,1),RFEM,TIME.K,TFE)
C \quad RFEM=.05
A \quad ER.K=FER.K*SE.K
A \quad FER.K=TABLE(FETAB,4,1,7,1),RFER,TIME.K,TFE)
C \quad RFER=.24
A \quad FS.K=FES.K*SE.K
A \quad FES.K=TABLE(FETAB,5,1,7,1),RFES,TIME.K,TFE)
C \quad RFES=.10
A \quad ESP.K=FESP.K*SE.K
A \quad FESP.K=TABLE(FETAB,6,1,7,1),RFESP,TIME.K,TFE)
C \quad RFESP=.30
\*10036\*10933\*MOVEMENT\*DATA

A EVK=FEV\*K*SE\*K
A FEV\*K=CLIP(TABLE(FETAB,7,1,7,1),REFV,TIMF\*K,TFF)
C RFEV=.10
T FETAB=.01/.20/.05/.24/.10/.30/.10
C TFF=1000

NOTE
NOTE *******CONTROL STATEMENTS
SPEC LENGTH=0/DT=.2/PPTPER=0
A PLTPER\*K=PLPERI+STEP(PLSTEP,PLTME)+STEP(PSSTEP,PTIME)
C PLPFRI=1
C PLSTEP=0
C PLTME=0
C PSSTEP=0
C PTIME=0

PLOT A=A/M=M/QAF=1,QME=2/SF=S/V=V,ASU=U,PFE=P,ACO=O/PF=F
U*M1936\1033\MOVEMENT.DEF.DATA

A  ACTORS (PERSONS)
AAE  AVERAGE ACTORS ENTERING (PERSONS/YEAR)
AARATE  RATE OF CHANGE OF AVERAGE ACTORS ENTERING (PERSONS/YEAR)
AC  ASPIRANT COVERAGE (YEARS)
ACCMNI  ACCOMPLISHMENT MULTIPLIER FROM NET INCREASE (DIM*LESS)
ACCMPF  ACCOMPLISHMENT MULTIPLIER FROM POSITIVE FEEDBACK (DIM*LESS)
ACMSME  ACCOMPLISHMENT MULTIPLIER FROM MEMBER SATISFACTION (DIM*LESS)
ACOD  ACTOR GROUP COHESION (COHESION UNITS)
AD  ACTOR DEDICATION (DEDICATION UNITS)
ADA  AVERAGE DISCUSSION ACTIVITY (VISIBILITY UNITS/YEAR)
ADMAE  ACTOR DEDICATION MULTIPLIER FROM QAF (DIM*LESS)
ADORATE  RATE OF CHANGE OF AVERAGE DISCUSSION ACTIVITY (VISIBILITY UNITS/YEAR)
AE  ACTORS ENTERING (PERSONS/YEAR)
AET  ADVERSITY EFFECT TIME (YEARS)
AFT  ACTORS FINISHING TRAINING (PERSONS/YEAR)
AL  ACTORS LEAVING (PERSONS/YEAR)
AM  AVERAGE MEMBERSHIP DURATION (YEARS)
AMR  APPROVAL MULTIPLIER FROM RELEVANCE (DIM*LESS)
AMRATE  RATE OF CHANGE OF AVERAGE MEMBERSHIP DURATION (YEARS/YEAR)
APJ  AVERAGE PERSONS JOINING (PERSONS/YEAR)
APR  AVERAGE PERSONS RETRACTING (PERSONS/YEAR)
AQP  ACTOR QUALITY PERCEPTION DELAY (YEARS)
AR  ACTOR REPORTING DELAY (YEARS)
ASP  ATTENTION SPAN (YEARS)
ASU  ACTOR SUITABILITY (SUITABILITY UNITS)
ATMCF  ATTRACTION MULTIPLIER FROM COUNTERFORCE (DIM*LESS)
ATMEC  ATTRACTION MULTIPLIER FROM ENTRY COST (DIM*LESS)
ATMOME  ATTRACTION MULTIPLIER FROM ONE (DIM*LESS)
ATMNS  ATTRACTION MULTIPLIER FROM SOCIAL NORMS (DIM*LESS)
ATMV  ATTRACTION MULTIPLIER FROM VISIBILITY (DIM*LESS)
CE  CURRENT EFFORT (PERSONS)
CEDP  CENTRALIZATION OF DECISION POWER (CENTRALIZATION UNITS)
CEMS  CENTRALIZATION MULTIPLIER FROM SIZE (DIM*LESS)
CEMSU  CENTRALIZATION MULTIPLIER FROM ACTOR SUITABILITY (DIM*LESS)
CET  CENTRALIZATION TIME (YEARS)
CFA  COUNTERFORCE APPLIED (PERSONS)
CIFC  CURRENT INFORMATION ON ENTRY COST (COST UNITS)
CIPRE  CURRENT INFORMATION ON PLATFORM RELEVANCE (RELEVANCE UNITS)
CMNS  COUNTERFORCE MULTIPLIER FROM NON-MEMBER STRENGTH (DIM*LESS)
CMPT  COUNTERFORCE MULTIPLIER FROM PERCEIVED THREAT (DIM*LESS)
COD  COHESION DECAY (COHESION UNITS/YEAR)
CODMAD  COHESION DECAY MULTIPLIER FROM ACTOR DEDICATION (DIM*LESS)
CODMS  COHESION DECAY MULTIPLIER FROM SIZE (DIM*LESS)
CODMSU  COHESION DECAY MULTIPLIER FROM ACTOR SUITABILITY (DIM*LESS)
COT  COHESION DECAY TIME (YEARS)
COG  COHESION GROWTH (COHESION UNITS/YEAR)
CR  MOVEMENT CREDIBILITY (CREDIBILITY UNITS)
DRT  DISCUSSION RESPONSE TIME (YEARS)
EC  ENTRY COST (COST UNITS)
ECMPF  ENTRY COST MULTIPLIER FROM POSITIVE FEEDBACK (DIM*LESS)
EH  EFFORT TO HIRING (PERSONS)
EI  EFFORT TO INCOME RAISING (PERSONS)
EM  EFFORT TO MAINTENANCE (PERSONS)
ER  EFFORT TO RELEVANCE (PERSONS)
ES  EFFORT TO SOCIALIZATION (PERSONS)
ESP  EFFORT TO SERVICE PRODUCTION (PERSONS)
PERATE  RATE OF CHANGE OF PERFORMANCE (ACHIEVEMENT UNITS/YEAR)
PERM  PRODUCTIVITY OF EFFORT TO RELEVANCE MULTIPLIER (DIM*LESS)
PERS  PERFORMANCE STANDARD (ACHIEVEMENT UNITS)
PESM  PRODUCTIVITY OF EFFORT TO SOCIALIZATION MULTIPLIER (DIM*LESS)
PESP  PRODUCTIVITY OF EFFORT TO SERVICE PRODUCTION (SERVICE UNITS/PEF
SON-YEAR)
PFVM  PRODUCTIVITY OF EFFORT TO VISIBILITY MULTIPLIER (DIM*LESS)
PF  POSITIVE FEEDBACK (APPROVAL UNITS)
PJ  PERSONS JOINING (PERSONS/YEAR)
PLPERI  PLOT PERIOD INITIALLY (YEARS)
PLSTEP  CHANGE IN PLOT PERIOD (YEARS)
PLTIME  TIME FOR CHANGE OF PLTPER (YEARS)
PLTPER  PLOT PERIOD (YEARS)
PMF  PERCEIVED MEMBER FRACTION (DIM*LESS)
PRERE  PERCEIVED PLATFORM RELEVANCE (RELEVANCE UNITS)
PR  PERSONS RETRACTING (PERSONS/YEAR)
PRE  PLATFORM RELEVANCE (RELEVANCE UNITS)
PRDL  RELEVANCE DECAY (RELEVANCE UNITS/YEAR)
PRDT  RELEVANCE DECAY TIME (YEARS)
PRFL  RELEVANCE INCREASE (RELEVANCE UNITS/YEAR)
PR  PERCEIVED SUCCESS (ACHIEVEMENT UNITS)
PSTP  CHANGE IN PLTPER (YEARS)
PT  PERCEIVED THREAT (THREAT UNITS)
PTIMF  TIME FOR CHANGE IN PLTPER (YEARS)
PTMG  PERCEIVED THREAT MULTIPLIER FROM GROWTH (DIM*LESS)
PTMS  PERCEIVED THREAT MULTIPLIER FROM SIZE (DIM*LESS)
PWL  PERCEIVED WORKLOAD (DIM*LESS)
PXA  PERCEIVED EXCESS ADVERSITY (ACHIEVEMENT UNITS)
QAE  QUALITY OF ACTOR EXPERIENCE (QUALITY UNITS)
QAFMAD  QAE MULTIPLIER FROM DEDICATION (DIM*LESS)
QAEMLT  QAE MULTIPLIER FROM LEISURE (DIM*LESS)
QAFMMD  QAE MULTIPLIER FROM MEMBER FRACTION (DIM*LESS)
QAFEO  QAE OBSERVED (QUALITY UNITS)
QAFERE  QAE REPORTED (QUALITY UNITS)
QAMACC  QAE MULTIPLIER FROM ACCOMPLISHMENT (DIM*LESS)
QAMASU  QAE MULTIPLIER FROM SUITABILITY (DIM*LESS)
QAMFLO  QAE MULTIPLIER FROM FLEXIBILITY (DIM*LESS)
QAMPRE  QAE MULTIPLIER FROM PLATFORM RELEVANCE (DIM*LESS)
QARATE  RATE OF CHANGE OF QAFEO (QUALITY UNITS/YEAR)
QM  QUALITY OF MEMBER EXPERIENCE (QUALITY UNITS)
QMEMMF  QME MULTIPLIER FROM MEMBER FRACTION (DIM*LESS)
QMMSW  QME MULTIPLIER FROM SATISFACTION OF WANTS (DIM*LESS)
QMEO  QME OBSERVED (QUALITY UNITS)
QMERE  QME REPORTED (QUALITY UNITS)
QMMPRE  QME MULTIPLIER FROM RELEVANCE (DIM*LESS)
QMMSME  QME MULTIPLIER FROM MEMBER SATISFACTION (DIM*LESS)
QRARTE  RATE OF CHANGE OF QMEO (QUALITY UNITS/YEAR)
RA  REFERENCE ACTORS (PERSONS)
RAAE  REFERENCE AVERAGE ACTORS ENTERING (PERSONS/YEAR)
RAC  REFERENCE ASPIRANT COVERAGE (YEARS)
RACO  REFERENCE ACTOR GROUP COHESION (COHESION UNITS)
RAD  REFERENCE ACTOR DEDICATION (DEDICATION UNITS)
RAMD  REFERENCE AVERAGE MEMBERSHIP DURATION (YEARS)
RASU  REFERENCE ACTOR SUITABILITY (SUITABILITY UNITS)
RCA  REFERENCE CURRENT EFFORT (PERSONS)
RCE  REFERENCE CENTRALIZATION OF DECISION POWER (CENTRALIZATION UNITS)
RCF  REFERENCE COUNTERFORCE (PERSONS)
RCDT  REFERENCE COHESION DECAY TIME (YEARS)
RCR  REFERENCE MOVEMENT CREDIBILITY (CREDIBILITY UNITS)
RDA  REFERENCE DISCUSSION ACTIVITY (VISIBILITY UNITS/YEARS)
REC  REFERENCE ENTRY COST (COST UNITS)
REG  REFERENCE EFFORT TO INCOME RAISING (PERSONS)
RFAA  REFERENCE FRACTION ATTRACTED TO ACTORSHIP (DIM*LESS)
RFACC  REFERENCE FEEDBACK ACCOMPLISHMENT (ACCOMPLISHMENT UNITS)
RFEH  REFERENCE FRACTION OF EFFORT TO HIPING (DIM*LESS)
RFEI  REFERENCE FRACTION OF EFFORT TO INCOME RAISING (DIM*LESS)
RFEN  REFERENCE FRACTION OF EFFORT TO MAINTENANCE (DIM*LESS)
RFER  REFERENCE FRACTION OF EFFORT TO RELEVANCE (DIM*LESS)
RIFES  REFERENCE FRACTION OF EFFORT TO SOCIALIZATION (DIM*LESS)
RIFESP  REFERENCE FRACTION OF EFFORT TO SERVICE PRODUCTION (DIM*LESS)
RFEV  REFERENCE FRACTION OF EFFORT TO VISIBILITY (DIM*LESS)
RFLO  REFERENCE FLEXIBILITY (FLEXIBILITY UNITS)
RFT  REFERENCE FRUSTRATION THRESHOLD (ACHIEVEMENT UNITS)
RGACC  REFERENCE GROWTH ACCOMPLISHMENT (ACCOMPLISHMENT UNITS)
RHP  REFERENCE HIRING PRODUCTIVITY (PERSONS/YEAR)/PERSON
RHR  REFERENCE INCOME ($)YEAR
RICE  REFERENCE INDICATED CENTRALIZATION (CENTRALIZATION UNITS)
RINCR  REFERENCE INDICATED CREDIBILITY (CREDIBILITY UNITS)
RTE  REFERENCE INDUCED EFFORT (PERSONS)
RIFE  REFERENCE INFORMAL EFFORT (PERSONS)
RIFT  REFERENCE IMPRESSION FORMATION TIME (YEARS)
RALT  REFERENCE LEISURE TIME (DIM*LESS =DAY/DAY)
RM  REFERENCE MEMBERS (PERSONS)
RMF  REFERENCE MEMBER FRACTION (DIM*LESS)
RMP  REFERENCE MAINTENANCE PRODUCTIVITY (COHESION UNITS/YEAR)
RMSPACC  REFERENCE MEMBER SATISFACTION ACCOMPLISHMENT (ACCOMPLISHMENT UNITS)
RNK  REFERENCE NEW ACTOR SUITABILITY (SUITABILITY UNITS)
RNF  REFERENCE NONMEMBER FRACTION (DIM*LESS)
RNK  REFERENCE NET INCREASE (PERSONS/YEAR)
RNE  REFERENCE OPERATING EFFICIENCY (DIM*LESS)
RPACC  REFERENCE PERCEIVED ACCOMPLISHMENT (ACCOMPLISHMENT UNITS)
RPB  REFERENCE PERCEPTION BIAS (DIM*LESS)
RPDEC  REFERENCE PERCEIVED ENTRY COST (COST UNITS)
RPF  REFERENCE POSITIVE FEEDBACK (APPROVAL UNITS)
RPME  REFERENCE PERCEIVED MEMBER FRACTION (DIM*LESS)
RPPRE  REFERENCE PERCEIVED PLATFORM RELVANCE (RELEVANCE UNITS)
RPRE  REFERENCE PLATFORM RELVANCE (RELEVANCE UNITS)
RPREP  REFERENCE RELEVANCE PRODUCTIVITY (RELEVANCE UNITS/(YEAR-PERSON))
RPT  REFERENCE PERCEIVED THREAT (THREAT UNITS)
RPWL  REFERENCE PERCEIVED WORKLOAD (DIM*LESS)
ROAE  REFERENCE QAE (QUALITY UNITS)
ROAEQ  REFERENCE QAE OBSERVED (QUALITY UNITS)
ROAREP  REFERENCE QAE REPORTED (QUALITY UNITS)
ROME  REFERENCE QME (QUALITY UNITS)
ROMEO  REFERENCE QME OBSERVED (QUALITY UNITS)
ROMREP  REFERENCE QME REPORTED (QUALITY UNITS)
RRA  REFERENCE RELEVANCE APPROVED (APPROVAL UNITS/PERSO)
RSE  REFERENCE SUSTAINABLE EFFORT (PERSONS)
RSEI  REFERENCE SUSTAINABLE EFFORT FROM INCOME (PERSONS)
RSEPP  REFERENCE SUSTAINABLE EFFORT PER PERSON (DIM*LESS)
RSHE  REFERENCE SATISFIED EXPECTATIONS (DIM*LESS)
RSP  REFERENCE SOCIALIZATION PRODUCTIVITY (SUITABILITY UNITS/YEAR)
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<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>RSPM</td>
<td>Reference Services Per Member (Service Units/Person-Year)</td>
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<td>RSW</td>
<td>Reference Satisfaction of Wants (Satisfaction Units)</td>
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<tr>
<td>RTG</td>
<td>Reference Threat from Growth (Threat Units)</td>
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<td>Reference Tendency to Join (1/Year)</td>
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<tr>
<td>RTO</td>
<td>Reference Turnover (1/Year)</td>
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<td>Reference Tendency to Retract (1/Year)</td>
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<td>RTS</td>
<td>Reference Threat from Size (Threat Units)</td>
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<td>RV</td>
<td>Reference Visibility (Visibility Units)</td>
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<td>RVP</td>
<td>Reference Visibility Productivity (Visibility Units/(Year x Persons))</td>
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<td>RXXA</td>
<td>Reference Experienced Excess Adversity (Achievement Units)</td>
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<td>Standard Adjustment Time (Years)</td>
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<td>Sustainable Effort (Persons)</td>
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<td>Sustainable Effort Multiplier from Income (Dim*Less)</td>
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<td>Sustainable Effort Per Person Multiplier from Dedication (Dim*Less)</td>
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<td>Sustainable Human Effort (Persons)</td>
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<td>Satisfaction of Membership Expectations (Dim*Less)</td>
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<td>Past Sustainable Effort (Persons)</td>
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<td>Services Per Member (Service Units/(Person-Year))</td>
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<td>Suitability Decay (Suitability Units/Year)</td>
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<td>Satisfaction Multiplier from Flexibility (Dim*Less)</td>
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<td>Training Duration (Year)</td>
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<td>Turnover Multiplier from QAE (Dim*Less)</td>
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<td>Workload (Dim*Less)</td>
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<td>Workload Perception Time (Years)</td>
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<td>Experienced Excess Adversity (Achievement Units)</td>
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**LIFECYCLE 4**

**NOTE**

**NUMBER OF LEADERS**

L = L + (DT) * (LEJK - LLJK)

**NOTE**

**LEADER SATISFACTION**

A = LS * RLS * LSMEK * LSMLK

**NOTE**

**NUMBER OF MEMBERS**

M = M + (DT) * (PJJK - PLJK - LEJK + LLJK)

**NOTE**

**MEMBER SATISFACTION**

A = MS * RMS * MSSTF * K * MSMTE * K * MSMM * K

**NOTE**

**RFME = 1**

**LEMLS = K**

**NOTE**

**TABLE**

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U.M10036.10933.LIFCYCLE.DA
A
MSMLTE.K=TABHLM.*MSMLTT+.AELTS*.K/R.AELTS+.0,+60,+10
T
MSMLTT=9*.1/2/3/3.5/3.8/3.9/4
L
N
AELTS=.5
C
ELTSAT=.5
C
RAELTS=.5
A
ELTS*.K=SE*.K*FLTS*.K
A
MSMM*.K=TABHLM.*MSMNT*.1.443*LOGN(M*.K/R*.M),-.1,.9,.1
T
MSMNT=.8/1/1,.4/1,.6/1,.45/1,.55/1,.25/1,.1,.06/1,.05
C
PM=.30
NOTE
NOTE
******SUSTAINABLE EFFORT
A
SE*.K=UEPM*.K*RUEPL*UEPLM*.K*L*.K
C
UEPM=.01
C
RUEPL=.1
A
UEPLM*.K=TABHLM.*UEPLMT*.1.443*LOGN(L*.K/R*.L),-.1,.6,.1
T
UEPLMT=.9/1/1.2/1.5/1.4/1.6/1.5
NOTE
NOTE
******ALLOCATION OF EFFORT
A
FTS*.K=1-FSL*.K-FSTSM*.K
L
N
FSL=.2
C
FSLAT=1
A
IFSL*.K=TABHLM.*(IFSL*.K/RPP*.K),.0,.5,.1
T
IFSLT=.3/.2/.13/.07/.05/.0
C
RPP=.8
L
N
FSTSM=.3
C
FSTSAT=1
A
IFSTSM*.K=TABHLM.*(IFSTST*.K/RPP*.K),.0,.4,.1
T
IFSTST=.7/.3/.15/.05/.0
A
PP*.K=PM*.K/MSS*.K
L
N
MSS=MSSI
C
MSSI=.25
C
MSSAT=4
NOTE
NOTE
******CONTROL STATEMENTS
C
DT=.2
C
PLTPER=.4
C
LENGTH=0
PLT L=L/M=MS=1/MS=2/FSTSM=,A,FSL=B,FLTS=01/PP=P/MSMM=S/LSML=F
AELTSM  AVERAGE EFFORT TO LONG-TERM SATISFACTION OF MEMBERS (PERSONS)
AFSPL  AVERAGE EFFORT TO SATISFACTION PER LEADER (PERSON/PERSON)
ELTSAT  EFFORT TO LONG-TERM SATISFACTION OF MEMBERS AVERAGING TIME (YEARS)
ELTSM  EFFORT TO LONG-TERM SATISFACTION OF MEMBERS (PERSONS)
ESPL  EFFORT TO SATISFACTION PER LEADER (PERSON/PERSON)
ESPLAT  EFFORT TO SATISFACTION PER LEADER AVERAGING TIME (YEARS)
ESTSPM  EFFORT TO SHORT-TERM SATISFACTION PER MEMBER (PERSON/PERSON)
FLTSM  FRACTION TO LONG-TERM SATISFACTION OF MEMBERS (DIM*LESS)
FSL  FRACTION TO SATISFACTION OF LEADERS (DIM*LESS)
FSLAT  FRACTION TO SATISFACTION OF LEADERS AVERAGING TIME (YEARS)
FSTSM  FRACTION TO SHORT-TERM SATISFACTION OF MEMBERS AVERAGING TIME (YEARS)
FSTSM  FRACTION TO SHORT-TERM SATISFACTION OF MEMBERS (DIM*LESS)
IFSIL  INDICATED FRACTION TO SATISFACTION OF LEADERS (DIM*LESS)
IFSL  INDICATED FRACTION TO SATISFACTION OF LEADERS TABLE (DIM*LESS)
IFSTSM  INDICATED FRACTION TO SHORT-TERM SATISFACTION OF MEMBERS (DIM*LE)
IFSILTSM  INDICATED FRACTION TO SHORT-TERM SATISFACTION OF MEMBERS (DIM*LE)
I  LEADERS (PERSONS)
LD  LEADERSHIP DURATION (YEARS)
LE  LEADERS ENTERING (PERSONS/YEAR)
LEMLS  LEADERS ENTERING MULTIPLIER FROM LEADER SATISFACTION (DIM*LESS)
LEMLES  LEADERS ENTERING MULTIPLIER FROM LEADER SATISFACTION TABLE (DIM*LESS)
LI  LEADERS INITIALLY (PERSONS)
LL  LEADERS LEAVING (PERSONS/YEAR)
LS  LEADER SATISFACTION (SATISFACTION UNITS)
LSME  LEADER SATISFACTION MULTIPLIER FROM EFFORT (DIM*LESS)
LSMET  LEADER SATISFACTION MULTIPLIER FROM EFFORT TABLE (DIM*LESS)
LSML  LEADER SATISFACTION MULTIPLIER FROM LEADERS (DIM*LESS)
LSMLT  LEADER SATISFACTION MULTIPLIER FROM LEADERS TABLE (DIM*LESS)
LSPT  LEADER SATISFACTION PERCEPTION TIME (YEARS)
M  MEMBERS (PERSONS)
MD  MEMBERSHIP DURATION (YEARS)
MI  MEMBERS INITIALLY (PERSONS)
MS  MEMBER SATISFACTION (SATISFACTION UNITS)
MSMLTF  MEMBER SATISFACTION MULTIPLIER FROM LONG-TERM EFFORT (DIM*LESS)
MSMLTT  MEMBER SATISFACTION MULTIPLIER FROM LONG-TERM EFFORT TABLE (DIM*LESS)
MSMN  MEMBER SATISFACTION MULTIPLIER FROM MEMBERS (DIM*LESS)
MSMNT  MEMBER SATISFACTION MULTIPLIER FROM MEMBERS TABLE (DIM*LESS)
MSMSTE  MEMBER SATISFACTION MULTIPLIER FROM SHORT-TERM EFFORT (DIM*LESS)
MSMSTT  MEMBER SATISFACTION MULTIPLIER FROM SHORT-TERM EFFORT TABLE (DIM*LESS)
MSPT  MEMBER SATISFACTION PERCEPTION TIME (YEARS)
MSS  MEMBER SATISFACTION STANDARD (SATISFACTION UNITS)
MSSAT  MEMBER SATISFACTION—STANDARD ADJUSTMENT TIME
MSSI  MEMBER SATISFACTION STANDARD INITIALLY (SATISFACTION UNITS)
N  NON-MEMBERS (PERSONS)
NI  NON-MEMBERS INITIALLY (PERSONS)
P  PERSONS JOINING (PERSONS/YEAR)
PJ  PERSONS JOINING MULTIPLIER FROM MEMBER SATISFACTION (DIM*LESS)
PJMLT  PERSONS JOINING MULTIPLIER FROM MEMBER SATISFACTION TABLE (DIM*LESS)
PJMLTT  PERSONS JOINING MULTIPLIER FROM MEMBER SATISFACTION TABLE (DIM*LESS)
PL  PERSONS LEAVING (PERSONS/YEAR)
PLS  PERCEIVED LEADER SATISFACTION (SATISFACTION UNITS)
PMS  PERCEIVED MEMBER SATISFACTION (SATISFACTION UNITS)
PMSI PERCEIVED MEMBER SATISFACTION INITIALLY (SATISFACTION UNITS)
PP   PERCEIVED PERFORMANCE (DIMLESS)
RAELTS REFERENCE AVERAGE EFFORT TO LONG-TERM SATISFACTION OF MEMBERS (PERSONS)
RASPL REFERENCE AVERAGE EFFORT TO SATISFACTION PER LEADER (PERSON/PERS ONS)
RESTSP REFERENCE EFFORT TO SHORT-TERM SATISFACTION PER MEMBER (PERSON/PERSON)
RME  REFERENCE FRACTION OF MEMBERS ENTERING (1/YEAR)
RFNJ REFERENCE FRACTION OF NON-MEMBERS JOINING (1/YEAR)
RL   REFERENCE LEADERS (PERSONS)
RLS  REFERENCE LEADER SATISFACTION (SATISFACTION UNITS)
RM   REFERENCE MEMBERS (PERSONS)
RMS  REFERENCE MEMBER SATISFACTION (SATISFACTION UNITS)
RPLS REFERENCE PERCEIVED LEADER SATISFACTION (SATISFACTION UNITS)
RPMS REFERENCE PERCEIVED MEMBER SATISFACTION (SATISFACTION UNITS)
RPP  REFERENCE PERCEIVED PERFORMANCE (DIMLESS)
RUEPL REFERENCE USEFUL EFFORT PER LEADER (PERSON/PERSON)
SE   SUSTAINABLE EFFORT (PERSONS)
UEPLML USEFUL EFFORT PER LEADER MULTIPLIER FROM LEADERS (DIMLESS)
UEPLMT USEFUL EFFORT PER LEADER MULTIPLIER FROM LEADERS TABLE (DIMLESS)
UEPM  USEFUL EFFORT PER MEMBER (PERSON/PERSON)
**NOTE**

********USER SATISFACTION**

A  PUS.K = SMOOTH(US.K, USPT)
C  USPT = 1
A  US.K = USMT.K * OS.K * 1
A  USMT.K = TABH(L(USMTT, AWT.K / RAWT), 5, 1)
T  USMTT = 1/5/1/7/4/25/1
A  AWT.K = SMOOTH(WT.K, WTAT)
C  WTAT = .5
C  RAWT = .2

**NOTE**

********QUALITY OF SERVICE**

A  QK = QSMEPU.K * PRP.K * 1
A  QSMEPU.K = TABH(L(QSMEPT, EPU.K / REP), 0, 2, 5)
T  QSMEPT = 0/6/1/1.3/1.5
A  EPK = SMOOTH(IEP.U.K, EPUAT)
C  EPUAT = .5
C  REP = .2
A  IEPK = RIEPU*EPUMT.K
C  RIEPU = .2
A  EPUMTV.K = TABH(L(EPUMTT, WT.K / RWT), 0, 5, 1)
T  FPUMTT = 2/1.5/3/2/1.15
A  RP.K = RP.K * IAS.K * RPMUS.K * PRP
A  RP.K = SMOOTH(LTF.K, LTEET)
C  LTEET = 3
A  IAS.K = TABH(L(IAS.T, SS.K / RSS), 3, 1, 2)
T  IAST = 0/1/3/6/9/1
C  RSS = 1
A  RPMUS.K = TABH(L(RP.MUST, AUS.K / RAUS), 0, 10, 2)
T  RPMUST = 1/1.4/2/1/2.7/3
C  RAUS = 5
C  PRP = 2.5

**NOTE**

********STAFF SATISFACTION AND SUITABILITY**

A  SS.K = SSU.K * 1
L  SSU.K = SSU.J * (DT) (SUC.JK)
N  SSU = SSUI
C  SSUI = 1
R  SUC.KL = (NSSU.K * SSU.K) * TFT.JK / S.K
A  NSSU.K = ICSU.K * NSUMTD.K
A  ICSU.K = RICSU*KABH(L(ICSU.T, PSS.K / RPSS), 0, 2, 5)
T  TCSUT = 2/5/1/6/1/8
C  RPSS = .5
A  PSS.K = SMOOTH(SS.K, SSPT)
C  SSPT = 5
C  RPSS = 1
A  NSUMTD.K = TABH(L(NSUMTT, ATD.K / RMTD), 0, 2, 5)
T  NSUMTT = 4/7/1/1.2/1.25
C  RMTD = .5

**NOTE**

********TRAINING DURATION**

A  ATD.K = SMOOTH(TD.K, TDAT)
C  TDAT = 1
A  TD.K = RMTD*TABH(L(TD.TPT.K, 0, 5, 1)
N  TD = 5
T  TDT = 1/1.4/2/3/3.7/4
U.M10036.10933.HELPORG.DAT

C RTD=5
A TPT,K=T,K/ESD.K
A ESD.K=FSK.K*5.K
NOTE
**STAFF**
I. S.K=S,J+(DT)(TFTJK-SLJK)
I S=S1
C S1=2
R TFT.KL=DELAY3(TK,TD.K,T.K)
R TE.KL=MAX(DICNE.K/HT.K,0)
L DICNE.K=DICNE.J+(DT/DT)(ICNE.J-DICNE.J)
N DICNE=0
C DICNE=0
A DICNE=K=FNE.K-NE.K
A FNE.K=I.K/CPE
A I.K=AUS.K*COS+STEPS(IS1,IT1)+STEPS(IS2,IT2)
C COS=8000
C IS1=40000
C IT1=200
C IS2=0
C IT2=200
C CPE=20000
A NE.K=T.K+S.K
A HT.K=RHT*TABHIL(HTT,PUST,K/RPUST,7.2.5)
T HTT=5/2.5/1/4/0
C PHT=1
A PUST,K=SMOOTH(UST,K,USTPT)
C USTPT=.5
C RPUS=1
R SL.KL=S.K/ALSS.K
A ALSS,K=RALSS*TABHIL(ALSST,PICNE.K/NE.K,-1,3,1)
T ALSST=.1/1/1.25/1.4/1.5
C RALS=5
A PICNE,K=SMOOTH(I,CNE,K,ICNEAT)
C ICNEAT=1
NOTE
**USERS**
L UW.K=UW.J+(DT)(UAJK-USE.JK)
U UW=UWI
C UW=1
R UA.KL=PU,K
R PU.K=RPUS*STABLE(PUT,PUS.K/RPUST,0,12,2)
T PUT=0/2/4/8/14/24/44
C RPU=5
R RPUS=1
C USE.KL=MIN(EUS.K*UST.K/EPU,K,UW,K/(3*DT))
A FUS,K=FUS.K*5.K
A UST,K=RUST*TABHIL(USTT,WT.K/RWT,0,5,1)
T USTT=0/1/1.4/1.7/1.9/2
C RUST=1
NOTE
**WAITING TIME**
A WT.K=UW.K/OUS.K
L OUS,K=OUS.J+(DT/DT)(USEJK-OUS.J)
N OUS=OUS1
C OUS=5
L AUS,K=AUS.J+(DT/USAT)(USEJK-AUS.J)
N     AUS=5
C     USAT=.5
NOTE  ******* ALLOCATION OF EFFORT
L     FUS.K=FUS.J+(DT/USAT)(IFUS.J-FUS.J)
N     FUS=FUSI
C     FUSI=.5
C     USAT=.5
A     IFUS.K=FUS.K*UMUS.K/UMLTE.K
A     UMUS.K=5*(USFWT.K*USFRS.K)
A     USFWT.K=TARI.F(UUSFFT,AWT.K/RWT.0,5,1)
T     UUSFFT=.5/1/.7/2.5/3.6/5
C     RWT.2
A     USFRS.K=TABLE(UUSFRT,PRSF.K,-1,1,.2)
T     UUSFRT=13/10/6/4/2/1/4/.2/.1/0/0
A     PRSF.K=SMOOTH(RSF.K,BSFPT)
C     BSFPT=.5
A     RSF.K=ICNE.K/I.K
I     FSD.K=FSD.J+(DT/FSDAT)(IFSD.J-FSD.J)
N     FSD=FSDI
C     FSDI=.3
C     FSDAT=1
A     IFSD.K=FSD.K*UMSD.K/UMLTE.K
A     UMSD.K=1*(USDFWT.K)
A     USDFWT.K=TABLE(USDFTT,AWT.K/RAWT.0,5,1)
T     USDFTT=.5/1/.8/2.7/3.7/5
A     UMLTE.K=TABHL(UMLTET,FLTE.K/RFLT.0,2,.5)
T     UMLTET=20/2.5/1/-5/0
A     FLTE.K=1-FSD.K-FUS.K
C     RFLT.2
A     LTE.K=FLTE.K*S.K
NOTE  ******* CONTROL STATEMENTS
C     DT=.125
C     LENGTH=0
C     PLTPRF.2
PLT  S=S/T=T/WT=W/BSF=F/FUS=A,FSD=R,FLTE=C(0,1)/SS=1/US=2/T0=D
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ALSS</td>
<td>Average Length of Staff Service (YFAPS)</td>
</tr>
<tr>
<td>ALSSST</td>
<td>ASSL Table (D*LESS)</td>
</tr>
<tr>
<td>ATD</td>
<td>Average Training Duration (YEARS)</td>
</tr>
<tr>
<td>AUS</td>
<td>Average Users Serviced (USERS/YEAR)</td>
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<tr>
<td>AWT</td>
<td>Average Waiting Time (YEARS)</td>
</tr>
<tr>
<td>BSF</td>
<td>Budget Surplus Fraction (D*LESS)</td>
</tr>
<tr>
<td>BSFPT</td>
<td>Budget Surplus Fraction Perception Time (YEARS)</td>
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<tr>
<td>COS</td>
<td>Cost of Service ($/USR)</td>
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<tr>
<td>CPE</td>
<td>Cost Per Employee ($/STAFF-YEAR)</td>
</tr>
<tr>
<td>DT</td>
<td>Time Increment (YEARS)</td>
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<tr>
<td>EPU</td>
<td>Energy Per User (STAFF-YEAR/USER)</td>
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<tr>
<td>EPUAT</td>
<td>Energy Per User Adjustment Time (YEARS)</td>
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<tr>
<td>EPUUMT</td>
<td>EPUUMT Table (D*LESS)</td>
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<tr>
<td>EPUUMWT</td>
<td>Energy Per User Multiplier from Waiting Time (D*LESS)</td>
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<tr>
<td>ESD</td>
<td>Effort to Staff Development (STAFF)</td>
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<tr>
<td>FUS</td>
<td>Effort to User Servicing (STAFF)</td>
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<tr>
<td>LTE</td>
<td>Fraction to Long-Term Effort (D*LESS)</td>
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<td>FNE</td>
<td>Feasible Number of Employees (STAFF)</td>
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<td>FSD</td>
<td>Fraction to Staff Development (D*LESS)</td>
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<tr>
<td>FSDAT</td>
<td>Fraction to Staff Development Adjustment Time (YEARS)</td>
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<tr>
<td>FSDI</td>
<td>FSD Initially (D*LESS)</td>
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<tr>
<td>FUS</td>
<td>Fraction to User Servicing (D*LESS)</td>
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<tr>
<td>FUSAT</td>
<td>Fraction to User Servicing Adjustment Time (YEARS)</td>
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<tr>
<td>FUSI</td>
<td>FUS Initially (D*LESS)</td>
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<tr>
<td>HT</td>
<td>Hiring Time (YEARS)</td>
</tr>
<tr>
<td>HTT</td>
<td>HT Table (D*LESS)</td>
</tr>
<tr>
<td>I</td>
<td>Income ($/YEAR)</td>
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<tr>
<td>IAS</td>
<td>Interpretative Ability of Staff (D*LESS)</td>
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<tr>
<td>IAST</td>
<td>IAS Table (D*LESS)</td>
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<tr>
<td>ICNE</td>
<td>Indicated Change in Number of Employees (STAFF)</td>
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<tr>
<td>ICNEAT</td>
<td>Indicated Change in Number of Employees Adjustment Time (YEARS)</td>
</tr>
<tr>
<td>ICSCU</td>
<td>Incoming Candidate Suitability (Suitability Units)</td>
</tr>
<tr>
<td>ICST</td>
<td>ICST Table (D*LESS)</td>
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<tr>
<td>IEPU</td>
<td>Indicated Energy Per User (STAFF-YEAR/USER)</td>
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<td>IFSD</td>
<td>Indicated Fraction to Staff Development (D*LESS)</td>
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<td>IFUS</td>
<td>Indicated Fraction to User Servicing (D*LESS)</td>
</tr>
<tr>
<td>IS1</td>
<td>Income Step One ($/YEAR)</td>
</tr>
<tr>
<td>IS2</td>
<td>Income Step Two ($/YEAR)</td>
</tr>
<tr>
<td>LENGTH</td>
<td>Simulation Period (YEARS)</td>
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<tr>
<td>LTEE</td>
<td>Long Term Effort (STAFF)</td>
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<tr>
<td>LTEET</td>
<td>Long Term Effort Effect Time (YEARS)</td>
</tr>
<tr>
<td>NE</td>
<td>Number of Employees (STAFF)</td>
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<tr>
<td>NSSU</td>
<td>New Staff Suitability (Suitability Units)</td>
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<tr>
<td>NSUMTD</td>
<td>New Staff Suitability Multiple from Training Duration (D*LESS)</td>
</tr>
<tr>
<td>OICNE</td>
<td>Observed Indicated Change in Number of Employees (STAFF)</td>
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<tr>
<td>OICNEI</td>
<td>OICNE Initially (STAFF)</td>
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<tr>
<td>OUS</td>
<td>Observed Users Serviced (USERS/YEAR)</td>
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<td>OUSI</td>
<td>OUS Initially (USERS/YEAR)</td>
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<tr>
<td>PASF</td>
<td>Perceived Budget Surplus Fraction (D*LESS)</td>
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<td>PICTNE</td>
<td>Perceived Indicated Change in Number of Employees (STAFF)</td>
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<td>PLTPER</td>
<td>Plot Period (YEARS)</td>
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<tr>
<td>PRP</td>
<td>Perceived Relevance of Platform (Relevance Units)</td>
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<tr>
<td>PSS</td>
<td>Perceived Staff Satisfaction (Satisfaction Units)</td>
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<tr>
<td>PU</td>
<td>Potential Users (USERS/YEAR)</td>
</tr>
<tr>
<td>PUS</td>
<td>Perceived User Satisfaction (Satisfaction Units)</td>
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<tr>
<td>PUST</td>
<td>Perceived Utilization of Staff (D*LESS)</td>
</tr>
<tr>
<td>PUT</td>
<td>PU Table (D*LESS)</td>
</tr>
</tbody>
</table>
QS QUALITY OF WFRVICE (QUALITY UNITS)
QSUMPT QSUMPTU TABLE
QSUMPU QUALITY OF SERVICE MULTIPLIER FROM ENERGY PER USER (D*LESS)
RALSS REFERENCE ALSS (YEARS)
RADT REFERENCE ATD (YEARS)
RAUS REFERENCE AUS (USERS/YEAR)
RAWT REFERENCE AWT (YEARS)
RFPU REFERENCE EPU (STAFF-YEAR/USER)
RFLTE REFERENCE FLTE (D*LESS)
RHT REFERENCE HT (STAFF/YEAR)
RICSU REFERENCE ICSU (SUITABILITY UNITS)
RFEPU REFERENCE IEPU (STAFF-YEAR/USER)
RP RELEVANCE OF PLATFORM (RELEVANCE UNITS)
RPMUS RELEVANCE OF PLATFORM MULTIPLIER FROM USER SERVICING (D*LESS)
RPMUST RPMUS TABLE (D*LESS)
RRPR REFERENCE PRP (RELEVANCE UNITS)
RPSS REFERENCE PSS (SATISFACTION UNITS)
RPIU REFERENCE PU (USERS/YEAR)
RPUS REFERENCE PUS (SATISFACTION UNITS)
RPUST REFERENCE PUST (D*LESS)
RSS REFERENCE SS (SATISFACTION UNITS)
RTD REFERENCE TD (YEARS)
RUST REFERENCE UST (D*LESS)
RWT REFERENCE WT (YEARS)
S STAFF (STAFF)
SI S INITIALLY (STAFF)
SL STAFF LEAVING (STAFF/YEAR)
SS STAFF SATISFACTION (SATISFACTION UNITS)
SSPT STAFF SATISFACTION PERCEPTION TIME (YEARS)
SSU STAFF SUITABILITY (SUITABILITY UNITS)
SSUI SSU INITIALLY (SUITABILITY UNITS)
SUC SUITABILITY CHANGE (SUITABILITY UNITS/YEAR)
T TRAINEES (STAFF)
TD TRAINING DURATION (YEARS)
TDAT TRAINING DURATION ADJUSTMENT TIME (YEARS)
TDT TD TABLE (D*LESS)
TE TRAINEES ENTERING (STAFF/YEAR)
TFT TRAINEES FINISHING TRAINING (STAFF/YEAR)
TP TRAINEES PER TRAINER (STAFF/STAFF)
UA USERS ACCEPTED (USERS/YEAR)
UMLTE UTILITY OF MORE LONG TERM EFFORT (D*LESS)
UMLTET UMLTE TABLE (D*LESS)
UNSD UTILITY OF MORE STAFF DEVELOPMENT (D*LESS)
UMUS UTILITY OF MORE USER SERVICING (D*LESS)
US USER SATISFACTION (SATISFACTION UNITS)
USAT USER SATISFACTION ADJUSTMENT TIME (YEAR)
USDFTT USDFTT TABLE (D*LESS)
USDFWT UTILITY OF MORE STAFF DEVELOPMENT MULTIPLIER FROM WAITING TIME (D*LESS)
USE USERS SERVICED (USERS/YEAR)
USMWTT USMWTT TABLE (D*LESS)
USPT USER SATISFACTION PERCEPTION TIME (YEARS)
UST UTILIZATION OF STAFF (D*LESS)
USTPT UTILIZATION OF STAFF PERCEPTION TIME (YEARS)
USTT UST TABLE (D*LESS)
USERSR UTILITY OF USER SERVICING MULTIPLIER FROM PERCEIVED BUDGET FRACTION (D*LESS)
UUSFAT  UUSFRS TABLE (D'LESS)
UUSFTT  UUSFWT TABLE (D'LESS)
UUSFWT  UTILITY OF MORE USER SERVICING MULTIPLIER FROM WAITING TIME (D'LESS)
UW     USERS WAITING (USERS)
UWI    UW INITIALLY (USERS)
WT     WAITING TIME (YEARS)
WTAT   WAITING TIME ADJUSTMENT TIME (YEARS)
LIST
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*    CIC 6
NOTE
NOTE  **********USER SATISFACTION
A   PUS.K=DLINF3(UJ.K,USPT)
C   USPT=1
A   US.K=OS.K*1
NOTE
NOTE  **********QUALITY OF SERVICE
A   QS.K=QSMEPK.K*1
A   QSMEPK.K=TABHL(QSMEPT,EPK.K/RFP,0,5)
T   QSMEPT=0/6/1/3/1.5
L   EPK.K=EPK.J+(DT)(EPUCR.K)
N   EPU=EPUI
C   EPUI=8
R   EPUCR.K=EPK.K*EPUMU.K*RFSCCR
A   EPUMU.K=TABHL(EPUCMT,UST.K/RUST,0,5)
T   EPUCMT=4/2.5/0/1.25/-1.5
C   REPUCR=1
C   REPUI=4
NOTE
NOTE  **********USERS
I.   UW.K=UW.J+(DT)(UA.JK-USE.JK)
N   UW=UWI
C   UWI=0
R   UA.K=PU.K
A   PU.K=RPU*TABLE(PU,PUS.K/RPUS,0,12,2)
T   PUT=0/2/4/8/14/24/44
C   RPU=5
C   RPUS=1
C   USE.K=SS.K*UST.K/EPU.K
A   SS.K=SI+STEP(SS,ST)
C   SI=2
C   SS=0
C   ST=0
A   UST.K=RUST*TABHI(USTT,MCT.K/RWT,0,5)
T   USTT=0/0.5/1.2/1.3
C   RUST=1
A   MCT.K=UW.K/(S.K/EPU.K)
C   RWT=2
NOTE
NOTE  **********WAITING TIME
A   WT.K=UW.K/AUS.K
L   AUS.K=AUS.J+(DT/USAT)(USK.JK-AUS.J)
N   AUS=AUSI
C   AUSI=1
C   USAT=2
NOTE
NOTE  **********CONTROL STATEMENTS
C   DT=0.05
C   LENGTH=0
C   PLTPE=0.2
PLOT  U(W/(0,16)/UA=A USE=S(0,20)/EP=E, WT=W(0,1))/UST=T, PUS=P, US=1(0,2)
<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>AUS</td>
<td>Average Users Serviced (Users/Year)</td>
</tr>
<tr>
<td>AUSI</td>
<td>AUS Initially (Users/Year)</td>
</tr>
<tr>
<td>DT</td>
<td>Time Increment (Years)</td>
</tr>
<tr>
<td>EPU</td>
<td>Energy Per User (Staff-Year/User)</td>
</tr>
<tr>
<td>EPUINC</td>
<td>EPU Increment (D*LESS)</td>
</tr>
<tr>
<td>EPUINCU</td>
<td>Energy Per User Change Rate Multiplier From Utilization (D*LESS)</td>
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<tr>
<td>EPUCR</td>
<td>Energy Per User Change Rate (Staff/User)</td>
</tr>
<tr>
<td>EPUIN</td>
<td>EPU Initially (Staff-Year/User)</td>
</tr>
<tr>
<td>LENGTH</td>
<td>Simulation Period (Years)</td>
</tr>
<tr>
<td>MCT</td>
<td>Maximum Completion Time (Years)</td>
</tr>
<tr>
<td>PLT PER</td>
<td>Plot Period (Years)</td>
</tr>
<tr>
<td>PU</td>
<td>Potential Users (Users/Year)</td>
</tr>
<tr>
<td>PUS</td>
<td>Perceived User Satisfaction (Satisfaction Units)</td>
</tr>
<tr>
<td>PUT</td>
<td>PU Table (D*LESS)</td>
</tr>
<tr>
<td>QS</td>
<td>Quality of Service (Quality Units)</td>
</tr>
<tr>
<td>QSMPT</td>
<td>QSMPT Table (D*LESS)</td>
</tr>
<tr>
<td>QSMPEPU</td>
<td>Quality of Service Multiplier From Energy Per User (D*LESS)</td>
</tr>
<tr>
<td>REP</td>
<td>Reference EPU (Staff-Year/User)</td>
</tr>
<tr>
<td>REPUCR</td>
<td>Reference EPUCR (Staff/User)</td>
</tr>
<tr>
<td>RPU</td>
<td>Reference PU (Users/Year)</td>
</tr>
<tr>
<td>RPS</td>
<td>Reference PUS (Satisfaction Units)</td>
</tr>
<tr>
<td>RUST</td>
<td>Reference UST (D*LESS)</td>
</tr>
<tr>
<td>RWT</td>
<td>Reference WT (Years)</td>
</tr>
<tr>
<td>S</td>
<td>Staff (Staff)</td>
</tr>
<tr>
<td>SI</td>
<td>Staff Initially (Staff)</td>
</tr>
<tr>
<td>SS</td>
<td>Staff Step (Staff)</td>
</tr>
<tr>
<td>ST</td>
<td>Staff Step Time (Year)</td>
</tr>
<tr>
<td>UA</td>
<td>Users Accepted (Users/Year)</td>
</tr>
<tr>
<td>US</td>
<td>User Satisfaction (Satisfaction Units)</td>
</tr>
<tr>
<td>USAT</td>
<td>Users Serviced Adjustment Time (Years)</td>
</tr>
<tr>
<td>USE</td>
<td>Users Serviced (Users/Year)</td>
</tr>
<tr>
<td>USPT</td>
<td>User Satisfaction Perception Time (Year)</td>
</tr>
<tr>
<td>UST</td>
<td>Utilization of Staff (D*LESS)</td>
</tr>
<tr>
<td>USTT</td>
<td>UST Table (D*LESS)</td>
</tr>
<tr>
<td>UW</td>
<td>Users Waiting (Users)</td>
</tr>
<tr>
<td>UWII</td>
<td>UW Initially (Users)</td>
</tr>
<tr>
<td>WT</td>
<td>Waiting Time (Years)</td>
</tr>
</tbody>
</table>
ADOPPTION 10

NOTE ****** ACCEPTANCE

L A.K = A.J + (DT)(AP.JK)
N A = AT
C A = 0.05
R AR.KL = ((PA.K - COA.K)/PA.K) * A.K / AAT
C AAT = 2
A COA.K = TABLE(COAT.A.K, 0, 1, .25)
T COAT = 0/0/1/3/40
A PA.K = RPA * PAMC.K * PAMIR.K * (ROE.K * EA.K + (1 - ROE.K) * CA.K)
C RPA = 4
A PAMC.K = TABHL(PAMC.T.A.K, 0, 1, .25)
T PAMC.T = 1/1.25/1.75/2.5/4
A PAMIR.K = TABHL(PAMIR.T.IB.K, 1, 1, .25)
T PAMIR.T = 5/5/55/65/81
NOTE ****** RELIANCE ON EXPERIENCE

A ROE.K = TABHL(ROST, ADI.K / GI.K, 2, 5)
T ROST = 1/1.2/1.35/1.75/0.95
A ADI.K = TABHL(ADIT, AAC.K, 0, 10, 2)
T ADIT = 0/4/7/R5/9.5/10
A AAC.K = AACJ + (DT)(ACJ - AACJ/JAACAT)
N AAC = AACI
C AACI = 0
A AACAT = 10
A AAC.K = RAC * IB.K
C RAC = 10
A CA.K = RCA * CAMPP.K
C RCA = 4
A CAMPP.K = TABLE(CAMPPT, PP.K, 0, 2, .5)
T CAMPPT = 2.5/1.6/1/1.9/7
L EA.K = EA.J + (DT/OD.J)(RA.J - EA.J)
N EA = EAI
C FAI = 0
A OD.K = ROD * ODMAC.K
C ROD = 8
A ODMAC.K = TABHL(ODMAC.T, AC.K, 0, 1, .2)
T ODMAC.T = 1/6/4/3/25/.25
NOTE ****** SOCIETAL RESISTANCE

L SR.K = SR.J + (DT/SRAT)(ISR.J - SR.J)
N SR = SRI
C SRT = 0
A ISR.K = RSR *(SRMRC.K * SRMIB.K)
C RSR = 1
A SRMRC.K = TABLE(SRMRCT, RC.K, -1, 1, .5)
T SRMRCT = 0/0/0/2/5
L RC.K = RC.J + (DT/RCAT)(AR.JK - RC.J)
N RC = RCI
C RCI = 0
A RCAT = 1
A SRMIR.K = TABHL(SRMIR.T.IB.K / DIB.K, 0, 1.5 .5)
T SRMIR.T = 0/0/1/6
L IB.K = IB.J + (DT/IBAT)(IIR.J - IB.J)
N IB = IBI
C IBI = 0
A IBAT = 3
A IIR.K = TABHL(IIB.T.A.K, 0, 1, .25)
**GROUP INFLUENCE**

\[
G_{i} = RGI * GIV_{i} * C_{i} \]

\[
RGI = 1
\]

\[
GIV_{i} = TABLE(GIMV_{i}, V_{i}, 0, 10, 2)
\]

\[
GIMV = 0.4/7/8.5/9.5/10
\]

\[
C_{i} = C_{i} + (DT/CAT) (INC_{i} - C_{i})
\]

\[
C = C_{i}
\]

\[
C1 = .75
\]

\[
CAT = 3
\]

\[
INC_{i} = TABHL(INC, PA_{i}/CA_{i}, K, 0, 2, .5)
\]

\[
INCT = 0.5/1.2/7.95/1
\]

\[
V_{i} = V_{i} + (DT/VAT) (IV_{i} - V_{i})
\]

\[
V = V_{i}
\]

\[
VI = 2
\]

\[
VAT_{i} = RVAT * VATM_{i}
\]

\[
RVAT = 3
\]

\[
VATM_{i} = TABLE(VATMVT, V_{i}, 0, 10, 2)
\]

\[
VATMVT = 1/1.2/1.5/1.92/2.4/3
\]

**INDICATED VISIBILITY**

\[
IV_{i} = RIV * (IVRM_{i} * IVMP_{i}) * IVMSR_{i}
\]

\[
RIV = 1
\]

\[
IVRM_{i} = TABLE(IVRMA_{i}, ACH_{i}, 0, 2, .4)
\]

\[
IVRM = 0/2/3.4/4.2/4.6/0
\]

\[
ACH_{i} = BCA_{i} * A_{i}
\]

\[
BCA = 2
\]

\[
IVMP_{i} = TABLE(IVMPPT, PP_{i}, 0, 2, .5)
\]

\[
PP_{i} = PACC_{i} / TACC_{i}
\]

\[
TACC_{i} = TACC_{i} + (DT/TACCAT) (PACC_{i} - TACC_{i})
\]

\[
TACC = TACCI
\]

\[
TACCI = 1
\]

\[
PACC_{i} = TABLE(PACC_{i}, RC_{i}, -5, 5, .25)
\]

\[
PACC = .01/.25/1.3/5.8
\]

\[
IVMSR_{i} = TABHL(IVMSRT, SR_{i}, 0, 2, .5)
\]

\[
IVMSRT = 1/1.5/1.3/8/0
\]

\[
RA_{i} = TABLE(RAT, TIME_{i}, 0, 20, 4)
\]

\[
RAT = 0/0/0/0/0/0
\]

SPEC DT = 1/PLTPEP = 2/LENGTH = 0

PLOT A = A, ROE = E, C = C, IR = I(0, 1)/V = V, PP = D, SR = S(0, 10)/PA = P
U.M10136.19933.ADOPTION.DEF.DATA

A  ACCEPTANCE (D*LESS)
AAC  AVERAGE ACTIVITY (ACTIVITY UNITS)
AACAT  AVERAGE ACTIVITY ADJUSTMENT TIME (YEARS)
AACI  AAC INITIALLY (ACTIVITY UNITS)
AAT  ACCEPTANCE ADJUSTMENT TIME (YEARS)
AC  ACTIVITY (ACTIVITY UNITS)
ACH  ACHIEVEMENT (D*LESS)
ADI  ADOPTER INFLUENCE (INFLUENCE UNITS)
ADIT  ADIT TABLE (INFLUENCE UNITS)
AI  A INITIALLY (D*LESS)
AR  ACCEPTANCE CHANGE RATE (1/YEAR)
BCA  ACHIEVED ADVANTAGE (D*LESS)
C  CREDIBILITY (D*LESS)
CA  CLAIMED ADVANTAGE (D*LESS)
CAMPP  CLAIMED ADVANTAGE MULTIPLIER FROM PERCEIVED PERFORMANCE (D*LESS)
CAMPT  CAMPP TABLE (D*LESS)
CAT  CREDIBILITY ADJUSTMENT TIME (YEARS)
CI  C INITIALLY (D*LESS)
CQA  COST OF ACCEPTANCE (D*LESS)
COAT  COA TABLE (D*LESS)
DIR  DESIRED INSTITUTIONALIZED BEHAVIOR (D*LESS)
DIBT  DIB TABLE (D*LESS)
EA  EXPERIENCED ADVANTAGE (D*LESS)
EAI  EA INITIALLY (D*LESS)
G1  GROUP INFLUENCE (INFLUENCE UNITS)
GIMU  GROUP INFLUENCE MULTIPLIER FROM VISIBILITY (D*LESS)
GIMUT  GIMU TABLE (D*LESS)
IB  INSTITUTIONALIZED BEHAVIOR (D*LESS)
IBAT  INSTITUTIONALIZED BEHAVIOR ADJUSTMENT TIME (YEARS)
IBI  IB INITIALLY (D*LESS)
IBIB  INDICATED INSTITUTIONALIZED BEHAVIOR (D*LESS)
IBIT  IBIB TABLE (D*LESS)
INC  INDICATED CREDIBILITY (D*LESS)
INCT  INC TABLE (D*LESS)
ISR  INDICATED SOCIETAL RESISTANCE (RESISTANCE UNITS)
IV  INDICATED VISIBILITY (VISIBILITY UNITS)
IVMPP  INDICATED VISIBILITY MULTIPLIER FROM PERCEIVED PERFORMANCE (D*LESS)
IVMPPT  IVMPP TABLE (D*LESS)
IVMRA  INDICATED VISIBILITY MULTIPLIER FROM PAST ACHIEVEMENT (D*LESS)
IVMRAT  IVMRA TABLE (D*LESS)
IVMSR  INDICATED VISIBILITY MULTIPLIER FROM SOCIETAL RESISTANCE (D*LESS)
IVMSRT  IVMSR TABLE (D*LESS)
OD  OBSERVATION DELAY (YEARS)
ODMAC  ODMAC TABLE (D*LESS)
PA  PERCEIVED ADVANTAGE (D*LESS)
PACC  PERCEIVED ACCOMPLISHMENT (ACCOMPLISHMENT UNITS)
PACCT  PACC TABLE (ACCOMPLISHMENT UNITS)
PAMC  PERCEIVED ADVANTAGE MULTIPLIER FROM CONFORMITY (D*LESS)
PAMCT  PAMC TABLE (D*LESS)
PAMIB  PERCEIVED ADVANTAGE MULTIPLIER FROM INSTITUTIONALIZED BEHAVIOR (D*LESS)
PAMIBT  PAMIB TABLE (D*LESS)
PLPER  PLOT PERIOD (YEARS)
PP  PERCEIVED PERFORMANCE (D*LESS)
RA  REAL ADVANTAGE (D*LESS)
RAC  REFERENCE AC (ACTIVITY UNITS)
RAT  RA TABLE (D*LESS)
RC  RECENT CHANGE (1/YEAR)
RCA  REFERENCE CA (D*LESS)
RCAT  RECENT CHANGE ADJUSTMENT TIME (YEARS)
RCI  RC INITIALLY (1/YEAR)
RGI  REFERENCE GI (INFLUENCE UNITS)
RIV  REFERENCE IV (VISIBILITY UNITS)
ROD  REFERENCE OD (YEARS)
ROE  RELIANCE ON EXPERIENCE (D*LESS)
ROET  ROE TABLE (D*LESS)
RPA  RPA REFERENCE PA (D*LESS)
RSR  REFERENCE SR (RESISTANCE UNITS)
RVAT  REFERENCE VAT (YEARS)
SR  SOCIETAL RESISTANCE (RESISTANCE UNITS)
SRAT  SOCIETAL RESISTANCE ADJUSTMENT TIME (YEARS)
SRI  SOCIETAL RESISTANCE INITIALLY (RESISTANCE UNITS)
SRMIB  SOCIETAL RESISTANCE MULTIPLIER FROM INSTITUTIONALIZED BEHAVIOR (D*LESS)
SRMBT  SRMIB TABLE (D*LESS)
SRMRC  SRMRC TABLE (D*LESS)
TACC  TRADITIONAL ACCOMPLISHMENT ADJUSTMENT (YEARS)
TACCAT  TRADITIONAL ACCOMPLISHMENT ADJUSTMENT TIME (YEARS)
TACCI  TACC INITIALLY (ACCOMPLISHMENT UNITS)
V  VISIBILITY (VISIBILITY UNITS)
VAT  VISIBILITY ADJUSTMENT TIME (YEARS)
VATMV  VISIBILITY ADJUSTMENT TIME MULTIPLIER FROM VISIBILITY (D*LESS)
VATMV T  VATMV TABLE (D*LESS)
VI  VISIBILITY INITIALLY (VISIBILITY UNITS)
* PROHIBITION II
NOTE **********ACCEPTANCE
N A=AI
C AI=.01
C AAT=2
C IA.K=RIA.TABHL(IAT,PA.K/RPA,3,17,2)
T IAT=0/.4/.7/.9/.96/1
C RIA=1
C RPA=1
C PA.K=(GI.K*CA+EI.K*EA.K+RI.K*RC)/(GI.K+EI.K+RI.K)
C CA=6
C RC=.5
NOTE **********GROUP INFLUENCE
A GI.K=C.K*GIMG.P.K
L C.K=C.J+(DT/CAT)(IC.J-C.J)
N C=CI
C CI=1
C CAT=2
C I.C.K=RIC.TABHL(ICT,(PA.K/C)/R1,.6/3,1)
T ICT=0/1/1.6/2
C RIC=1
C R1=1
A GIMG.P.K=RGIMG.P.TABHL(GIMG.PT,GP.K/RGP,0,1,.2)
T GIMG.PT=0/1.2/1.9/2.5/2.8/3
C RGIMG.P=1
C RGP=1
NOTE **********GROUP PRESSURE
L GP.K=GP.J+(DT/GPAT)(IGP.J-GP.J)
N GP=GPI
C GPI=.02
C GPAT=4
A IGP.K=GPMA.K
A GPMA.K=RGPMATABHL(GPMAT,AK/RA,0,1,.2)
T GPMAT=0/4/.7/.9/1/3
C RGPMAT=1
C RA=1
NOTE **********ACTIVE RESISTANCE
A RI.K=RR1.TABHL(RIT,AR.K/RAR,0,1,.2)
T RIT=0/.3/.6/5.8/7/7.8/8
C RRI=1
C RAR=1
L AR.K=AR.J+(DT/ARAT)(IAR.J-AR.J)
N AR=ARI
C ARI=0
C ARAT=6
A IAR.K=RIAR.TABHL(IART,(IA.K-A.K)/R2,0,1,.2)
T IART=0/.5/.75/.9/.96/1
C RIAR=1
C R2=1
NOTE **********EXPERIENCE
A E1.K=REI.TABHL(E1T,EX.K/REX,0,1,.2)
T E1T=0/5/7.5/9/9.6/10
C REI=1
C REX=1
L EX.K=EX.J+(DT)(SR.J-EX.J/EXAT)
N EX=EXI
U.M10036.17933.PROHIBTN.DATA

C EXI=0
C EXAT=15
A SB.K=IB.K
L EA.K=FA.J+(DT/NO.J)(RADV.J-FA.J)
N EA=EA1
C EA1=6.
A RADV.K=RADV1
C RADVI=1
A ODT.K=ROD*TARHL(ODT,SB.K/RSR,?1,?2)
T ODT=6/3.5/2.4/1.6/1.2/1
C ROD=6
C RSR=1
NOTE INSTITUTIONALIZED BEHAVIOR
A IR.K=DLINE3(IIR.K,TBAT)
N IB=IB1
C : TBI=0
C TBAT=2
A IIB.K=IIB*TABHL(IIRT,A.K/RA,0,1,1)
T IIRT=0/0/0/0/0/0/1/1/1/1
C IIB=1
NOTE **********CONTROL STATEMENTS
SPEC DT=1/PLT1PER=1/LENGTH=0
PLOT A=A,AR=R,GP=G,IR=T(0,1)/GI=1,EL=2,RI=3(0,10)/PA=P,EA=E(0,6)/C=C(0,2)
A    ACCEPTANCE (D'LESS)
AAT  ACCEPTANCE ADJUSTMENT TIME (YEARS)
AI   A INITIALLY (D'LESS)
AP   ACTIVE RESISTANCE (RESISTANCE UNITS)
APAT  ACTIVE RESISTANCE ADJUSTMENT TIME (YEARS)
ARI  AR INITIALLY (D'LESS)
C    CREDIBILITY (D'LESS)
CA   CLAIMED ADVANTAGE (D'LESS)
CAT  CREDIBILITY ADJUSTMENT TIME (YEARS)
CI   C INITIALLY (D'LESS)
EA   EXPERIENCED ADVANTAGE (D'LESS)
FAI  FA INITIALLY (D'LESS)
EI   EXPERIENCE INFLUENCE (INFLUENCE UNITS)
EIT  EI TABLE (D'LESS)
EX   EXPERIENCE (EXPERIENCE UNITS)
EXAT  EXPERIENCE ADJUSTMENT TIME (YEARS)
EXI  EX INITIALLY (EXPERIENCE UNITS)
GI   GROUP INFLUENCE (INFLUENCE UNITS)
GIMGP  GROUP INFLUENCE MULTIPLIER FROM GROUP PRESSURE (INFLUENCE UNITS)
GIMGPT  GIMGP TABLE (D'LESS)
GP   GROUP PRESSURE (PRESSURE UNITS)
GPAT  GROUP PRESSURE ADJUSTMENT TIME (YEARS)
GPT  GP INITIALLY (PRESSURE UNITS)
GPMA  GROUP PRESSURE MULTIPLIER FROM ACCEPTANCE (PRESSURE UNITS)
GPMAT  GPMA TABLE (D'LESS)
IA   INDICATED ACCEPTANCE (D'LESS)
IAR  INDICATED ACTIVE RESISTANCE (RESISTANCE UNITS)
IART  IAR TABLE (D'LESS)
IAT  INDICATED ACCEPTANCE ADJUSTMENT TIME (YEARS)
IB  INSTITUTIONALIZED BEHAVIOR (D'LESS)
IBAT  INSTITUTIONALIZED BEHAVIOR ADJUSTMENT TIME (YEARS)
IBI  IB INITIALLY (D'LESS)
IC   INDICATED CREDIBILITY (D'LESS)
ICT  IC TABLE (D'LESS)
IGP  INDICATED GROUP PRESSURE (PRESSURE UNITS)
IIB  INDICATED INSTITUTIONALIZED BEHAVIOR (D'LESS)
IIBT  IIB TABLE (D'LESS)
OD   OBSERVATION DELAY (YEARS)
ODT  OD TABLE (D'LESS)
PA   PERCEIVED ADVANTAGE (D'LESS)
PLT PER PLOT PERIOD (YEARS)
RA   REFERENCE A (D'LESS)
RADV  REAL ADVANTAGE (D'LESS)
RADVI  RADV INITIALLY (D'LESS)
RAR  REFERENCE AR (RESISTANCE UNITS)
RC   REFERENCE C (D'LESS)
REI  REFERENCE FI (INFLUENCE UNITS)
REX  REFERENCE EX (EXPERIENCE UNITS)
RGIMG  REFERENCE GIMG (INFLUENCE UNITS)
RGP  REFERENCE GP (PRESSURE UNITS)
RGPMMA  REFERENCE GPMA (PRESSURE UNITS)
RI   RESISTANCE INFLUENCE (INFLUENCE UNITS)
RIA  REFERENCE IA (D'LESS)
RIAR  REFERENCE IAR (RESISTANCE UNITS)
RIC  REFERENCE IC (D'LESS)
RIIB  REFERENCE IIB (D'LESS)
RIT  RI TABLE (D'LESS)
ROD  REFERENCE OD (YEARS)
RPA  REFERENCE PA (D'LESS)
RRI  REFERENCE RI (INFLUENCE UNITS)
RSB  REFERENCE SB (D'LESS)
R1   REFERENCE PA/CA (D'LESS)
R2   REFERENCE IB-A (D'LESS)
SB   SOCIETAL BEHAVIOR (D'LESS)
NOTE

**NEWIDEA 12**

**NEWIDEA 12**

NOTE

************ACCEPTANCE**

NOTE

A. K=A.J+(DT)(CON.JK-VER.JK)

NOTE

CON.KL=CLIP((IA.K-A.K)/CT,0,(IA.K-A.K)/CT,0)

NOTE

CT=.5

NOTE

IA.K=FC.K*IAMPAD.K

NOTE

FC.K=TABHL(FCT,CA.K/PCA,0,.3,0)

NOTE

FCT=.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/.05/
U.M10036.10933.NEWSIDEA.DATA

READI=.5
READTC=17
RCAD=.5

NOTE ******GROUP INFLUENCE
NOTE
A  GIN*K=RGIN*GINME*K*C.K
C  RGIN=1
A  GINME.K=TABHL(GINMET,E.K/PE,0,50,10)
T  GINMET=0/10/15/20/22/23
L  C.K=C.J+(DT)(C.J*CMC.J*CME.J*FC.J)
N  C=CI
C  CI=1
A  CMC.K=TABHL(CMCT,1.44*LOGN(C.K/PC),-3,2,1)
T  CMCT=0/.25/.55/1/1.75/0
C  RC=1
A  CME.K=RCME*TABHL(CMET,CLAD.K/PEAD.K,0,3,.5)
T  CMET=-2/C/.1/.08/9/-2/-4
C  RCME=1
L  E.K=FC.J+(DT)(ECR.JK)
C  E=EI
C  EI=1
R  ECR.KL=(IE.K-E.K)/EDT.K
A  IE.K=RIE*(RA.K/RA)*IEMXG.K*IEMEN.K*IEMAS.K
C  RIE=1.03
C  RA=.01
A  IEMXG.K=TABLE(IEMXGT,XG.K/RXG,0,1,.25)
T  IEMXGT=.1/.85/.95/.97/1
A  XG.K=CLAD.K*(1-A.K)
C  RXG=1.98
A  EDT.K=REDT*TABLE(EDTT,E.K/RE,0,30,1)
T  EDTT=.25/4/6/7.8/8.8/9.6/10
C  REDT=1
C  RE=1
A  IEMEN.K=RIEMEN*TABLE(IEMENT,EN.K/REN,0,3,.5)
T  IEMENT=.5/.7/1/1.5/1.9/1.95/2
C  RIEMEN=1
C  REN=1
L  EN.K=EN.J+(DT)(ENC.RJK)
C  EN=ENI
C  ENI=1
R  ENCR.KL=EN.K*ENMP.K
A  ENMP.K=RFNMP*TABLE(RENMP,CP.K/AS.K,0,3,.5)
T  RENMP=-1/-.07/0/.03/.045/.05/.05
C  RENMP=1
A  IEMAS.K=RIEMAS*TABLE(IEMAST,AS.K/RAS,0,5,1)
T  IEMAST=.5/1.2/1.35/1.45/1.5
C  RIEMAS=1
C  RAS=.15
A  AS.K=TP.K*WX+FAS*(1-WX)
C  WX=.5
C  FAS=.1
L  TP.K=TP.J+(DT/TPAT)(CP.J-TP.J)
N  TP=TPI
C  TPI=.15
C  TPAT=4

NOTE
U10036.10933.NEWIDEA DATA

NOTE  ****************RESISTANCE INFLUENCE
NOT
A
ARIN.K=ARIN*KTABHL(ARINT,AR.K/RAR,0,3,9,6)
T
ARINT=0/6/12/18/22/25
C
RAR=1
L
AR=ARI
C
ARI=1
R
ABC=K=ARI*J+(DT)(ARCR.JK)
A
CR=AK
C
ARCR.K=AR.K*ARFC.K
A
ARFC.K=RARFC*TABHL(ARFC,T,AR.K/RAR.K,0,3,5)
T
ARFC=-1/-06/0/-3/-7/-9/1
C
ARFC=1
A
IAR.K=RIAR*(1-A.K)*IARMA.K*IARMC.P.K
C
RIAR=1
A
IARMA.K=RIARMA*TABHL(IARMAT,A.K,7,1,2)
T
IARMAT=1/4/10/30/100/150
C
IARMA=1
A
IARMC.P.K=RIARMC.P*TABHL(IARMCT,CP.K/RCP,0,5,1)
T
IARMCT=5/1/3/5/7/5/10
C
IARMC.P=1
C
RCP=15
L
CP.K=CP.J+(DT/CPAT)(GR.J-CP.J)
C
CP=CP1
C
CP1=0.15
C
CPAT=2
A
GR.K=CON.JK/A.K

NOTE  ****************EXPERIENCE INFLUENCE
NOTE
A
EXIN.K=RFXIN*TABHL(EXINT,EX.K/REX,0,1,2)
T
EXINT=0/14/26/33/38/40
C
REX=1
C
EX=EXI
C
EXI=0.1
L
EXG.K=EX*J+(DT)(EXG.JK-EXD.JK)
C
EX=EXI
C
EXI=0.1
A
EXG.K=EXD.K/EXDE.K
A
MEX.K=RMEX*TABLE(MEXT,0.K,0,1,2)
C
MEXT=0.5/1/2/4/8/1
C
RMEX=1
C
EXD.K=EX.K/EXDT
C
EXDT=30
C
D.K=TABHL(DOT,PD.K/RPD,0,20,5)
C
DOT=0/30/6/72/88
C
RPD=1
A
PD.K=PDMA.K+PD.M.K
A
PDMA.K=RPDMA*TABLE(PDMAT,A.K,0,1,2)
A
PDMAT=1/2/5/8/13/20
A
RPDMA=1
A
RPD.M.K=RPDMA*INS.K
A
RPDM=10
A
INS.K=INS*J+(DT/INSAT)(INJ.INS-J-INS.J)
A
INS=INSI
C
INSI=0
C
INSAT=10
A
INJ.K=TABHL(INJST,A.K,0,1,2)
T
NOTE
NOTE
NOTE
SPEC
PLOT
X
INST=0/0/0/1/1/1
**********CONTROL STATEMENTS
LENGTH=9/PLTREP=2/DT=.1
GIN=G, ARIN=R, EXIN=E(0,40)/A=A, PA=x=F(0,1)/
C=C, PEA=P, CLAD=L(0,6)/EN=N, IN=I(0,2)
ACCEPTANCE (D*LESS)
A INITIAL (D*LESS)
ACTIVE RESISTANCE (RESISTANCE UNITS)
ACTIVE RESISTANCE CHANGE RATE (RESISTANCE UNITS/YEAR)
ACTIVE RESISTANCE FRACTIONAL CHANGE (1/YEAR)
ACTIVE RESISTANCE TABLE (D*LESS)
AR INITIALLY (RESISTANCE UNITS)
ACTIVE RESISTANCE INFLUENCE (INFLUENCE UNITS)
AR TABLE (D*LESS)
AS ASPIRATIONS (1/YEAR)
BIAS BIAS IN GROUP CLAIM (D*LESS)
BIAS TABLE (D*LESS)
C GROUP CREDIBILITY (CREDIBILITY UNITS)
CA CURRENT ACTIVITY (INFLUENCE UNITS)
CT C INITIALLY (CREDIBILITY UNITS)
CLAIMED ADVANTAGE (D*LESS)
CMC CREDIBILITY CHANGE MULTIPLIER FROM CREDIBILITY (D*LESS)
CMCT CMC TABLE (D*LESS)
CME CREDIBILITY CHANGE MULTIPLIER FROM EXAGGERATION (D*LESS)
CMET CME TABLE (D*LESS)
CON CONVERSIONS (1/YEAR)
CP CURRENT PROGRESS (1/YEAR)
CPAT CURRENT PROGRESS AVERAGING TIME (YEARS)
CPI CP INITIALLY (1/YEAR)
CS CURRENT SATISFACTION (D*LESS)
CT CONVERSION TIME (YEARS)
D ADOPTION (D*LESS)
DOT D TABLE (D*LESS)
E GROUP EFFORT (EFFORT UNITS)
ECR GROUP EFFORT CHANGE RATE (EFFORT UNITS/YEAR)
EDT GROUP EFFORT CHANGE TIME (YEARS)
EDTT EDT TABLE (D*LESS)
EI GROUP EFFORT INITIALLY (EFFORT UNITS)
EN GROUP ENTHUSIASM (ENTHUSIASM UNITS)
ENC GROUP ENTHUSIASM CHANGE RATE (ENTHUSIASM UNITS/YEAR)
ENI GROUP ENTHUSIASM INITIALLY (ENTHUSIASM UNITS)
ENMP ENTHUSIASM MULTIPLIER FROM PROGRESS (D*LESS)
ENMP ET ENMP TABLE (D*LESS)
EX PRACTICAL EXPERIENCE (EXPERIENCE UNITS)
EXAD EXPERIENCED ADVANTAGE (D*LESS)
EXADI EXAD INITIALLY (D*LESS)
EXD PRACTICAL EXPERIENCE DECAY (EXPERIENCE UNITS/YEAR)
EXDE EXPERIENCE DECAY (YEARS)
EXDET EXDE TABLE (D*LESS)
EXDT PRACTICAL EXPERIENCE DECAY TIME (YEARS)
EXG PRACTICAL EXPERIENCE GENERATION (EXPERIENCE UNITS/YEAR)
EXI EX INITIALLY (EXPERIENCE UNITS)
EXIN EXPERIENCE INFLUENCE (INFLUENCE UNITS)
EXINT EXIN TABLE (D*LESS)
FA FIXED ASPIRATIONS (1/YEAR)
FC FRACTION CONCERNED (D*LESS)
FCT FC TABLE (D*LESS)
GIN GROUP INFLUENCE (INFLUENCE UNITS)
GINME GROUP INFLUENCE MULTIPLIER FROM GROUP EFFORT (D*LESS)
GINMET GINME TABLE (D*LESS)
GR GROWTH RATE (1/YEAR)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>Indicated Acceptance (D*LESS)</td>
</tr>
<tr>
<td>IAMPAD</td>
<td>Indicated Acceptance Multiplier from Perceived Advantage (D*LESS)</td>
</tr>
<tr>
<td>IAMPAT</td>
<td>IAMPAT Table (D*LESS)</td>
</tr>
<tr>
<td>IAR</td>
<td>Indicated Active Resistance (Resistance Units)</td>
</tr>
<tr>
<td>IARMA</td>
<td>Indicated Active Resistance Multiplier from Acceptance (D*LESS)</td>
</tr>
<tr>
<td>IARMAT</td>
<td>IARMAT Table (D*LESS)</td>
</tr>
<tr>
<td>IARMCP</td>
<td>Indicated Active Resistance Multiplier from Current Progress (D*LESS)</td>
</tr>
<tr>
<td>IARMCT</td>
<td>IARMCT Table (D*LESS)</td>
</tr>
<tr>
<td>IF</td>
<td>Indicated Group Effort (Effort Units)</td>
</tr>
<tr>
<td>IEMAS</td>
<td>Indicated Group Effort Multiplier from Aspirations (D*LESS)</td>
</tr>
<tr>
<td>IEMAST</td>
<td>IEMAS Table (D*LESS)</td>
</tr>
<tr>
<td>IEMEN</td>
<td>Indicated Group Effort Multiplier from Enthusiasm (D*LESS)</td>
</tr>
<tr>
<td>EMENT</td>
<td>IEMEN Table (D*LESS)</td>
</tr>
<tr>
<td>IEMXG</td>
<td>Indicated Group Effort Multiplier from Expected Gain (D*LESS)</td>
</tr>
<tr>
<td>IEMXGT</td>
<td>IEMXG Table (D*LESS)</td>
</tr>
<tr>
<td>IINS</td>
<td>Indicated Institutionalization (D*LESS)</td>
</tr>
<tr>
<td>INST</td>
<td>IINS Table (D*LESS)</td>
</tr>
<tr>
<td>IN</td>
<td>Internalization (D*LESS)</td>
</tr>
<tr>
<td>INAT</td>
<td>Institutionalization Averaging Time (Years)</td>
</tr>
<tr>
<td>INIT</td>
<td>In Initially (D*LESS)</td>
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<td>INS</td>
<td>Institutionalization (D*LESS)</td>
</tr>
<tr>
<td>INSAT</td>
<td>Institutionalization Adjustment Time (Years)</td>
</tr>
<tr>
<td>INSI</td>
<td>INS Initially (D*LESS)</td>
</tr>
<tr>
<td>MEX</td>
<td>Maximum Experience (Experience Units)</td>
</tr>
<tr>
<td>MEXT</td>
<td>MEX Table (D*LESS)</td>
</tr>
<tr>
<td>PA</td>
<td>Past Activity (Influence Units)</td>
</tr>
<tr>
<td>PAAT</td>
<td>Past Activity Averaging Time (Years)</td>
</tr>
<tr>
<td>PAI</td>
<td>PA Initially (Influence Units)</td>
</tr>
<tr>
<td>PAMC</td>
<td>Perceived Advantage Conformity Multiplier (D*LESS)</td>
</tr>
<tr>
<td>PAMCO</td>
<td>Perceived Advantage Coercion/Complexity Multiplier (D*LESS)</td>
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<tr>
<td>PANCRT</td>
<td>PANCRT Table (D*LESS)</td>
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<td>PAMP</td>
<td>Perceived Advantage Multiplier from Past Activity (D*LESS)</td>
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<tr>
<td>PAMPAT</td>
<td>PAMPAT Table (D*LESS)</td>
</tr>
<tr>
<td>PD</td>
<td>Pressure for Adoption (Pressure Units)</td>
</tr>
<tr>
<td>PDMA</td>
<td>Pressure for Adoption Multiplier from Acceptance (D*LESS)</td>
</tr>
<tr>
<td>PDMAT</td>
<td>PDMA Table (D*LESS)</td>
</tr>
<tr>
<td>PDRT</td>
<td>Pressure for Adoption Multiplier from Institutionalization (D*LESS)</td>
</tr>
<tr>
<td>PEAD</td>
<td>Perceived Advantage (D*LESS)</td>
</tr>
<tr>
<td>PLTPER</td>
<td>Plot Period (Years)</td>
</tr>
<tr>
<td>RA</td>
<td>Reference A (D*LESS)</td>
</tr>
<tr>
<td>RAR</td>
<td>Reference RA (Resistance Units)</td>
</tr>
<tr>
<td>RARFC</td>
<td>Reference RARFC (1/YEAR)</td>
</tr>
<tr>
<td>RARIN</td>
<td>Reference RARIN (Influence Units)</td>
</tr>
<tr>
<td>RAS</td>
<td>Reference RAS (1/YEAR)</td>
</tr>
<tr>
<td>RBIAS</td>
<td>Reference RBIAS (D*LESS)</td>
</tr>
<tr>
<td>RC</td>
<td>Reference RC (Credibility Units)</td>
</tr>
<tr>
<td>RCA</td>
<td>Reference RCA (Influence Units)</td>
</tr>
<tr>
<td>RCAD</td>
<td>Advantage Claimed by Resistance (D*LESS)</td>
</tr>
<tr>
<td>RCMF</td>
<td>Reference RCMF (1/YEAR)</td>
</tr>
<tr>
<td>RCP</td>
<td>Reference RCP (1/YEAR)</td>
</tr>
<tr>
<td>RE</td>
<td>Reference RE (Effort Units)</td>
</tr>
<tr>
<td>READ</td>
<td>Real Advantage (D*LESS)</td>
</tr>
<tr>
<td>READI</td>
<td>Real Advantage Initially (D*LESS)</td>
</tr>
<tr>
<td>READTC</td>
<td>Real Advantage Growth Time Constant (Years)</td>
</tr>
</tbody>
</table>
REDT  REFERENCE EDT (YEARS)
REN  REFERENCE EN (ENTHUSIASM UNITS)
RENMP  REFERENCE FMNP (D*LESS)
REX  REFERENCE EX (EXPERIENCE UNITS)
REXDE  REFERENCE EXDE (YEARS)
REXIN  REFERENCE EXIN (INFLUENCE UNITS)
RGIN  REFERENCE GIN (INFLUENCE UNITS)
RIAR  REFERENCE IAR (RESISTANCE UNITS)
RIARMA  REFERENCE IARMA (D*LESS)
RIARMCP  REFERENCE IARMCP (D*LESS)
RIF  REFERENCE IE (EFFORT UNITS)
RIEMAS  REFERENCE IEMAS (D*LESS)
RIEMEN  REFERENCE IEMEN (D*LESS)
RIN  REFERENCE IN (D*LESS)
RIMEX  REFERENCE MEX (EXPERIENCE UNITS)
RP  REFERENCE PA (INFLUENCE UNITS)
RPAD  REPORTED ADVANTAGE (D*LESS)
RPD  REFERENCE PD (PRESSURE UNITS)
RPDMA  REFERENCE PDM (PRESSURE UNITS)
RPDMI  REFERENCE PDMI (PRESSURE UNITS)
RPREAD  REFERENCE PEAD (D*LESS)
RVT  REFERENCE VT (YEARS)
RXG  REFERENCE XG (D*LESS)
TP  TRADITIONAL PROGRESS (1/YEAR)
TPAT  TRADITIONAL PROGRESS AVERAGING TIME (YEARS)
TPI  TP INITIAL (1/YEARS)
VER  REVERSIONS (1/YEAR)
VT  REVERSION TIME (YEARS)
VTT  VT TABLE (D*LESS)
WX  WEIGHT ON EXPERIENCE (D*LESS)
XG  EXPECTED GAIN (D*LESS)