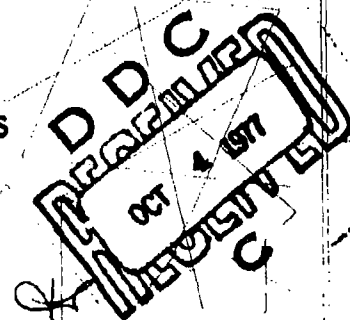ADA044810

HANDBOOK
OF
FORECASTING
TECHNIQUES

A REPORT SUBMITTED TO

THE U.S. ARMY ENGINEER
INSTITUTE FOR WATER RESOURCES
KINGMAN BUILDING
FORT BELVOIR, VIRGINIA 22060

PART II
DESCRIPTION OF 31 TECHNIQUES

AUGUST 1977

SUPPLEMENT TO
IWR CONTRACT REPORT 75-7

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PART II,

DESCRIPTION OF 31 TECHNIQUES,

Final re, t.,

A Report Submitted to:

U.S. Army Engineer Institute for Water Resources
Kingman Building
Fort Belvoir, Virginia 22060

by

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Stanford Research Institute
Menlo Park, California 94025

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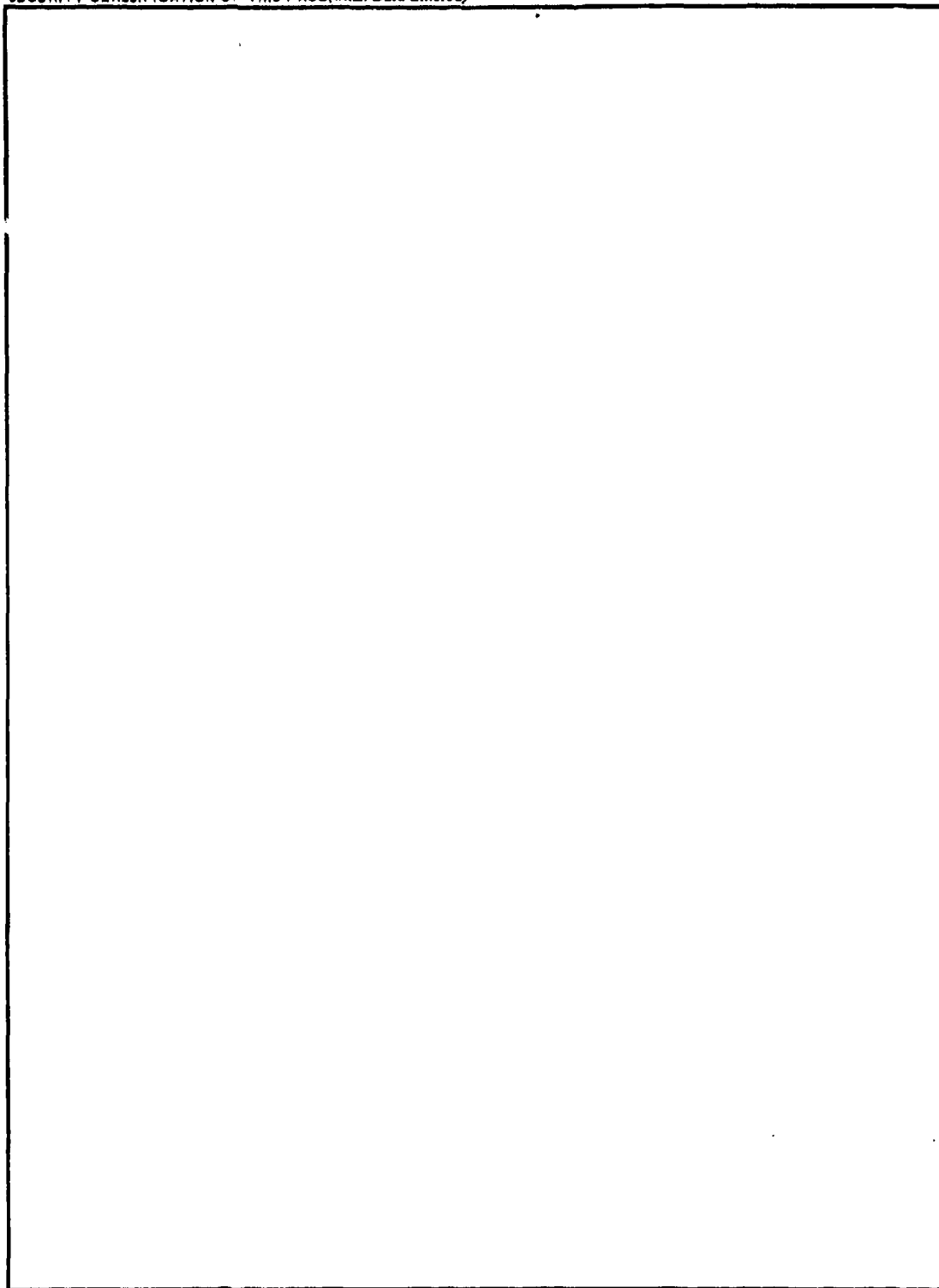
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This Supplement to the Handbook of Forecasting Techniques (IWR Contract Report 75-7) is in two parts: Part 2 of the Supplement contains 31 forecasting techniques described in some detail. These techniques were selected from the 73 listed in Part 1. Twenty-five of these 31 techniques were finally collapsed into 12 for more detailed treatment in the Handbook. This part should also be a valuable addition to the Handbook because it provides easy-to-read but informative discussion of the most popular techniques used by forecasters.

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List of 31 Forecasting Techniques

INTRODUCTION

This Supplement to the Handbook of Forecasting Techniques (IWR Contract Report 75-7) is in two parts: Part 1 consists of brief descriptions of the 73 forecasting techniques presented to a group of Corps planners for selection for inclusion into the Handbook. Each technique is explained in a one-page description designed to answer simple questions such as: What is it? What do you get? How do you do it? and What do you need? This part should prove to be a valuable reference to the users of the Handbook in terms of coverage and format of presentation.

Part 2 of the Supplement contains 31 forecasting techniques described in some detail. These techniques were selected from the 73 listed in Part 1. Twenty-five of these 31 techniques were finally collapsed into 12 for more detailed treatment in the Handbook. This part should also be a valuable addition to the Handbook because it provides easy-to-read but informative discussion of the most popular techniques used by forecasters.

The material presented in the Supplement was prepared by the Center for the Study of Social Policy, Stanford Research Institute and was provided IWR as a byproduct of the research contract that produces the Handbook. Funds for printing the supplement are from OCE (CWP-S).

TREND EXTRAPOLATION

Abstract

Trend extrapolation is the general name for a variety of mathematical forecasting methods, all of which determine future values for a single variable through some process for the identification of a relationship valid for the past values of the variables and solution for future values. It is generally useful for only a single variable. It must be recognized that since only quantifiable variables may be forecast this way a bias is introduced against that which is non-quantifiable. Also these methods are not able to deal well with unanticipated changes in the historical pattern of the data. Trend extrapolation includes such methods as moving averages, exponential smoothing, substitution and growth curves, envelope curves and simple and multiple regression.

Definition

Trend extrapolation is the general name for a variety of specific techniques used for determining future values of some continuous phenomenon of the past. It assumes that the continuous behavior of the past will persist into the future. It also assumes that the conditions which have shaped the trend will not change during the forecast time horizon. For example, since the middle of the last century until very recently the growth of energy consumption in the U.S. has exhibited a relatively smooth growth. On the basis of this extensive historical data one could extrapolate very precise values for energy consumption in the future. The range of techniques available for extrapolating trends reflects the variety of kinds of trends to be forecast and the varying levels of effort devoted to forecasting.

History

The specific origins of trend extrapolation as a general approach are unknown. It is not unreasonable to assume that the Greeks, for example, made certain kinds of forecasts, i.e., economic, by extrapolation. In this general sense, then, trend extrapolation is as old as man's ability to intuitively foresee the future on the basis of the past. Mathematical methods of extrapolation are, of course, a more recent development. The recognition of characteristic patterns of trends such as growth curves was an advance of the nineteenth century. Recent decades have seen the emergence of more complex statistical methods and the application of computers. In a hardware sense the introduction in 1973 of the HP-80 hand-held calculator which can automatically calculate simple regression of trend lines represents another kind of advance. Work is now in progress which will allow the forecaster to study the multiple interactions of trends short of the development of complex computer models.

Main Uses

Trend extrapolation is most often used when a quantitative forecast of a single variable is needed. This implies, of course, that the variable itself be quantifiable. While all the methods of extrapolation do demand quantification it is possible in some instances to devise proxy measures of nonquantifiable variables. For example, this may be accomplished by identifying some quantity which one assumes is related directly to the variable of interest (e.g., for the variable of degree of environmental consciousness in the U.S. population, one might select the sum of the membership of environmental groups as a proxy measure).

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Limits and Cautions

As noted in the previous section trend extrapolation requires quantification
of the variables. Thus if one relies entirely on such forecasting methods one
introduces a bias in favor of those variables which can readily be quantified.
Thus, since there is an apparent precision to the forecast those variables which
are nonquantifiable often are simply ignored. This sometimes results in very
important elements receiving little or no consideration. For example, a continued
rise in the GNP does not necessarily imply a similar rise in social welfare.
One way to avoid this trap is to consider in any decision a number of related
forecasts derived through different methods, some quantitative and others non-
quantitative.

In a related sense, there is a seeming certainty to quantitative extrapolative
forecasts. Little uncertainty is allowed for. In times of rapid change, as
today, this apparent certainty can be very misleading. Those forces which shape
a trend can change in such a way as to give no warning to the forecaster through
study of the trend itself. A recent example in population forecasting is quite
dramatic. The Census Bureau's population forecasts all had to be grossly re-
vised when the birth rate plummeted in the early seventies. Only the careful
study of trend shaping forces--the anatomy of a trend--can provide a warning to
potential discontinuities. Where such discontinuities seem plausible, the
forecaster must then consider alternative forecasts or a range of forecasts
based on differing assumptions.

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Other Techniques

Trend extrapolation is often done on a simply intuitive basis, i.e., "eye-balling." In more rigorous contexts, such as system dynamics, methods of extrapolation are included as part of the mathematical considerations. Likewise they can be linked to cross-impact methods through the consideration of cross-impacts of trends.

Procedures

A variety of methods are available for trend extrapolation. Which method to choose depends mainly on the resources (e.g., people, time, money, computers, etc.) available and what is known about the data. Also some methods such as moving averages are only useful for a single time increment into the future. If, for example, the pattern of the data suggests exponential growth and an upper limit is known, then one of "S" or logistic curves such as the Pearl or Gompertz curves may be applied. If the data does not fit a clear pattern other than linearity and also seem to primarily only on one variable then linear regression may apply. In contrast, if the variable of interest is a function of more than one variable then multiple regression--which usually requires a computer--may need to be applied. All of the methods have in common the definition of some relationship for the historical data which is solved for the future time intervals of interest.

Products or Results

The basic output of a trend extrapolation is a series of future values for a single variable of interest either in the form of a table or a graph.

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The extrapolation may also show up unexpected information. For example, if the trend follows an exponential increasing rise at some point it will approximate a vertical line indicating impossibly high values. This should tell the forecaster that his approach has been naive and that at some point in time some force will intervene to retard the continued growth of the trend line.

With the statistical methods various measures of confidence may be applied to aid in assessing the reliability of the forecast. These methods rely on the degree of spread of the historical data around the historical trend line.

Span of Forecasts

Some of the methods, such as moving averages, are appropriate for very short spans. These are usually the simpler methods. The more complex methods such as multiple regression are more useful for longer spans. In general, however, the span of the forecast is a function of the faith the forecaster has in the continuity of the trend.

Resources

All the methods require the availability of reliable historical data. Beyond that the resources need for the simpler methods may be as little as a French curve, a slide rule and a few minutes--for the more complex methods, advanced statistical skills, a computer and many days.

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SOCIAL TRENDS AND SOCIAL INDICATORS

Abstract

Broadly, a social trend is any persistent, observable development in a society and a social indicator is anything which reflects the status of the trend. The need for social trend analysis is great, so that current interest and activity is high. Regretfully, there is no satisfactory theory of social change so that social trend analyses must be treated with caution. Used to support or refute assumptions or evidence gathered in other ways, social trend analysis can be of great value. Interpretive time-series analysis is the most widely accepted form. Efforts to analyze social trends are as old as the decennial census provided for by the U.S. Constitution.

Definition

Social trend is a very broad term. It refers to any noticeable, per-sisting tendency of a population to change its beliefs or behaviors in some particular way. As currently used, social trends studied are those believed to lower or improve the state of well-being in a population. A social indicator is any measure which purports to reflect the development of a social trend. A social indicator may relate to the ascent or decline of a social belief or behavior, or to the rate of change, or to the direction in which a trend is developing. EXAMPLE: A current social trend is the tendency towards more equal treatment of men and women in their work roles. Some social indicators which reflect this trend are:

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1) Number of court actions addressing this issue;

2) Legislative activity level in the field; and

3) Number of books and articles on the issue being published.

Social trend analysis assumes that particular developments in society (women's liberation) can and will be acknowledged by qualified observers as actualities (it is happening). It is also assumed that such developments can be understood or explained by relating them to other current developments which "cause" them. It is assumed that any given explanation is able to be verified or refuted by objective investigation, later on in principle if not now in fact. It is the basic assumption that certain developments "cause" others which is the basis for social indicator research. In proposing to develop social indicators, it is assumed that the observance of one thing can be accepted as evidence that another thing exists or is happening. An analogous idea is the physician's diagnosis of a disease on the basis of a particular set of symptoms.

History

In requiring a national census every 10 years, the Constitution itself acknowledges that a people changes, and that it is important to track and record social changes. In recent years, the Russell Sage Foundation has been a unique and major source of support for research and development in social trend analysis and social indicators. The Department of Health, Education, and Welfare for some years maintained a Panel On Social Indicators. More recently, in 1973, the Statistical Policy Division of the Office of Management and Budget published Social Indicators 1973, with a new edition scheduled

for 1976. Great Britain, France, and O.E.C.D. have also been active in the field for some years. Senator Walter Mondale of Minnesota for some years sponsored legislation to create a Presidential Council of Social Advisors. One of Mondale's principal objectives was to build support and acceptance for social indicators equivalent to that provided for economic indicators by the Council of Economic Advisors after it was established by the Full Employment Act of 1946.

Main Uses

The major intended use of social trend analysis and social indicators lies in the field of public policy setting and program development. EXAMPLE: If it can be established that sexual equality will persist and increase, that has major implications for employment policies, training programs, child care services, etc. In the private sector, a few organizations such as the National Planning Association and the Institute of Life Insurance also engage in social trend analysis. In the private sector, the objective is to identify threats to enterprise or to support strategic marketing research.

Limits and Cautions

Support for social trend analysis and social indicators research and development has been persistent for some years. The motive is honest and evident: we badly need reliable indicators of social trends. Because the need is so great, some people may uncritically accept analyses and indicators which serve their self interest. Regretfully, it must be pointed out that all work in this field is essentially unsupported by any overall or generally

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acknowledged theory of social change. Thus any given social trend analysis or social indicator should be regarded as symptomatic and contributive, but not as definitive in itself.

Other Techniques

Elected or appointed political and governmental leaders have always needed to know what is going on in any society, so that they could decide what to do about it. Intuition, hunch, use of experienced advisors, and many other methods have always been used in the absence of something better. Social trend analysis and social indicator systems represent little more than an attempt to make such procedures more explicit and systematic, so that in time they may be improved and made more reliable and more germane.

Procedures

A wide variety of approaches is employed. The basic method, however, is reasonably uniform from occasion to occasion. First, one must define or at least describe the social trend of interest. Then one tries to guess what observable developments should accompany the development of the trend in a given direction. By using existing information or by engaging in research to generate new information, one tries to confirm or refute the assumptions already made. Invariably, the definition, description, or perception of the trend is revised and refined as the effort continues. By interpreting the eventual evidence, the analysis tries to show that a given trend exists, and is developing at a certain rate in a certain direction, as evidenced by certain evidence treated as social indicators.

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Product or Result

In its preferred form, the product of a social trend analysis is an array of time-series data, presented as a set of trend-line curves, as a numerical table, or both. The actual data will be accompanied by explanatory narrative which states the assumptions made, procedures used, conclusions drawn. Beyond this narrow range, the ultimate product may be nearly anything—a set of visual images, subjective statements of opinion not testable by experiment, etc.

A wide range of detail is possible. At its most rigorous, when well-documented time-series data is arrayed, explained, and interpreted the level of detail is fixed by the phenomenon of interest and by the detail-level of available data. EXAMPLE: trends in mortality and morbidity in the U.S. based on official records provide detail which is more extensive, complete, and verifiable than any data which might be invoked to document a trend toward greater sexual equality.

Level of Confidence of Results

Confidence levels for social trend analyses and social indicators vary greatly from topic to topic, situation to situation, and person to person. EXAMPLES: Topic to topic: trends in the labor force can be accepted with much greater confidence than can trends in sexual behavior. Situation-to-situation: Labor force trends analyses will be accepted with greater confidence in the Department of Labor than in the White House. Person-to-person: An experienced social scientist may have less confidence in social trend

analysis or in a social indicator than does an untrained political official who nonetheless requires a rational basis for making social policy decisions.

Communicability of Results

A major problem in social trend analysis is to verify that the results have been communicated as intended. Special interest groups tend to discover in statistics what they prefer to see, and not necessarily what analysis by social statisticians suggest. Even where motivation does not bias, social trends are complex, difficult to define, difficult to relate clearly to measurable events. Given the lack of a comprehensive theory of social change accepted by all, it is small wonder that communicating results of a social trend analysis is extremely difficult.

Span of Forecasts

To date, most of the rigorous, hard-data work in the field has been limited to what did happen, and to what is happening. Projection or forecast based on most social-trend data is difficult-to-impossible. Demographic data is sometimes the exception: if we know how many one-year-ods there are today, we can make reliable forecasts about how many twenty-year-olds there will be two decades hence. But who would care to forecast, say, fashion trends twenty years hence, or political issue priorities ten years out?

Resources

There are two basic research approaches in the best practice. One is to analyze existing data gathered for other purposes. This approach can be fairly successful--if appropriate data exists on a standard basis for enough

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history, and if analysis does not exceed what the data validly permits. The
other approach is to design an experiment and conduct it to collect new data
specifically for research. This is usually extremely expensive, and often
impractical--suppose one feels the need to gather data for 10-20-50 years?
There are enough social scientists trained in existing methods to meet any
conceivable need--but the methods are often inappropriate or of dubious value.

Comments

Anyone interested in engaging in or using the results of social trend
analysis including social indicator research would be well advised to consult
the following organizations: (1) Statistical Policy Division, Office of
Management and Budget, Washington, D.C. (2) Russell Sage Foundation, New
York. (3) Social Science Research Council, New York.

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STUDY OF PRECURSOR EVENTS

Abstract

Most closely identified with technological forecasting, this method presumes that the forecaster has or can devise explanatory models about modes and mechanisms of change pertinent to a given topic. The forecaster fleshes out his model with historic or current data which are organized into what are assumed to be current, precursor events. On the basis of these alleged events and the model invoked, the forecaster seeks to predict the nature and timing of subsequent events pertinent to the topic. Because the approach is often used in complex, obscure situations the communicability and credibility of forecast results may be marginal.

Definition

That "coming events cast their shadows before" was first enunciated by Thomas Campbell (1777-1844). In contemporary futures research, the analysis of precursory events as a forecasting method has been most closely identified with technological forecasting. The principle is quite a general as well as an ancient one, however. Since Newton, the western world has increasingly acknowledged the universality of cause-effect explanations, with cause invariably preceding effect. Whenever a cause can be acknowledged, it is feasible in theory and often in practice to estimate what future events can and/or cannot succeed specified past or present events. Thus cause-effect explanatory models can be used to

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identify precursor events and to conjecture systematically about potential
subsequent events--in short, to forecast.

History

Much of the earlier history of this subject has been suggested in
the section of "Modes and Mechanisms of Change" in this manual. In the
contemporary era, the approach can be conveniently divided under two main
headings: hypothetical events and actual (retrospective) events. Fritz
Zwicky's morphological forecasting approach (for which see) is perhaps
the clearest exposition of the hypothetical approach. Specifying techno-
logical needs-functions to be served, Zwicky sought to identify all
possible ways such needs might be met or such functions might be performed.
Using this inventory of hypothetical events, one might then track the
present to see which actual combination appeared to be becoming actualized.
The Department of Defense Project Hindsight is a convenient example of the
actual (retrospective) event approach. In Hindsight, DOD identified a
large number of actual technological innovations, then sought to trace
their origins in complex sequences of preceding events. The rationale
in this case was that if one could make general inferences from the his-
toric record, one might be able to specify or at least identify precursor
events and their "postcursor" consequences.

Main Uses

As mentioned above, the main application of precursor event analysis
in modern forecasting has been in the field of technology forecasting.

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In principle, the approach is equally applicable and valid wherever firm cause-effect relationships are acknowledged. For example, this year's number of births is an important precursor event for determining the number of twenty-year-olds two decades hence. The power of precursor event fore-casting in behavioral and societal sectors is extremely limited, however, because there is no generally accepted or adequate theory of personality change or societal change.

Limits and Cautions

There is a seductive and widely committed logical fallacy which one must be aware of in attempting to use precursor event analysis as a fore-casting method. It is the fallacy of the so-called intervening variable. Simply because Event A precedes Event B there is not thereby adequate reason to suppose that Event A is the cause of Event B. To use an absurd example, if I belch and that trivial gastric event is immediately followed by an earthquake, there is no good reason to assume that my stomach dis-order was responsible for the earthquake. So explained, the fallacy seems clear and simple to avoid. Regrettably, the logical error is not often that easy to spot. For example, was inflation the cause of our current recession, or vice versa, or were other factors still responsible for both? The jury of economists is out in heated disarry.

Other Techniques

As explained under "Modes and Mechanisms of Change," cause-effect explanations are always present to some extent in every forecasting approach.

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Beyond this underlying premise, however, in one sense or application or another, any or all of the other methods cited in this Manual may be considered as potential substitute methodologies for each other, including the method discussed here.

Procedures

In using this method, the forecaster must first clearly identify the forecast topic of interest. Then he borrows or devises a cause-effect model by which he proposes to explain how events and developments pertinent to the topic have changed, are changing, or even can change. Then by observation, the forecaster seeks to identify current events which are suggested by his model. Having done so, he designates these events as precursor events. The balance of the forecasting effort is devoted to estimating what postcursor events should follow, and when, and what their implications may be.

Product Or Result

Dependent on the topic, data available, and the forecaster's resources, the product in this case may range between a simple descriptive narrative to a complex, computerized interactive model. In any case, the product must incorporate and explain the cause-effect model invoked, the historic or current data cited to apply the model to the specific forecast topic, and the conjectural interpretations of the modelled evidence on the basis of which the forecast is presented, explained, and defended.

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Level of Detail of Results

The level of detail in a precursor event forecast is dependent primarily on the scope of the forecast topic and on the amount of precision incorporated into the   cause-effect model used. In political forecasting, for example, the explanatory model may deal with gross national voting behavior, or it may be extended to deal with numerous factional minorities at the precinct level.

Level of Confidence of Results

Confidence in explanatory cause-effect models varies widely from topic to topic, time to time, and audience to audience. For example, in the western world universal, deeply felt confidence is imputed to simple physical models (if a ball is released from the hand it will fall to the ground at a specified rate, always, because...). On the other hand, explanatory models which purport to predict the specific behavior of a particular person or group is much less acceptable.

Communicability of Results

Precursor event forecasting tends to be used in situations which are complex enough and obscure enough to frustrate self-evident explanations to most people. (Example: if it was obvious to everyone what must follow upon that current set of events known loosely as the Energy Crisis, there would be no need for forecast analysis.) Given the situations in which precursor event forecasting is typically invoked,

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the models used and the results based on the model often are difficult to convey to the diverse interested parties addressed.

Credibility of Results

As mentioned immediately above, the results of a precursor event forecast are difficult to convey. For that and other reasons, the credibility of such a forecast may be widely suspect. If the forecaster's audience does not comprehend his explanatory model or if they are not convinced of his model's validity, then they are unlikely to find his results credible.

Span of Forecasts

The span of a precursor event forecast is determined by the time constants in the underlying explanatory model. The appearance of comets in terrestrial orbits, for example, can be forecast with great precision and confidence many years or decades ahead. On the other hand, forecast of sales in a given census tract next week may be extremely imprecise and uncertain.

Resources Needed

The first and foremost resource needed is an explanatory cause-effect model appropriate to the topic and powerful enough to yield forecasts of sufficient detail and time span. The second fundamental resource needed is a source of pertinent, valid data or the capacity to generate same. Either or both of these resources may often be lacking in those practical

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situations where it is desired to use the method--for example, in fore-

casting public response to a Corp of Engineers project.

MODES AND MECHANISMS OF CHANGE

Abstract

Assumptions concerning modes and mechanisms of change underlie every forecast. These cause-effect explanations are obviously crucial to the reliability of the forecast, yet they often are not stated or even recognized by the forecaster himself. These modes and mechanisms range from simple straight-line models, to analogies, to complex models such as input-output or econometric models. Forecasters need a better appreciation of classes of models, the implication of using them, and the need for explicating them for the benefit of users of the forecast.

Definition

Modes and mechanisms of change refers to the basic cause-effect explanations assumed which underlie every forecasting method. Obviously, the variety of explanations which might be assumed is very great. (Example: "Red in the morning, sailors take warning; red at night, sailors' delight." Example: The rate of economic growth is determined by the rates of capital formation and productivity.) Cause-effect explanations may be stated explicitly; as often as not, significant portions of the explanation are unrealized and unmentioned.

The approach assumes that whatever happens is not entirely random or accidental, that in fact whatever happens now or will happen later is caused--that is, that it is attributable to and explainable by a preceding

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train of effects. Further, it is assumed that cause-effect relationships
in one situation may be usefully invoked to describe or explain cause-effect
relationships in another situation. (Example: Opinion polls assume that
the motivation-observed behavior patterns of a sample of the population
can be used to explain the motivation and observed behavior of the entire
population.) Finally, it is assumed that forecasts can be made by studying
the probable outcome of cause-effect relations in a given situation under
hypothetical conditions which may be actualized in future. (Example: If
we believe that most parents wish to have at least one son and if we
stipulate that science may one day permit parents to pre-select their
childrens' sexes, then we can predict that the ratio of boys to girls in
a population will increase when the parents are given the power to pre-
select.)

History

Assumed explanations about how things change are as old as the history
of the human mind. In ancient times, it was assumed that the gods inter-
vened arbitrarily to make changes according to their whims, and this was
accepted as a satisfactory explanation of whatever happened. Historians
have used the ideas of the Great Man, climate, and challenge-response to
explain historical evolution. Social scientists have used endless numbers
of analogies, metaphors, and models to explain social change and stability:
The Ant Hill, the clockwork, the pecking order, Parsons' "structures and
functions," econometric input-output models, etc. While the examples

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cited differ wildly in sophistication and explanatory power, they are nonetheless all equally instances of invoking particular cause-effect explanations, then using these to make predictions.

Main Uses

Particular modes and mechanisms of changes are introduced by assumption at the earliest stages of a forecasting effort. They are used to decide what issues are important, what questions might be asked, and what data might be pertinent. Once introduced and used, they are apt to be accepted without further questioning in mid-project, then re-emphasized as the central finding or thesis in interpreting forecast evidence.

Limits and Cautions

The use of selected explanations of modes and mechanisms of change is at once essential and extremely treacherous. In a vast computerized economic model, for example, hundreds or even thousands of such explanations may have been used. Yet the number, validity, or even the fact that these explanations--and not others--were used may be difficult or impossible to establish in working with the model's outputs. Nor is there any ultimate validation in the fact that the model seems to replicate actual experience, so far as we can tell: identical results may be attainable by many significantly different means. Necessarily, explanations about modes and mechanisms of change oversimplify, throwing out all by a few factors. In assessing a forecast, it is important to consider whether or not the most

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appropriate factors have been excluded and included by the explanatory mechanisms used.

Other Techniques

The number and variety of explanations about modes and mechanisms of change is very large. In a sense, each is a "different" technique. Yet all can equally be said to be various aspects of a single technique-- the technique of selecting particular cause-effect relationships, and using these to explain and predict changes.

Procedures

For topics in which forecasting activity is high, certain cause-effect explanations have come to be well accepted, while others have been ignored or renounced. For topics in which forecasting activity is new or recent, there is what amounts to a competition among various forecasters to see whose explanations are most powerful in suggesting and validating infer- ences and predictions. Ultimately, it would appear that personal experience, judgment, and insight is the basis for selecting particular cause-effect explanations to apply in a given forecasting effort.

Product or Result

The main product here is developed at an early stage in a forecasting project for use by the forecaster himself. The product is an analogy, metaphor, or model which the forecaster elects to accept, develop, and explore in making his forecast. This model may or may not be explicitly

or by inference described in his final forecast report, but in either case it will become a central component in any interpretive comments made by the forecaster.

If the explanation used is a simple, intuitive one, it may not be discernible to the outsider in the final forecast. If the model is elaborate and the forecast project is substantial, the final product may devote as much or more attention to the model as to the results obtained with its use. In the latter case, the explanation could take the form of many interlocked linear or non-linear equations embedded in a computer.

Level of Detail of Results

Forecasters quickly discover that the number of factors evidently pertinent to their forecasts always exceed their capacity to deal effectively. Explanations about modes and mechanisms of change are introduced precisely so that only what are then assumed to be "the few most important factors" can be dealt with, while others are touched on or ignored. For the few factors dealt with, the level of detail ranges from cursory to exhaustive; for the other factors, the level of detail ranges from none to cursory.

Level of Confidence of Results

A forecaster who accepts some given explanation of modes and mechanisms of change comes to think in terms of his model. For him, therefore, there is a high level of confidence in his explanations. For others

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considering his forecast, the level of confidence in the forecast tends
to rest on how well his explanation is understood and accepted as pertinent
and valid. A monk who invoked the explanation of God's power and inclina-
tion to intervene might find that his forecast of future miracles was
accepted with great confidence by the bishop, only to be rejected violent-
ly by the village atheist.

Communicability of Results

A good explanation of modes and mechanisms of change is a simple ex-
planation. To explain that the solar system works like a clock, or vice
versa is to give a satisfying explanation to Westerners acquainted with
clocks, and no explanation at all to a New Guinea bushman. Just as parti-
cular cause-effect explanations are accepted to simply forecasting activi-
ties, so are such explanations valuable in conveying the results of a
forecast. It must be repeated, however, that communication inevitably
means simplification, so that apparent and actual communication may be
quite different from each other.

Credibility of Results to Critics

Cause-effect explanations of modes and mechanisms of change are
essentially presumptions about the nature of reality. So long as one's
critics are members of the same or a similar sub-culture, the explanations
the forecaster tends to use will be those his critics will tend to accept,
although they may argue about his data or his interpretation. Most fore-

casters, regrettably, find that their forecasts are most wanted by persons whose sub-culture is significantly different from their own. Thus the Secretary of the Treasury may find the results of the Wharton national econometric model incredible, because he explains economic phenomena in quite a different way.

Span of Forecasts

The basic presumption when selecting given explanations of modes and mechanisms of change is that they are timeless--if a stone falls at a given rate today because of gravity, it is predicted that the same stone in the same place would fall at the same rate a million years hence. Similarly, if greed is used as an explanation of human behavior, it is assumed that it will play the same role in human behavior forever--although the role may be played out in different ways according to different cultural rules from time to time.

Resources

Even to predict whether a penny tossed will come up heads or tails requires the use of some explanatory mechanisms. In that minimal sense, no resources other than the experience by which a person comes to reason are needed for some forecasts. At the other extreme, to inventory, assess, and select a certain few explanatory models for a given application--out of the infinite possibilities--would often be an impossible task. In actual practice, the forecaster tends to bring to his task from prior

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experience a few explanatory models which he plugs in early and uses constantly. It needs to be pointed out, however, that the cost of development of some models has run into the millions--in fact, into the tens of millions--of dollars.

Comments

The reader is once again reminded that what has been described here is an underlying aspect of every forecasting method yet developed or ever to be developed. Because the use of explanation is so frequent, so apparently simple and casual, and yet so powerful in determining forecast results, it is important and extremely profitable to identify and assess the adequacy of explanatory models invoked in a given forecast.

BOX-JENKINS METHOD

Abstract

The Box-Jenkins Method is a powerful forecasting tool useful where
the variable of interest is a complex function of a variety of factors.
It illuminates the pattern of the time-series data and uses that pattern
to generate the forecast. It does this through multiple iterations
gradually refining the model. As a result, however, it is complex to
apply, costly, time consuming and requires extensive computer time.

Definition

The Box-Jenkins method is a quantitative forecasting approach designed
to handle complex time series data where no ready pattern to the data is
apparent. Unlike most other quantitative techniques Box-Jenkins does not
require a clear definition of the trend. In fact, the method is intended
to discover the pattern of the trend. This is accomplished by multiple
iterations of the data, with each iteration providing information which
allows the next to more closely approximate the actual pattern of the data.

History

The Box-Jenkins method is a relatively recent innovation in forecasting.
It was developed in the late sixties by Professors G.E. Box and G.M. Jenkins
and published first in 1970 in their book Time Series Analysis.

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Main Uses

This method is useful where the desired forecast has an extended time span, the data composing the time series is complex and where a relatively high degree of precision is both required and meaningful. It is also useful in that the method itself provides information on the statistical error in the forecast independent of other statistical tests.

Limits and Cautions

Like all quantitative forecasting techniques relying on historical data, the forecast at best can only be as good as the data used. Thus, the quality of the data is an important and often ignored limit in forecasting. The Box-Jenkins method in particular is one of the most complex and costly methods of quantitative forecasting. It requires considerable computer time and generally longer time to complete a forecast. Its complexity demands a high degree of skill in mathematical methods.

Other Techniques

Box-Jenkins sits somewhere between multiple regression analysis and computer simulation models. It is a good deal more complex than multiple regression. However, it forecasts only a single variable and is therefore less powerful than simulation models.

Procedures

Initially, the person using the Box-Jenkins method postulates a general class of forecasting methods for his particular situation. In

stage 1 a specific model that can be tentatively entertained as the fore-
casting method best suited to that situation is identified. Stage 2 then
consists of fitting that model to the available historical data and then
running a check to determine whether it is adequate. If it is not, the
approach returns to stage 1 and an alternative model is identified. When
an adequate model has been isolated, stage 3 or 4 is pursued stage 3 being
development of a forecast for some future time period and stage 4, the de-
velopment of a control algorithm for a situation in which the forecasting
method is to be used for control purposes.

Product or Result

Box-Jenkins produces two results. The first is the forecast itself
in either tabular or graphical form. It provides the most likely value
as an upper and lower bound to the probability range. Equally important
is the identification of a model for the data which may be used to generate
future forecasts.

Level of Confidence of Results

The method includes as part of the approach, statistical techniques
for evaluating the confidence. In general, however, Box-Jenkins tends
to be more accurate than the less complex methods.

Span of Forecasts

Box-Jenkins is suitable for forecasts of the very short-range to the
intermediate level of a few years. Beyond that the reliability of the
identified pattern derived from the complex of variables cannot be counted on.

Resources

The necessary resources to successfully apply the Box-Jenkins method are considerable. It is costly and time consuming. It requires extensive computer time. A high level of mathematical skills is also necessary.

PROBABILISTIC FORECASTING

Abstract

Probabilistic forecasting encompasses a number of different techniques all of which use some aspect of probability theory. It's major use is to predict the probability of occurrence of future events for some time dependent random process. Some of the probabilistic forecasting techniques are:

- Point and interval estimation
- Monte-Carlo simulation
- Markov processes
- Parametric sensitivity analysis
- Inventory theory
- Queueing theory

Generally, all of these techniques require modeling of events and estimations of probability functions.

Definition

Probabilistic forecasting encompasses a number of different techniques all of which use some aspect of probability theory. Probability theory is regarded here as the study of mathematical models of random phenomena. A random phenomenon is defined as an empirical phenomenon that obeys probabilistic, rather than deterministic laws.

A random phenomenon that is time developing in a manner controlled by probabilistic laws is called a stochastic process. Thus the motion of a particle in Brownian motion, the growth of a population such as a bacteria colony, and the occurrence of floods on a river are examples of stochastic processes. In general, probabilistic forecasting is the result of a stochastic process.

History

Huyghens (1657) published the first book on probability theory which was a treatise on problems of games of chance. There were no published

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writings on this subject before 1657, although evidence exists that a number of fifteenth- and sixteenth century Italian mathematicians worked out solutions to various probability problems concerning games of chance. General methods of attack on such problems seem to have first been given by Pascal and Fermat in a celebrated correspondence beginning in 1654. It is a fascinating cultural puzzle that the calculus of probability did not emerge until the seventeenth century, although random phenomena, such as those arising in games of chance, have always been present in man's environment.

Eighteenth century development was enriched by the works of a number of men including Bernoulli and Poisson. The work of Laplace (1812) marks a natural diversion on the history of probability, since his works are not only basis of much of modern probability but his stated belief that probability calculus is relevant to "the most important questions of life" and not just to repetitive games of chance.

Main Uses

The major use of probabilistic forecasting is to predict the probability of occurrence of future events for some stochastic process. Changes or modifications to the stochastic process can be evaluated by the use of parametric sensitivity analysis. For example, the flooding of a river can be evaluated as a stochastic process. The introduction of various flood control measures on the river can be included in the evaluation by means of parametric analysis.

Limits and Cautions

Probabilistic forecasting is based on the development of a stochastic model to duplicate the hypothetical occurrence of events in the real world. The validity of the results of the forecasts are, therefore, dependent on how well the stochastic model duplicates the real world and on the availability and precision of inputs required by the model. The general procedure used to overcome this difficulty is to "bracket" the outcomes hypothetical forecasts by varing inputs over their range of uncertainty by the use of parametric sensitivity analysis.

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Other Techniques

There are a number of alternatives available to probabilities fore-
casting. Historically, subjective opinion by "experts" has been the most
used alternative. The use of subjective opinion by "experts" has been
structured in recent years into methodologies of their own (e.g., the
Delphi technique). Deterministic modeling is another alternative that
is generally applied to very complex systems. The results of the deter-
ministic models are usually labeled as expected values with the term,
expected, being used in a rather loose statistical sense.

The entire field of decision analysis can be regarded as a subset
of probabilistic forecasting; however, because of its importance, it is
being treated as a separate method.

Procedures

Probabilistic forecasting uses a number of different techniques.
There are some steps, however, that are common to all of the techniques.
These include:

- Detailing all possible events.

- Estimating probabilities of occurrence of events
  subject to various conditions.

- A modeling effort which is specific to the forecasting
  technique to be applied.

Descriptions of some of the probabilistic forecasting techniques that
may be used singularly or in combination include:

- Point and interval estimation. This method attempts
  to describe the probability of outcomes for a single
  event. An example would be the maximum annual water
  level of a river. The event of concern would be a flood,
  i.e., when the water level exceeds a given depth.

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- <u>Monte-Carlo Simulation</u>. This method simulates all or part of a process by running a sequence of events repeatedly, with random combinations of values, until sufficient statistical material is accumulated to determine the probability distribution of the outcome. The values used in each run are selected because of the assumed underlying statistical distribution.

- <u>Markov Process</u>. The procedure used in the Markov process is to model the situation based on a matrix of transition probabilities. These transition probabilities are the probability of going from one event to another and are assumed to be independent of the sequence of events. Points of interest to the Markov process are the expected times required to go from one event to another and the steady state solutions, i.e., the long-run probability of being in any state.

- <u>Non-Markov Process</u>. This process is similar to the Markov process, only it is assumed that the transition probabilities can depend on the preceding sequence of events.

- <u>Parametric Sensitivity Analysis</u>. In this type of analysis, the input parameters or model formulation are varied in a systematic manner to evaluate their effect on possible outcomes. Variables whose variation have little or no effect on possible outcomes can then be treated in a deterministic manner.

- <u>Inventory Theory</u>. Two problems of considerable importance to retail shops, wholesale distributors, manufacturers, and consumers holding stocks of spare parts are: (1) deciding when to place an order for replacement of their stock items,

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and (2) deciding how large an order to place. Two kinds
of uncertainty must be taken into account: (1) number of
items that will be demanded during a time period, and
(2) time-of-delivery lag that will elapse between order
and receipt of goods. Inventory control is concerned
with minimizing the cost of maintaining inventories, while
at the same time keeping a sufficient stock on hand to meet
all contingencies.

* **Queues.** A queue (or waiting line) is generated when
customers (or servers) arriving at some point to receive
(or render) service there must wait to receive (or render)
service. The group waiting to receive (or render) service
is called a queue. In the mathematical theory of queues,
waiting lines are classified according to four aspects:
(1) the input distribution (the probability law of the
times between successive arrivals of customers); (2) the
service time distribution (the probability law of the time
it takes to serve a customer); (3) the number of service
channels; and (4) the queue discipline (the manner in which
customers are selected to be served; possible policies are
"first come, first served," random selection for service,
and service according to order of priority). Queueing
theory is concerned with the effect that each of these
four aspects has on various quantities of interest, such
as the length of the queue and the waiting time of a
customer for service.

Product or Results

The actual results depend on the procedure employed. Generally, the
results include tabular and graphical presentations. These might give

expected outcomes over time and their associated probability intervals.
If parametric sensitivity analysis is used, there might be a different
set of results for the conditions studied.

Communicability of Results

Some knowledge of basic statistics is required to understand the
results. Otherwise, the results, which are presented in tabular and
graphical form, can be readily comprehended. Because of the nature
of the modeling and estimation of probabilities required, the results
can be subject to criticism. This, however, is less of a problem than
with other forecasting techniques.

Span of Forecasts

The most accurate forecasts are for the near and medium term time
frames. As the time span increases, the validity of the underlying
assumptions decreases. Moreover, it is more difficult for the person
or persons developing the model to enumerate all possible events for
the longer-term situations.

Resources

The resources required to conduct probabilistic forecasting include
experts in the applied subject area and in statistics who are able to
model events, data, and estimates of conditional probability distribu-
tions for the occurrence of events, given the occurrence of other events;
and many of the forecasting techniques require the use of a computer.
The cost of the development of probabilistic forecasting models and their
associated inputs may require anywhere from a few dollars to many thousands
of dollars, depending on their size, scope, and application.

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Special Comments

Since there are a number of different probabilistic forecasting techniques that can be used with varying levels of detail, the validity of the forecast will depend on the model and data used. A carefully designed model used with a good data base and using parametric sensitivity analysis to explore the effect of less reliable inputs can give extremely useful results.

SUBJECTIVE ESTIMATES OF PROBABILITIES

Abstract

The subjective component is incorporated in every estimate of future probability, and consists of that basis for the weighting of respective outcomes to which no numerical basis can be assigned. As a method, however, the term refers especially to those procedures in which the subjective component is alleged or acknowledged to be of major or crucial importance to the forecast contents. Subjective estimates of probabilities are routinely relied upon in trivial, moment to moment decision-making and in the vast, ultimate questions for which no objective appraisal is yet feasible. The subjective approach in fact has dominated most decision-making until the recent past, and undoubtedly dominates decision-making for most people in the world even at present. Many futures forecasting methods of recent vintage amount to little more than systematic attempts to make subjective estimates of probabilities more explicit and thus more "objective."

Definition

No potential future outcome is absolutely certain until it has been actualized in the present. In that strict sense, all estimates of probability are subjective. The concept of probability, however, implies that potential outcomes can be estimated and expressed in quantitative or at least metric terms--"the odds are 60 to 40 against," for example.

The subjective component of any probability estimate consists of that weighting assigned to probabilities whose weight itself cannot be explicitly counted or measured--"my experience and intuition tell me that this outcome is less likely than that," for example. Every estimate of probability includes some component of subjectivity. The method specifically referred to here, however, includes all cases where the subjective component is alleged or acknowledged to be major and crucial in determining the content of a forecast.

This approach assumes that past experience can be and often is linked rationally and properly to the forecaster's ability to predict future developments and events. It is further assumed that some experience--in many cases, much of the most valuable experience--has not been and perhaps even never can be applied or described in numerical terms. For example, on what numerical basis might an art or music critic predict whether or not a current work of art will be recognized as such by future generations? The ultimate entrepreneurial risks in every enterprise are similar to judgments about works of art in this respect. In such situations, subjective, intuitive experience is invoked in making forecasts, either as a supplement or as the only credible basis available.

History

The use of explicit, objective reasoning to estimate future probabilities is relatively recent in civilization, perhaps dating from Descartes in the 17th Century. Until then--and still in many quarters representing

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the majority of the world's peoples--subjective estimates in one form or another were the only type of estimate known, let alone employed. Intuition, experience, judgment, wisdom, insight--most of the qualities by which people, especially leaders are judged--are ultimately explainable only in subjective terms. Even now in the citadels of objective reason, it is a brave soul who argues that the complexities of personal and social behavior can be explained on an entirely objective basis--whatever that phrase may mean.

Main Uses

Resort to subjective estimates of probabilities of future outcomes is determined primarily by the scale of cost, risk, and complexity involved in a given situation. In the making of routine, trivial, minute-by-minute decisions often it is neither necessary or worthwhile to strive for objectivity. In ordering lunch, selecting a suit of clothes, or choosing a route through the park, one's intuitive preferences are usually adequate. In speculating about the prospects for peace, humanity, religion, or the state objective estimates often are clearly inadequate and not worth making. It is only at intermediate levels of cost, risk, and complexity that it may seem worthwhile to invest in studied, objective estimates. State and national budgets, corporate diversification plans, manpower and training programs--these are examples of intermediate activities in which objective estimates of probabilities are attainable and useful.

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In a special sense, then, it is fair to say that we use subjective
estimates of probabilities to settle both the smallest and the largest
issues and uncertainties, reserving objective estimates for intermediate
matters.

Limits and Cautions

Subjective estimates of probability are adequate so long as they
are acceptable to all parties concerned or so long as objective events
do not create unmanageable difficulties. There is a Great Pumpkin so
long as Charlie Brown believes in Him and so long as He actually does
appear on Halloween in a form even the skeptics must acknowledge. When
these conditions are not met--as perhaps at present when people are
ceasing to believe in the possibility of full employment because of
current unemployment rates--grave, insurmountable crises may rapidly
develop.

Other Techniques

As suggested above, subjective estimates of probabilities are used
when more objective estimates are unnecessary or inaccessible. It should
be noted that no estimation procedure is either purely subjective or
purely objective. Any forecast topic has many aspects, and the question
always must be how many and which aspects can be treated objectively or
subjectively.

Procedures

Unsurprisingly, considering how ancient and universal subjective estimation is, procedures for making subjective extimates are subjects of constant development, experiment, and testing. For example, in this manual the reader's attention is directed to the following methods: KSIM, Cross-Impact Analysis, Study of Precursor Events, Scenarios, Surprise-Free and Canonical Projections, Authority Forecasting, Surveys of Intentions and Attitudes, Panels, Delphi, Divergence Mapping, Modes and Mechanisms of Changes, Synectics, and Contextual Mapping. Subjective estimates are adequate only to the extent that they can be shared and are convincing; these conditions tend to be met only to the extent that estimation procedures tend to be explicit and logical and plausible, if not objective. It is in pursuit of these objectives that constant experimentation procedds with the regularization of subjective procedures for estimating probabilities.

Product or Results

Given the range and diversity of subjective estimation methods, the corresponding range and diversity of products is commensurately large and diverse. The range varies between simple assertion--"I believe (for whatever reasons, unstated) that such-and-such will happen"--to elaborate, computerized models in which subjective weights have been quantized and cross-correlated in complex ways at many levels.

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Level of Detail of Results

Infinitely variable, from the grossest generalization to mountains of computer print outs.

Level of Confidence of Results

Those who sponsor and those who offer these kinds of forecasts profess great confidence in them, because the forecasts are used to justify decisions and actions, past or pending. Beyond these parties, also, the level of confidence acknowledged in a subjective forecast usually depends on the values and views of those concerned. Where the forecast serves or can be made to serve positions established on ohter grounds the forecast is accepted with great confidence. Where the forecast attacks previously established positions it is ignored, attacked, or minimized.

Communicability of Results

Communicability is an interesting facet of subjective forecasts. On the one hand, those who sponsor or make the forecast wish their audience to accept without question the superior insights and opinions allegedly contained in the forecast. For this reason, the factual content of the forecast may be minimal, or may deliberately be made difficult to understand. On the other hand, a subjective forecast connot serve its intended end unless it persuades to some extent those parties which are on record as hostile or skeptical. In striving to meet these opposed objectives, the forecast typically clearly states certain of its major premises and

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all of its major conclusions while obscuring the chain of reasoning which links the two. Examples of this abound in the literature.

Credibility of Results to Critics

What has been said above about communicability covers this matter adequately.

Span of Forecast

Of all the aspects of forecasting by mothod, perhaps the most subjective of all is the estimate of how far into the future it is feasible to conjecture with credibility. Such being the case, subjective estimate forecast time horizons vary literally between the next sixty seconds and the remainder of the history of the universe, dependent purely on the topic, the forecaster's opinion, and the credibility of his audience. Given topics tend to have a characteristic time horizon, however: economic forecasts tend to deal with the next three to eighteen months, technological forecasts tend to deal with the next three to thirty years, etc.

Resources Needed

Depending on the application, the topic, and the audience the range of resources literally varies between the minimum of one person with a strong opinion and a maximum of many years of opinion-poll data from normalized samples.

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ENVIRONMENTAL SYSTEMS ANALYSIS

Abstract

Systems analysis is not a specific forecasting technique, rather it
is an approach to complex problem solving. The approach has been employed
to resolve governmental, social, business, and, most recently, environmental
problems The central motive for using systems analysis in environmental
planning is the complexity of ecological processes. However, planners
wishing to apply environmental systems analysis should not expect to find
a ready made "cookbook" forecasting technique. There is a generalized
approach with literally hundreds of useful tools suggested at each step;
but the details of exactly "how to do it" for a specific problem are left
to the imagination and ingenuity of the planner.

Definition

Systems analysis is probably not amenable to a clean, sharp, one sen-
tence definition. Generally speaking, it is a systematic way to look at
complex problems to assure the achievement of a larger objective more effec-
tively than if individual parts were examined in isolation. The central
aim of systems analysis is that of making the optimal choice from among an
array of alternative strategies. It is an approach for grasping a large com-
plex problem by looking at the broad goals to be achieved, alternative methods
to achieve them, and then examining the costs and benefits of various
approaches to achieve the objective. Designed to clarify objectives, it is
also a method to discover alternatives and measure their appropriateness
in light of all sorts of costs that are relevant to a problem - money, lives,
personal satisfaction, foregone opportunities, and so on - in light of benefits
to be achieved by taking a particular course of action Benefits may also be
of many different varieties - money, lives, time, and so on. In the process
of analysis, risks, costs, and objectives are weighed and balanced. (Steiner.
1969)

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Perhaps the most basic component of systems analysis is the operating maxim that extremely complex processes can be most easily dissected into a large number of very simple unit components, rather then a small number of relatively complex units. A second extremely important notion is that complex historical processes in which all variables change with time (evolve) can be dealt with most straightforwardly in terms of reoccurence formula that expresses the state of a system at time $t + 1$ as a function of the system at time t. Thus the process is understood in terms of the cause-effect relationship that operates through the typical time interval. Another important basic tenet of systems analysis is that optimization of processes is the central aim of research. (Watt, 1966)

History

The term Systems Analysis was probably first used by the RAND Corporation in the mid-1940's. The concept was developed during the desperate military situation that arose in England in World War II. It occurred to people responsible for the defense of the country that physicists, biologists, mathematicians, and other highly specialized people might have something to contribute to what historically were considered strictly military problems. Since the war, the systems approach has been employed in some fashion by almost all disciplines from the "hard sciences" to the softest of social sciences. Some environmental applications include: Monitoring the activities of small animals, analysis of bird navigation, determination of populations systems, ecological models, salmon management, and numerous environmental impact analyses and assessments.

Main Uses

The systems methodology deals effectively with important, broad, ill-structured problems but can also apply to much narrower problems, such as

allocating finds for a project. System analyses are undertaken for numerous
uses from policy guidance to compliance with environmental directives on the
most routine level. Policy guidance can be provided usually for decisions
in which rigorous quantitative analysis can only provide part of the solution.
The analysis should aid in understanding the important and fundamental princi-
pals involved. The decision-maker does not ordinarily have time to work
through all the aspects of the analysis and to understand those that he cannot
accept intuitively. Therefore, the analyst must provide the common sense
reasoning necessary to understanding. (Quade, 1964)

In response to NEPA the systems approach can accommodate the require-
ments to: blend the knowledge of many disciplines, employ and emphasize
a scientific method, understand the present situation (develop a model),
evaluate alternatives, consider the future implications, and deal explicitly
with uncertainty.

Limits and Cautions

Quade identified the two major pitfalls of systems analysis as 1) failure
to really define the problem, and 2) relying too heavily on quantitative
methods (greater interest in models then the real world). The fundamental
limitations according to Steiner are that the analysis is necessarily incom-
plete; measures of effectiveness are inevitably approximate; and ways to
predict the future are lacking. However, the major problem for planners
may be that systems analysis is an art not a science. Thus, it is impossible
to explain to the planner just how to carryout a systems analysis.

Procedure

While there is no one specific procedure, the basic approach usually
involves the following phases.

Problem Definition--The approach, research needs, and boundary conditions.
Choosing Objectives--Kinds of objectives in the value system and opti-
     mizing the value system.
System Synthesis--Functional design, delineating subsystems.

Analysis--Applying analytical tools, deducing uncertain consequences.

Selecting the Optimum System--Decision problems and alternatives.

Probability techniques such as decision trees, utility profiles, simulations, linear programming, and PERT reviews are tools used in system analysis.

Product or Results

Discovery is the basic product from the analysis. According to Henry Rowen, President of RAND, "discoveries, not of things, but about objectives or values, or relationships, or facts." In the area of general government, a simple systems analysis might indicate whether the Army Corps of Engineers should spend $10,000,000 on flood control in Missouri versus Ohio. On a more difficult level would be determination of the preferred use of the land; a flood plain or a recreational park. Determining the best allocation of water resources to improve the habitability of U.S. cities could be the result of an involved system analysis.

Output and Level of Detail

The output is problem dependent and usually specified in the early stages of problem formulation. Oftentimes the final output will contain a discussion of the specific system design as well as a comparison of alternatives. For an impact profile of three plausible waste disposal systems, the output in tabular form shows rank order lists of human and environmental impact elements. Values are displayed for the worst and best cases. The results also include an estimate of reliability for all of the elements considered. The output should produce generalized solutions as well as detailed analytical backup. Systems analysis is a standard approach in engineering and accepted in most other fields. For many interests the confidence level dwindles if the approach is too mathematical.

Communicability of Results

Experience has shown that the approach can be readily explained to and understood by audiences having diverse backgrounds and capabilities.

Because of this, an extremely promising application is in accessing comunity perception of impact for the purpose of (1) identifying and clarifying issues and sources of conflict, and (2) educating the public and stimulating informed public participation. The results of environmental analyses can be compared among groups and used to develop information for clarifying misconceptions about system designs and their impacts. The environmental procedure can also serve as an effective catalyst for involving the public in the design process. (Peterson, 1973)

Credibility of Results to Critics

Systems analysis is a relatively new descipline and in some sense not verifiable. Nevertheless, the credibility of the approach is high. The credibility of the results, however, are completely dependent upon the user. As was mentioned earlier, the analysis can be top caliber yet fail to address the correct problem.

Resources

A systems analysis approach to environmental planning suggests the use of several experts from various disciplines to work together on a problem. The team may well include: ecologists, biclogists, limnologists, engineers, statisticians, social scientists and economists. While it is not essential, there is usually a requirement for mathematical modeling and/or statistical evaluations. Frequently computers are utilized to carry out numerical computations. Time and cost increase with the complexity of the problem.

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DYNAMIC MODELS

Abstract

The system dynamics methodology is a model building tool for construction of dynamic models of complex, nonlinear systems, and studying the evolution of systems through time. Simulation is commonly employed to solve the problems posed by dynamic models by following the changes in the system over time. Among the many applications, dynamic models have been used to suggest an over-all framework whereby water supply and water quality can be related to broad considerations of population, employment, investment, and life-style. While dynamic models require extensive time, resources, and skills on the part of the developers, they appear to be an extremely popular and useful modeling tool.

Definition and Description

A dynamic model is a formal model that allows the changes in system attributes to be derived as a function tf time. The derivation may be made with an analytical solution or with a numerical computation, depending upon the complexity of the model. Dynamic mathematical models that can be solved analytically and give practical results are not very common. Usually, numeric methods such as simulation are employed to solve the problems posed by dynamic models. Basically, dynamic models consist of a number of reservoirs, or levels, interconnected by flow paths. The rates of flow are controlled by decision functions that depend upon conditions in the system. The levels represent the accumulation of various entities in the system. Rates are defined to represent the instantaneous flow to or from a level. Decision functions or, as they are also called, rate equations determine how the flow rates depend upon the levels.

Underlying Rationale and Assumptions

A System Dynamics model makes explicit assumptions about how decisions are made controlling, for example, the rate of flow of capital, resources, manpower, and goods. These decision variables, or rates, must be formulated

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by mathematical equations indicating how the decision or rate depends upon
the perceived state of the system at a given instant in time. A System
Dynamics model, therefore, is primarily a statement of how the state of a
system influences the subsequent changes in the state of that system (Anderson,
1972).

History, Including Previous Applications

The dynamic modeling technique--systems dynamics--was developed by
Professor Jay Forrester and his coworkers at Massachusetts Institute of
Technology in the early 1960's. There have been several applications of
the technique and numerous publications. Entire books either devoted to
or based on the technique include: Industrial Dynamics, Urban Dynamics,
World Dynamics, Limits to Growth, and most recently, Mankind at the Turning
Point.

Main Uses

A System Dynamics model is uniquely qualified for assessing the con-
sequences of action taken within a system and for testing the alternatives
open to policy-makers and planners. Because System Dynamics is a simula-
tion methodology, it is possible to test the sensitivity of the model to
the parameters which quantify the model, that is, to assess how important
a particular parameter is in the consequences which the model projects for
the system. Sensitivity tests have two useful functions: first, they indi-
cate where more research is urgently needed to allow definitive assessments
of the system's future; second, they indicate points in the structure of a
system where policy change is most effective.

Limits and Cautions

It is often difficult to provide a quantitative formulation for a
decision variable or rate. The commitment of time and resources is signi-
ficant. Feedback loops must be designated and each control factor specified.

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Equations must be developed for all rates and flows. Moreover, this methodology requires a large amount of data (either generated or collected) and an experienced model builder skilled in System Dynamics and Simulation.

Other Techniques for Doing the Same Job

System Dynamics is rather unique in terms of simulations. KSIM is often referred to as a poor man's System Dynamics but does not offer the sophistication of the Forrester technique.

Procedure

The task of modeling a system begins with conceptualizing the system. This job occupies most of the modeler's efforts. He first must establish the boundary of the system in both time and space. The model-builder next uses his knowledge of the system, his contacts with participants in the system or expert observers of the system to set forth the structure of the system. A very useful tool for describing system structure is the feedback loop. Feedback loops provide a qualitative picture of the system structure. This structure must then be mapped into a quantitative or formal mathematical model. The simulation language DYNAMO is ideally suited to this task, although other computer languages can be used.

In order to quantify the model, specific numerical values are required for the parameters identified in the system structure. The System Dynamics model-builder places heavy reliance on experts in the field to supply these data.

Product and Form of Output

The results of a dynamic model are a series of graphs illustrating the growth and decline of the system variables. The product peresents the results of various alternatives as they compete for the defined resources.

Level of Detail

While the feedback loops in a dynamic model usually characterize
broad concepts, such as water quality, the parameters involved in the de-
finition of the water quality loop may be extremely detailed and include
such parameters as dissolved oxygen, required treatment, investment, and
capital costs. The output display usually illustrates change in the levels
of major variables such as the level of dissolved oxygen required for vari-
ous treatment plant costs.

Level of Confidence in the Results

The validity of the model rests as much on the acceptance of its
assumptions by experts as on any quantitative test, although it is often
possible for a model to be constructed so that it can simulate past history
for quantitative verification.

Communicability of Results

Dynamic models rely heavily on feedback loops to illustrate basic
model structure. While these are usually good display devices, detailed
models often require extensive examination and explanation to gain under-
standing. The output graphics are presented in such a way as to facilitate
ease in assessing trade-offs between alternatives.

Credibility of Results to Critics

While the Forrester/Meadows dynamic modeling technique is possibly
one of the most heavily commented upon in the forecasting literature,
its proponents are as strong as its critics. Dynamic modeling is extremely
popular and sure to be utilized to an increasing degree in the future.

Span of Forecasts

Dynamic models are designed to produce long range forecasts. While
most models simulate changes for at least fifty years, the technique can
accommodate both longer and shorter forecast periods.

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Resources Needed

Dynamic models usually require large amounts of data in tabular form. Often times the extensive data requirements present problems and are time consuming. A team approach is recommended to develop a dynamic model. Because the interaction between modeler and field expert must be close, in both the conceptual and data-collection steps of model building, it is extremely important for the two to work together throughout the modeling process. In this way the model's client-respondent easily grows into the model's user-expert, and the model becomes an implementable practical tool rather than an isolated or sterile exercise. Unfortunately, the time requirement for developing such a model is extensive and thus, it is not feasible for the decision-maker to participate.

A computer is required to carry out the computations of the simulation. While a DYNAMO compiler is ideally suited for the simulation, the simulations can be run on a more standard system.

While I do not have specific data, I would estimate that a minimum time of six months would be required to collect the data, develop the feedback loops and test the model. Computer costs for running the simulation are small compared to the development costs.

CROSS-IMPACT ANALYSIS

Abstract

Cross-impact analysis strives to identify interactions among events or developments by specifying how one event will influence the likelihood, timing, and mode of impact of another event in a different but associated field. Cross-impact analysis is used not only to probe primary and secondary effects of a specified event, but to improve forecasts and to generate single forecasts (or scenarios) from multiple forecasts. The method is also a tool useful in many sophisticated forecasting techniques.

Definition

Cross-impact analysis is a systematic means of studying the interactions among events or developments. The underlying assumption is that a change in technology, social practices, values, or any other area will affect the surrounding environment in three ways: (1) it will change the probability of occurrence of interconnected events, (2) it will change the timing of interconnected events, and (3) it will affect the mode of impact of interconnected events.

History

The cross-impact method was developed during the 1960s by Gordon and Helmer as an outgrowth of objections that the Delphi technique of forecasting often failed to consider the interconnections among events. The method has found widespread use in technological as well as social forecasting. Perhaps

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the most advanced cross-impact analyses have been carried out at the Institute 'for the Future.

Main Uses

The main use of the method is to describe and quantify the impact of one development upon others. Most frequently it is used to explore the implications of an advance in technology. Cross-impact analysis is often used to compare the implications of differing forecasts in a given field and to combine separate forecasts in discrete but allied fields into a single forecast.

Results have been used to define primary and secondary effects of a change (or a forecasted change) in one area upon: social trends, new or altered social demands, institutional functions (personnel, production, distribution, etc.), development in allied technologies, markets, long range plans, management policies, R&D decisions, and similar areas. The technique provides insight into trade-off options and is useful in testing the consequences of various policy actions. By clarifying the critical events underlying possible future developments, the method helps to identify the contingencies of future profit potentials for proposed programs. Computerized runs of cross-impact matrices establish better estimates of the probability of occurrence of individual events, facilitate tests of the most effective responses under various circumstances, and point to the key events to be monitored for future planning.

Limits and Cautions

Cross-impact analyses cannot allow for events not included in the matrix.

Therefore defective or inadequate models of interacting elements can yield misleading results. Two other problems are evident. First, assignment of probabilities of interactions are subject to much uncertainty, especially in areas whose origin and anatomy are not clear. Examples include such "soft" trends as alienation, changing priorities and values, political disruption, or crime. Second, as pointed out by Bright, "use of one forecast at a time as 'true' is clearly erroneous, since the future results from the interactions of a number of events, some simultaneous and others very early. These events, coming in clusters, often must create a very different impact on other future events than the impact from events taken individually."

Other Techniques

Intuitively, participants in brainstorming, scenario writing, and Delphi forecasting make use of cross-impact analysis, although not necessarily in a focussed or systematic fashion. The technique is used as part of such forecasting methods as feedback analysis and relevance trees. It is a central element in interactive simulation techniques of forecasting, such as Forrester type dynamic models or KSIM.

Procedures

In the usual procedure the first step is to construct a matrix consisting of the events or items to be cross-impacted. This can be done in a variety of ways. A symmetrical matrix with identical items along both axes is perhaps most commonly used. The specific event or development is then assumed to occur. Its nature, mode, timing, etc., are specified. One then specifically inquires

what the impacts of this development would be on all the other items of the matrix. At a minimum estimates are made of the influence of the first event on the probability, timing, and impact of the other items in the matrix. In some cases mini-scenarios of the interactions between two items are prepared. Usually, experts are used to make the cross-impact assessments. Simple matrices can be done by hand; elaborate matrices require computerization.

Products or Results

The core output is a table or series of tables showing interactions among items. Major studies may include numerous computer runs showing one-to-one interactions using a variety of assumptions; primary, secondary, and tertiary levels of impact; interactions among clusters of events (aggregated forecasts) or among subdivided events (decomposed forecasts). Very often interactions identified on a matrix are strung together on a time basis to create a scenario.

Results can be qualitative, quantitative, or both. They can be gross or detailed and fairly certain or highly speculative. They can cover any time span. Credibility of results will range from high to doubtful depending on the qualifications of the judges and the nature of the material being cross-impacted.

Resources

The most crucial resource is imaginative people knowledgable in the field being cross-impacted. This is a difficult combination to find in many areas of engineering and science so it is often wise to leaven the judgment of experts with that of people of sound and imaginative judgment although not expert in the field.

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Cross-impacting is difficult and demanding work. Computerized assistance is essential if complex simultaneous interaction must be considered.

Requirements of time and money depend wholly on the nature of the problem.

Comment

Cross-impact analysis is a basic forecasting tool helpful if not essential in most sophisticated forecasting. Every forecaster dealing with interacting trends should have an appreciation of the principles involved.

KSIM

Abstract

KSIM is a cross-impact simulation technique used to aid planners
to better forecast and assess long-range requirements and impacts of
water resource development alternatives. The technique provides a tool
to interface broad planning issues with detailed dynamic modeling need
so that more effective use can be made of planning resources. In addition,
the technique contributes a potentially valuable needs identification pro-
cedure to overall planning for such programs as urban studies. KSIM com-
bines a small group workshop procedure with a mathematical forecasting
model and a computer program to generate changes over time in a few signi-
ficant planning variables.

Definition and Description

KSIM presents a mathematical means of articulating and visualizing what
people sense to be the relationships among a number of interacting vari-
ables. As a simulation tool, it combines expert opinions with analytical
computing techniques to analyze realtionships among broadly defined vari-
ables in socio-economic systems. The technique enables a team of people,
first, to define and structure a set of variables describing a perceived
problem and then, using an interactive computer program, to calculate and
display the changes in the variables over tire. By observing the changes
and then making modifications and refinements, the team develops a model
of the problem situation. With the model individuals can test various
alternatives and review and improve their understanding of the problem.

Underlying Rationale and Assumptions

Like all simulations, KSIM seeks to establish if-then relationships;
however, KSIM has the distinctive feature of accommodation subjective or

intuitive concepts as well as quantitative data. The mathematical formulation encompasses two concepts that are particularly relevant in modeling human or social systems. The first is that all variables are bounded, and the second is the idea of S-shaped growth curves. For example, when discussing the population capacity of the United States, we are aware of an upper and lower bound. There is not an infinite number of people. Rather there is some limit or upper bound within the context of one's thinking. If the maximum population capacity of the United States is estimated at 500 million people, then 500 million is set equal to the upper bound and no people would represent the minimum value or lower bound.

Nonlinear growth curves are characteristic of human systems. There is no reason why human physical growth rates near birth should be comparable to growth rates near maturation. The same is true of social institutions. The equations used in this procedure gives a S-shaped curve that has been shown to be realistic for biological systems, and is also observed in social, political, and economic institutions. While it is extremely useful to begin with this growth curve, perturbations are easily incorporated into the KSIM methodology. Thus, planners who feel confident of specific growth trends can be accommodated.

History, Including Previous Applications

KSIM was developed in the early 1970's by Dr. Julius Kane on the premise that, "it is the 'soft data'—value judgements, opinions, cherished notions— that control the dynamics of the political machine. If computers are to be effective instruments of policy, they they must have open channels that can accept subjective data and give it its proper role." Although the technique is quite new there have been a number of applications. These include:

New Ventures or products—Pilkington Brothers LDT., England

Impact assessment workshops—Institute for Water Resources

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Environmental Planning--Departments of Environment and
and Industrial Trade, Canada

Educational tool for systems analysis: UBC, Portland State
University

Water Resource Planning--Corps of Engineers.

Main Uses

KSIM is a useful problem formulation, needs identification and
communication tool. It allows planners to understand system structure,
relate quantitative and qualitative factors, and directly communicate
their perceived outcome of proposed planning interventions. Corps planners
can use KSIM to study the implications of changes that can result from the
interaction of system variables or from implementation of an alternative
solution for water resource planning. It can also be an effective proce-
dure for incorporating community or expert opinion into water resource
planning.

Limits and Cautions

The simulation does not tell planners what alternative solution to
choose. Rather, it is an information and display device by which major
issues, needs and concerns emerge. The procedure is designed to handle
broad scope variables and may only be applicable in the early stages of
Corps planning. The procedure requires a skilled leader and special caution
should be exercised in attempting to translate human intuition into a mathe-
matical technique.

Other Techniques for Doing the Same Job

KSIM is a blend of many techniques, thus, depending on the situation,
planners may gainfully employ: brainstorming, authority forecasting, work-
shops, or delphi for expert opinion; cross-impact analysis or input-output
analysis for interactions or feedback analysis; dynamic modeling for simula-
tion and alternative futures for assessing the outcome of projects under various
conditions.

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Procedure

While the procedure should be designed to accommodate the situation, the basic requirements are to 1) formulate the problem, 2) identify the variables, 3) develop the connections between the variables, 4) refine the model, and 5) analyze the effects of imposed planning interventions.

Product or Results

Ideally the product of a KSIM simulation is a working model of the problem. The model is used to test planning options by exploring how a range of likely futures may shape a plan and/or by examining how various changes, such as in public preferences, could affect plans. The output appears either as column of numerical forecasts or graphics illustrating the changes of significant variables over time.

Level of Detail of Results

KSIM deals with aggregrate variables (6-12) and structural relationships and does not give precise numerical answers. Output values for all variables range between zero and one.

Level of Confidence of Results

The model reflects the experience and judgements of the team members. While the results may be limited by the availability of "hard data," the confidence in results is usually determined by the level of confidence placed in the participants.

Communicability of Results

Results from a KSIM exercise are generally straightforward and easy to communicate. The cross-impact matrix clearly illustrates the relationships between all variables and output for various alternatives can be readily displayed and compared.

Credibility of Results to Critics

When presented as the teams perception of the existing situation and changes due to planning, the results are generally accepted. However, the KSIM technique is fairly new and has not undergone extensive testing. Thus, its credibility as a forecasting technique has yet to be established.

Span of Forecasts

The procedure is designed to accomodate both short term and long term relationships. However, since the concepts usually involve broad first stage planning objectives, long-term (30 to 50 years) forecast are the most common.

Resources Needed

Resources include a leader, participants and access to a computer. As was mentioned earlier, an experienced coordinator is required to lead a formal KSIM workshop. Thus, while a workshop can be completed in less than a week, there is a requirement to either hire a leader or learn the procedure. It is estimated that learning the subleties of KSIM could take anywhere from a few days to several months depending upon the background of the potential leader. Participants should be experts in their designated fields, but need no experience in mathematics, modeling or systems analysis. The KSIM computer program is available on line or batch via IWR or the Waterways Experiment Station at Vicksburg. Output costs are estimated at approximately one dollar per run but vary depending on the computer system employed.

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INPUT-OUTPUT ANALYSIS

Abstract

Input-output analysis is a means of interrelating industry inputs and outputs in a single model showing the consequences to all other sectors of a specified change in one. Different models deal with the nation, with regions, with specific industries, etc. I-O analyses are of great value in quantifying changes in a region's or subregion's commodity flows and likely industrialization patterns resulting from specific projects--such as improved navigational facilities or a new recreational site. Principal problems to its use include lack of detail in coverage in I-O matrices, out-of-date data, and high cost of developing specialty I-O tables.

Definition

Input-output refers to the flow of goods and services among industries during the process of manufacture and then to final users (or GNP). An example of the flow among industries is that of the output from the iron and steel manufacturing industry through the fabricated metal products industry to the motor vehicles and equipment industry. An example of the flow to final users is that of finished automobiles and trucks from the motor vehicles and equipment industry to individuals, businesses, and government agencies.

Specifically, an "input" refers to the value of the goods or services purchased by industry A from industry B, or from another industry, to enable industry A to make its own products or services. The value added by industry A is also one of its inputs. "Output" is the total value of all of the goods and services which are produced by industry A to sell to other industries or to final users.

Input-Output tables are devices customarily used to develop and to show graphically the flow of goods and services among industries and among industries and final users. I-O tables may be constructed to show this movement either for all industries and final users or for a selected group of industries and final users. An I-O table may show the flow of goods and services within a metropolitan area, state, a non-political region such as a watershed, a country, or even a group of countries. It customarily includes all of the transactions or flows of goods and services which occur, or are expected to occur, in a particular year. I-O tables are usually produced in each of three different forms: one covering dollar transactions; one direct requirements; and one, total requirements.

Input-output analysis is the use of input-output tables and projections to assist in tracing, predicting, or evaluating the effect on a particular industry or region of changes in the demand for goods and services by final users and by other industries. Many I-O tables have been computerized to make it easier to insert desired changes.

History

Interindustry input-output (I-O) analysis received its original impetus from Wassily W. Leontief, who published the first national I-O table in 1937. Growth was slow until the postwar period, when tables were developed as a guide to economic reconstruction by a number of European countries, including Norway, the Netherlands, and Italy. During the past fifteen years many national I-O tables have been developed for studying and projecting economic growth patterns and the potential impact of major policy moves. Over sixty countries now have one of some kind, and a single integrated table has been published for the European Common Market. In addition, a number of regional I-O tables have been developed for individual states, multistate regions, major watersheds, and metropolitan areas. The most recent national I-O table for the U.S. was published by the Department of Commerce in 1974.

A variety of individual firms and research organizations have also developed I-O matrices for numerous specialty purposes. It is apparent that the development and use of I-O tables will continue, as they give an overall interconnected view of the industries of a country or a region which no other technique can rival.

Main Uses

The Corps of Engineers would probably use I-O primarily for study of changes in regional and subregional commodity flows and industrialization patterns resulting from specified Corps projects. For this purpose the technique has unique capabilities.

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I-O analysis is extensively used by (particularly large-sized) businesses for market analysis, sales and market forecasting, capital investment planning, diversification planning, planning operations overseas, employment planning, purchasing planning, and planning exports and imports. Several of these uses may be of interest to the Corps for internal planning.

I-O is, of course, also used at state and federal levels of government to generate basic economic information required in a host of policy decisions.

Limits and Cautions

Two basic cautions must be observed in using I-O analyses.

First, data for I-O tables are usually fairly old. For example, the national industry table issued late in 1969 used information collected in 1963. The 1974 update employs 1967 data. On the average, tables reflect industry flows and technologies of about eight years earlier. This is a serious deficiency since the economy and technology is far from static. To remedy the situation some analysts have attempted to update old data by estimating new technical coefficients relating sectors of the economy.

Second, data often are not fine enough for all the analyses one might wish to make. The 1969 national table covers 367 industrial sectors. Enormous as this is, there is often need for specific data on regions and localities and for non-industry categories. Resort may be had to

specialty tables developed by private organizations. These sometimes are
more directly pertinent, but unfortunately they often employ data and
coefficients of questionable validity.

Other Techniques

I-O is clearly superior to other cross-impact and relevance techniques
for measuring many kinds of inter-industry relationships. No other method
attempts to compete in I-O's specialty domains.

Procedures

A rough idea of what is involved in updating or projecting a table may
be had from a brief account of some of the major steps involved in updating
the U.S. I-O table from 1974. These included:

o A complete update or projection of GNP components for the update

   year or the starting and ending years of the projection, sub-

   divided into columns (sectors) of roughly eighty categories,

   and conversion of these to the industry categories in the I-O

   table in terms of producer prices, rather than purchaser prices.

o A complete update or projection of the gross output of each

   of the eighty industries.

o Selective change of coefficients to reflect changes in tech-

   nology, in the product-mix of each industry, in consumer taste,

   and in the relative abundance of different inputs. Expert

   industry know-how and forecasting ability are essential for

   this is probably the hardest part of the whole job.

o   Rebalancing the whole table to reflect a harmonious blend of

coefficient changes and projected or known sector totals for

industry output and final demand categories. This should be

done by experts who are fully cognizant of the strengths and

weaknesses of the various ways of doing it, such as the RAS

(Richard Stone) method, the SCM (C. B. Tilanus) method, or the

purely iterative method. All methods, of course, require

extensive judgment and recalculation. In addition, the cal-

culations must be programmed for and run on a high speed computer

to avoid high time costs.

The upshot is that construction of new I-O tables or updating of old

is extraordinarily expensive. The use of existing tables, in contrast,

is straightforward and does not require high levels of expertise.

Product or Result

An I-O table consists of a matrix with identical industry (or other)

categories on each side. In each cell appears a number (a coefficient)

which indicates the relationship of the industry sector identified on one

axis of the matrix to the sector on the other axis. In toto, the matrix

defines interrelationships among all sectors treated in the table. Different

tables reflect dollar flows, direct inter-industry requirements, and total

requirements.

Level of Detail of Results

This has been discussed under "Limits and Cautions."

Level of Confidence in Results

An I-O table projection can be no better than the individual forecasts
of final demand (GNP) and the industry inputcoefficients which are combined
to make it up. Confidence in these matters depends largely on one's
expectations and grasp of what is and is not included. Use of automated
data reduces confidence. Nevertheless, there is widespread agreement that
I-O relationships warrant more confidence than those derived in other ways.

Communicability of Results

In a technical sense, communicability is very low. Results are usually
presented in technical, mathematical form and reflect great numbers of
assumptions hidden even from scholars. (Roots and bases of the forecasts
used in developing tables are rarely understood in detail.)

In a general sense, the concept of levels of interdependence among
industries is easy to grasp.

Span of Forecasts

I-O is usually used for short-to medium-range forecasts. Although it
could be used for long-range forecasting, it is not uniquely adapted for
that purpose.

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Resources

Given a suitable I-O table, much analytical work can be done with it by personnel of minimum training without an excessive expenditure of time.

The situation is very different if a more specialized table must be devised or if an old table must be updated. Cost and time requirements exceed the capabilities of all but large organizations. Generally, it is best to pay a qualified consulting firm to develop the information if it is determined that the cost of a new table is warranted.

Access to a high speed computer is a must for 1-O analysis.

OPTIMIZING TECHNIQUES

Abstract

Most predictions can be viewed as a description of how scarce resources
are allocated over time. Optimizing techniques are one way of describing
such allocations. More specifically, optimizing techniques can be used to
select, from the various alternatives, a program for allocating resources
that optimize some numerical measure taken as a surrogate for a decision-
maker's goals. The program selected constitutes a prediction of how resources
would be used if the decision-maker were to achieve the goals, set forth by
the measure, with optimal use of the available resources. By suitable varia-
tion of the measure, it is possible to study a wide range of alternative
allocations, and hence, of alternative futures. A broad variety of applicable
optimizing techniques are available and, subject to certain qualifications,
can be used to make predictions about a large number of subjects.

Definition

Optimization is one way of determining how scarce resources might be
allocated over time. Most predictions can be viewed as a description of how
scarce resources will be allocated over time. Typical examples of questions
requiring prediction are: will the rain-god smile on my crops; will there be
enough money for the dam; and how will we divide available resources for future
energy development?

In this approach, a single real quantity (objective function), summarizing
the result of some program for allocating scarce resources over time, is iso-
lated and optimized (i.e., either maximized or minimized, depending on the
situation). The optimum is achieved by proper selection among alternat⋯
that do not require more than the available resources and do meet the ⋯
constraints. In the present context, the selected program constitu⋯ a
prediction of (1) what resources would be used, and (2) when they would be

applied, if the decision-maker's goals were precisely described by the
objective function. The best known example of this kind of approach is
in the field of economics, where it is frequently assumed that the entre-
preneur seeks to maximize his profits by allocating his scarce resources
(capital, equipment, management skills, wasting resources, etc.) in the best
possible manner over time.

History

The utility of optimization was formally recognized during World War II
when scientists were striving to achieve performance measures for physical
principles and designing or explaining technical weapon systems.

The results were extremely successful and by the early 1950's, the tech-
niques had been successfully applied to problems such as the construction of
an optimum stock portfolio. Moreover, the concepts were supported by pro-
fessional societies, such as the Operations Research Society and the Insti-
tute of Management Science, and supporting analytical tools such as linear
programming were developed. Today, optimization techniques are incorporated
in undergraduate and graduate curriculum and probably are familiar to most
engineering graduates.

Main Uses

Optimization techniques have been applied (with varying degrees of
success) to a broad spectrum of problems ranging from sophisticated hard-
ware to complex social systems. In the present context, their main function
would appear to be the prediction of resource use and timing associated with
the pursuit of some normative goal. Optimization techniques have been used
in cost/benefit analysis and in most forms of engineering economics. However,
for better or worse, the field still contains a number of yet-to-be-tried
opportunities.

Limits and Cautions

This approach has the obvious advantage of simplicity, preciseness, elegance, and a formalism that frequently leads to new insights. It also has obvious limitations, due to the fact that not all, and perhaps only a few, real-world problems can be defined in terms of single, mathematically tractable, function whose optimum value represents the best of all possible worlds. Also, its practitioners and their clients must be alert for two undesirable tendencies. The first of these is either to "study a problem to death" or to make an elaborate formulation where a simple rule-of-thumb may do just as well. The second is to become attached to a particular approach, so that the practitioner becomes a "solution" looking for a problem. However, optimization techniques, properly used, offer a broad range of opportunities for the mathematically inclined.

Other Techniques

A small but growing minority of practitioners in this field have begun to question the idea that the rigor adopted from such fields as physics and mathematics can only be applied under the rubric of optimization. Simulation seems to be the most frequently used alternative. A number of other approaches, including hierarchical selection, behavioral (satisfying) approaches, interactive multi-goal analysis, and efficient multi-criteria techniques, have all been suggested and, in a few cases, applied.

Procedures

A large number of techniques have been invented and described in the literature, and some general models with well-defiend characteristics have been created. The most important, for the purposes of this review, are capital budgeting models, R & D project selection models, and linear programming adaptations of input/output data.

Almost all useful optimizing models require interaction between the analysts and the decision-maker and/or members of his staff. Such

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interactions are necessary in order to define objectives, viable alternatives for achieving the objectives, and resource and time constraints. With this information, the analyst creates either a deterministic or stochastic mathematical abstraction which attempts to model the real world.

Once a model has been agreed on, the analyst uses mathematical analysis to obtain an optimum solution. In a certain sense, the optimum value is of less interest than the program, i.e., the amount and timing of resource allocations, designed to produce the optimum. This is because the uncertainties associated with real-world problems make achievement of the predicted optimum highly unlikely. Consequently, a robust solution, i.e., one which will produce nearly the same result over a broad range of conditions, is frequently sought. To study this part of the problem, the analysts often perform sensitivity and post-optimality analysis. Computation procedures for producing the latter kind of data are sometimes included in some of the more common mathematical techniques, linear programming being a case in point.

Product

Ideally, the result of the analysis is a robust program designed to achieve the objectives of the decision-maker. For management, one of the more rewarding aspects of the model-making process is the new insight on virtually all phases of the operation being modeled. There are some people who argue that these insights are the principal rewards of the attempt to optimize. In effect, the program predicts the amount and timing of the resource expenditures that would be made by a decision-maker pursuing the objectives set up in the model. By considering the objectives and constraints affecting the various types of decision-makers, it is possible to obtain information on how resources will be used under a wide variety of alternative futures.

A wide range of detail is possible. Since the models are usually computerized, sensitivity or other analysis are readily performed. If the model is stochastic, then confidence limits are usually available. On the hand, the stochastic models are less readily applied.

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Level of Confidence of Results

Since optimization techniques usually model complex and unique situations, it is frequently difficult to check the accuracy of the results. Since computer techniques are usually employed, a great deal of time should be spent to make certain that the results are not affected by programming bugs. Also, both decision-makers and/or their staffs, and analysts should make certain that all the assumptions built into the model are well understood.

On the other hand, the fact that the model represents an idealized situation frequently means that the results can serve as upper or lower bounds for the results estimated on the basis of more realistic but less rigorous approaches.

Communication of Results

In one sense, communication of results is excellent, since a good model should reflect the decision criteria or variables that are of most interest to the decision-maker. However, communication sometimes breaks down because, during the time spent on the construction of the model, the decision-maker, or his viewpoint, may change. Indeed, the latter effect can occur as a result of the insights gained by the decision-maker in his interactions with the analyst--and sometimes the effect of the insights does not become apparent until long after the analyst is committed to a now inappropriate optimization model. Even when both decision-maker and analyst have good communication, it sometimes happens that subsequent users fail to appreciate the assumption of the model and consequently apply or intercept the results incorrectly.

Span of Forecasts

In theory, the span of the forecast is only limited by the data. However, in practice, the probability that the decision-maker will (1) continue to follow the presumed optimum path, or (2) even perceive the concept represented by the objective function as being optimal, undoubtedly decreases with time.

Resources

Both the data required and its availability will vary with each problem. Some problems fit easily and naturally into the data structure of the organization asking the question. Other problems are never satisfactorily solved because of the lack of data.

In general, application of optimization techniques requires an operations research or systems analyst and frequently programmers, data aids, etc. Access to an appropriate computer system is usually necessary.

Time on the order of months and sometimes years and money for college-trained analysts must be provided, since a rather sophisticated abstraction of reality is being constructed (however, see the comments below).

Comments

Two points should be kept in mind in using optimization techniques. The first point is that the potential user must expect to spend a reasonable amount of time making certain that (1) the model is a reasonable representation of the problem of interest, and (2) that he understands the limitations engendered in abstracting a mathematically tractable model from reality. The second point is that development of optimization techniques involving complex representations and solution techniques should, in general, be avoided whenever possible. The amount of mutual understanding, customer satisfaction, and time and money saved are usually significantly greater if the study begins as simply as possible.

DECISION TREES

Abstract

Decision trees are one of the primary tools used in the field of Decision Analysis. Decision Analysis was developed by combining aspects of systems analysis and statistical decision theory in an effort to reveal how to be logical in complex, dynamic and uncertain situation. Decision trees provide a logical framework for balancing several considerations such as uncertair'y, preference, and long run implications. The tree permits mathematical modeling of the decision, computational implementation of the model, and quantitative evaluation of the various courses of action. (Matheson, Howard, 1968) While decision trees present logical paths toward decisions and may be a valuable learning tool for the developers, they are extremely complex and require a large commitment of time and resources.

Definition and Description

A decision tree represents the structure of all possible sequences of decisions and outcomes and provides for cost, value, and probability inputs. Such trees contain two types of nodes (decision nodes and chance nodes) and two types of branches (alternative branches and outcome branches). Emanating from each decision node is a set of alternative branches, each branch representing one of the alternatives available for selection at that point of decision. Each chance node is followed by a set of outcome branches, one branch for each outcome that may be achieved following that chance node. Probabilities of occurrence and values are assigned to each of these outcomes; costs are assigned to each decision alternative. (Matheson, Howard, 1968).

Underlying Rationale and Assumptions

Two fundamental operations, expectation and maximization, are used to determine the most economic decision from the tree. At each chance node, the expected profit is comput·d by summing the probabilities of each outcome,

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multiplied by the value of that outcome plus expected profit of the node
following that outcome. At each decision node, the expected profit of each
alternative is calculated as the expected profit of the following node less
the cost of the alternative. The optimum decision is found by maximization
of these values over the set of possible alternatives, i.e., by selecting
the alternative of highest expected profit. (Matheson, Howard, 1968)

History, Including Previous Applications

The concept of trees was developed in the early 1960s as a means of
evaluating the importance of technological needs and thus facilitating the
allocation of resources. Two early versions were those of Jestice and Esch
(Honeywell's PATTERN) and Linstone (RAND's General Purpose Forces Mission
Analysis). Decision trees have been employed to analyze new product intro-
duction and design for space program planning.

Main Uses

Trees are used mainly to evaluate alternatives and determine the se-
quences of decisions that should be used to pursue planning goals. Of
particular interest to Corps planners is the use of value assignments,
whereby they can specify values to be attached to the outcomes of a program.
"A value tree is simply a convenient way of showing how the total value of
the project is to be broken down into its component outcomes." Trees can be
valuable throughout the life of a project. Presumably, knowledge of the
costs, probabilities, and values will improve as the project progresses
and changes can be used in the decision process. Specifically, the tree
can be used to present the overall structure of a program and the factors
relevant to the project decisions.

Limits and Cautions to Its Use

Planners should be aware of the fact that trees are: complex, static
and unable to treat interactions, and inherently biased toward qualitative
needs. A characteristic of trees is their complexity. They are designed
on a hierarchy scheme and by the sixth level planners may well be faced with
several hundred primary systems. At the next level there are likely to

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be several thousand subsystems. Also, trees are static and do not deal with interactions which may produce counterintuitive effects of major significance. Possibly simulation and interaction models should be used in combination with the trees to check and recalculate values. "Moreover, trees are inherently weak in dealing with tradeoff situations, conflicting goals, and negative effects. (Linstone, 1975) The possibility that "more of the same" might satisfy a need as well as an innovative system is ignored. While this approach is understandable for some users, many Corps problems must deal with quantitative rather than qualitative deficiencies. Energy and food shortages, excessive pollution and the environment and allocation of resources are all problems because of quantitative inadequacies. There is another important caution with regard to the assignment of weights and probabilities. In dealing with concepts such as energy supply needs and environmental quality, the numbers assigned would be significantly different from the view point of different stakeholder groups. In fact, many Corps problems assume their particular form largely because different stakeholder groups perceive the goal priorities differently, and the subsequent conflict is part of what must be worked out.

Other Techniques for Doing the Same Job

Decision matrices and mission flow diagrams and various applications of pert charts may be used to lay out the critical paths and decision points in a planning project. To evaluate alternative solutions, planners may also look to the fields of systems analysis and operations research and employ such tools as simulation, optimization, linear programming, and alternative futures.

Procedure

Decision trees are the heart of the model in what is described as the decision analysis cycle. There are three sequential phases in the procedure: the deterministic phase, the probabilistic phase, and the informational phase. In each of these phases there is a modeling and analysis task. After

completion of these three phases a decision must be made to either ACT or GATHER NEW INFORMATION and repeat the cycle. The deterministic phase is essentially a systems analysis of the problem. The modeling involves bounding decisions, identifying alternatives, establishing outcomes, selecting variables and creating models of structure, value and preference. The analysis involves measuring sensitivity.

The probabilistic phase determines the uncertainty in value and worth. Modeling here involves encoding uncertainty and risk perference and the analysis involves measuring stochastic and risk sensitivity.

The fundamental idea in the informational phase is that of placing a monetary value on additional information. The analysis in this phase is a measure of economic sensitivity.

Product or Results

The final tree represents the logical flow of decisions and alternatives from origination to completion or realization of some prespecified goal. As was mentioned before, it can become a working document of a project illustrating the decisions and probabilities associated with alternative paths. Ideally, it can serve to focus attention on issues of major concern or provide a means of identifying areas of critical weaknesses. If the trees were not so complex and the procedure could be designed for lay people, then possibly the results from one stakeholder group could be compared to another group and a path of resolution achieved (maybe?)

Form of Output and Level of Detail

The output of a decision tree is a map that graphically illustrates the route between decision nodes and chance nodes to either success or failure terminal nodes. The state of the project at each node is specified and the expected profit, cash flow, and probability that the branch will be taken is also shown. These trees can be EXTREMELY detailed. The output from one project could easily paper any Corps office. However these complex trees can be

summarized into rather broad aggregate value trees showing how the total value of the project is to be broken down into its component outcomes.

Level of Confidence of Results

Confidence in this technique varies widely and is not necessarily related to the level of effort expended. On the other hand, as was stated earlier, trees present a static picture and cannot handle interactions. Decision theory is typically invoked where complexity, costs, risks, and potential benefits are large and/or critical. In such situations, heavy reliance may necessarily be placed on the methods used. Confidence levels are high IF the technology is sufficiently well identified, potential applications are available, and needs priorities for potential applications can be estimated.

Communicability of Results

Completion of a decision tree provides the visual aid to facilitate communication. Value trees can be prepared to summarize the overall results, while the detailed tree is available for those who wish to take the time to follow individual paths.

Credibility of Results to Critics

In instances where the tree is used to chart out alternative paths for a specific goal and where weights and probabilities are assigned from a unique viewpoint, namely the official stance of the controlling agency, the credibility is high and rests mainly upon the availability of data and the experience and knowledge of the developers. However, when the tree is utilized to focus on critical societal issues, there is apt to be a broad range of acceptability depending on the viewpoints of the stakeholders involved and how the tradeoffs concerning inequities and efficiency are handled.

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Span of Forecast

While the forecast horizon may be "dateless" (decision sequences considered apart from time intervals required for each item) or date by cumulative considerations apart from time interval estimate of times required to complete each step in sequence, the usual applications have been medium range forecasts (5 to 10 years).

Resources Needed to Use Technique

This technique requires a skilled, experienced leader, computational assistance (in terms of a computer program and access to a computer), and an experienced team of experts chosen for their skills in the various fields relevant to the problem under investigation. The development of any minimally useful output is relatively expensive requiring from several months to a year of effort and costing in the tens of thousands of dollars.

NORMEX FORECASTING

Abstract

Normex forecasting is so called because it combines normative forecasting (i.e., need or market-oriented) with exploratory forecasting (i.e., extrapolation of trends) to arrive at market forecasts said to be superior to results from either normative or exploratory approaches alone. At present, the method is applied chiefly to markets for technology-intensive products and survices. A major advantage of the technique is that it provides a measure of the uncertainty associated with the forecast. The method is costly to apply but its sophistication justifies the cost in many circumstances.

Definition

Because this approach applies exploratory (trend extrapolation) techniques to obtain a normative (that is, need or market-demand oriented) type of forecast, the technique is termed "normex." The central idea is to obtain improved estimates of future market demand for technology-intensive products by relating the characteristics of the marketplace to technological performance parameters. This relationship is expressed in mathematical terms.

The rationale of the method is that both technological and social-economic environments affect market demand. The usual extrapolations

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of advances in technological parameters affecting progress in a technical field occur in the context of a specific sociological and economic environment. Trends in both areas interact. Therefore, it makes sense to quantify this interaction as fully as possible into a "normex" forecast.

History

The technique was developed in the very late 1960s. Some areas to which it has been applied are jet engines and the computer memory market. The technique--especially with respect to its mathematical procedures--is still undergoing development.

Main Uses

To date normex forecasting appears to be confined to the area of future markets for high-technology products and services. However, the methodology is general and should be applicable to products whose sales depend primarily on other characteristics such as marketing, advertising budgets, production, and so on, provided that the product's sales are related to the correct parameters. Through its ability to forecast both the mean and variance associated with future technological performance parameters, the normex technique provides the capability for evaluating the level of undertainty associated with a forecast, and hence a measure of the extent of possible error is presented along with the forecast.

The principal advantages of the technique are as follows:

1. The results give an indication of the technical requirements
   for future product designs and can serve to establish goals

and priorities for future research programs necessary to achieve the technology requirements demanded by the market in a specified future time period.

2. The techique can indicate markut oriented trade-offs between technological performance parameters and can serve to indicate the desired interface between technological capability and market demand.

3. The normex technique produces an evaluation of both the mean and the variance of technological parameter forecasts and thereby provides a clear indication of the uncertainty associated with future forecasts.

Limits and Cautions

Normex forecasts are based on the assumption that currently existing trends will continue in the future. To the extent that this hypothesis is invalid, error will be introduced. Also, the normex technique is predicated on the assumption that there is a strong relationship between a product's sales potential and its technological performance parameters; that is, its application (within the context of its current formulation) is largely restricted to technologically intensive products.

In general, it would appear that forecast errors would be minimized by making a number of different individual forecasts utilizing many different analytical techniques applicable to the same time period and basing the final forecast on those forecasts having the greatest degree

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of internal consistency. It would appear that the normex technique would be most useful in this context; that is, it should serve as an adjunct to existing forecasting techniques to provide useful consistency checks.

Other Techniques

A similar but less sophisticated forecast could be derived by (1) making a forecast of technological developments in the conventional fashion, (2) forecast social, economic, and other market factors, using conventional techniques, and (3) do a cross-impact and sensitivity analysis between the two, thus, arriving at a "poor man's normex forecast."

Procedures

An outline of the five steps involved in making a normex forecast of jet engine characteristics reveals the basic procedures of the technique:

1. Historical data were assembled on annual world sales and on the technological performance characteristics of the products which contributed to annual sales.

2. For selected years, histograms were constructed of the frequency distributions of sales as functions of engine performance parameters.

3. For each of the above histograms, cumulative frequency plots were constructed on lognormal probability paper and the mean and standard deviation of the underlying normal distribution were estimated graphically.

4. Values of the mean and standard deviation of the underlying normal distributions as determined for the selected years were plotted versus time and extrapolated into the future. Similar plots were constructed of annual unit sales and were also extrapolated into the future.

5. Using the extrapolated values obtained above in Step 4, along with extrapolated values of future world sales obtained above in Step 1, frequency distributions of sales as a function of technological performance parameters were calculated utilizing Equation (3) for future years of interest.

Product or Result

Forecast conclusions are usually supported by large numbers of graphs showing historical and projected of components on which the forecast is based. Data are also provided on uncertainty on the forecast, usually in mathematical form. The basic forecasting model in a key product.

Level of Detail of Results

Results tend to be supported by detailed series. The end forecast itself is a lump-sum kind of product.

Level of Confidence

Problems affecting the level of confidence in normex results are cited in the "Limits and Cautions" section. Confidence levels necessarily depend greatly on the subject being forecast, its span in time, the richness of data on components, the perfection of fit between model and data, and other factors.

Communicability of Results

The methodology is distinctly technical and complex and requires an expert's knowledge of the field being forecast to be fully appreciated. The "lump-sum" forecast conclusion, on the other hand, is easily communicated.

Credibility of Results to Critics

The technique is sophisticated and, within acknowledged limits, is probably at least as credible to critics as competing techniques.

Span of Forecasts

From short to as far ahead as technological advance can reasonably be forecast. In new, fast-changing fields the outermost limits might be ten to fifteen years; for massive, slow-developing areas (e.g. rail or water transport) the time horizon may extend to fifty or more years.

Resources

Normex forecasting requires (1) experts in the technology under study, (2) input from economists, sociologists, and marketers familiar with use patterns of the product, (3) statisticians or mathematicians, and (4) people acquainted with the requirements of long range corporate planning so as to assure the forecast is framed in operationally useful forms.

In general, normex forecasting is expensive and time consuming, exact requirements depending on the topic under study.

POLICY CAPTURE

Abstract

Capturing the policy of an individual involves building a model which, given the same information the individual has, will accurately reproduce his judgments. The goal is not simply to predict or reproduce judgments accurately, rather policy capture seeks to generate some descriptions of the judgment behavior which are helpful in identifying characteristic differences between individuals. It is felt that the judgmental process can be described mathematically with a reasonable amount of success. The technique has greatest Corps application in the areas of public participation and evaluating the tradeoffs among various .s.

Definition

In general terms, capturing a person's judgment policy means constructing a mathematical description of that policy which can be used both to predict future judgments and understand them. From the viewpoint of social judgment theory, judgment assigns __weights__ to the various dimensions of the problem, assigns different __value functions__ to different dimensions of the problem, __organizes__ the information according to some principle, and does all this with a reasonable amount of cognitive control. (Hammond, 1974) The technique relies upon individual judgments and linear regression to compute explicitly the relative importance assigned to different variables (cues) in a problem based upon the assigned preferences for different solution scenarios for a problem.

Differences in judgment are a major source of conflict and misunderstanding. The best, and perhaps the only, way to obtain an accurate description of judgment policy is through an emperical analysis of actual

judgments. Mathematical analyses of judgments can exhibit and clarify the differing policies that are the causes of differing judgments. Showing people that conflict is the result of honest differences in judgment policy, rather than competing self interests, increases understanding and promotes conditions favorable to conflict reduction and management, if not conflict resolution. (Stewart, 1973)

History

Policy capturing technique was developed by Dr. Kenneth Hammond in the early 1970's at the Institute of Behavioral Science, University of Colorado, Boulder, Colorado. It is based on earlier concepts of judgment theory by Tolmen and Brunswik (1935).

Policy capture has been applied in the areas of the public sector for: policy analysis, government planning, citizen participation, community goals, and land use allocation. In the private sector, applications include: award of loans, forecasting interest rates, business promotions, and conflict resolution in labor management.

Main Uses

The procedures are flexible enough to be useful for a wide variety of problems. The analysis may be carried out in any desired degree of depth, from a limited study (i.e., allocation funds among five categories) to an extensive study involving a variety of procedures and objectives. The major contributions are that it externalizes the decision process, gives an objective basis for communication between decision-makers and provides a model for repetitive decisions. Policy capture can be an effective means of including both individual citizens and representatives from stakeholder groups into the planning process. It is an excellent public participation tool for it allows citizens to make judgments about combinations of goals and evaluate tradeoffs.

Limits and Cautions

There are three general cautions or pitfalls associated with policy capture procedure. First it is difficult to select appropriate cues and the form in which they are presented is very important. Second, due to time constraints, it is difficult to involve high level decision-makers. Those people involved must be interested (take it seriously), repeat the process several times and be properly guided. Finally, the use of linear regression has drawbacks for such analyses.

With respect to public participation, it is difficult to predict the "typical" member of an interest group since all members have different judgment policies. It must also be emphasized that to predict judgments is not to predict behavior. Judgments of citizens are important because they reflect values and beliefs about what should be. They also indicate public acceptance or rejection but they do not predict the consequences of alternative policies.

Procedure

The following procedure was designed to allow citizens to exercise their judgment about planning alternatives and provide useful information for planners. Six steps are required.

1. Define the problem area of interest.
2. Identify the important dimensions of the problem.
   Note: Be inclusive, citizens should participate, and describe in nontechnical terms.
3. Construct a number of alternatives each consisting of different combinations of levels of the dimensions - be realistic.
4. Obtain judgments of each alternative from a sample of citizens and from planners and elected officials.
5. Compute each person's weights and function forms for the dimensions through statistical analysis of judgments (multiple regression and and cluster analysis).
6. Use the information - discussion mechanism or for further analysis.

Product: or Results

Policy capture makes explicit the priorities and tradeoffs among goals. The technique can reveal the relative importance of community goals as well as the diversity of citizen views. It indicates what cues (dimensions) were actually used by the "decision-maker" and what importance (weight) was placed on the cues that were used. Precise calculation of the amount of increase in category X needed to exactly compensate for a given decrease in category Y is possible. Furthermore, the discovery of curvilinear function forms implies that tradeoffs would not be constant across all levels of spending. For example, the fact that tradeoffs among spending categories vary with levels of spending would almost certainly not emerge in public hearings or in written budget recommendations, y· this fact may be of great importance in making budget decisions. (Stewart, Gelberd, 1973)

Output: Form and Level of Detail

There are two types of results from a policy analysis; participant feedback graphics (illustrating weights and functions) and numerical computations from the regression and cluster analysis. The graphs indicate the relative importance of each dimension of the problem to the person in making his judgments. Large weights (in the form of bar charts) indicate a large effect on judgments of desirability. Small weights indicate relative indifference. Functions (illustrated as plots) show the form of the relationship between the information used to make judgments and the judgments.

Level of Confidence of Results

The predictive accuracy is extremely high. Mathematical policy capturing techniques can predict the judgments of the interest group members with an accuracy (correlation) ranging from 0.71 to 0.94 with a median of 0.81. Work by Stewart and Steinmann with consistency and reliability of the desirability judgments, indicates that the method is appropriate for a large proportion of interviewed people (sample size 173). (Stewart, Gelberd, 1973) Also, the results of a number of studies indicate that

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when "judges" are shown descriptions of the judgment policies of interest group members, in terms of weights and function forms, then their ability to predict the judgment of others increases dramatically. In short, it is felt that policy capturing procedures can be used effectively to increase understanding. (Hammond, 1971).

Communicability of Results

This information is in a precise numerical form which can be presented graphically, is easily understood, and can be used in further analysis. The relative importance of the various problem dimensions, and the trade-offs among them are made explicit. The analysis applies whether tradeoffs are constant or vary with levels of dimensions. This approach can result in a significant improvement in the quality and utility of citizen input. (Stewart, Gelberd, 1973)

Resources Needed

Besides an analyst or skilled user, the people requirements are: decision-makers who can make decisions (judgments) under various sets of conditions. The types of judgments are:

binary--yes or no/accept or reject
continuous--on some scale, e.g., 1-10 where 1 indicates very
       undersirable and 10 indicates very desirable, and
rank order

Computational backup is required to perform a multiple regression. More elaborate computer techniques are available and are discussed under dis-cussed under special comments.

Special Comments

The full potential of judgment policy capturing can be realized with
the aid of an interactive computer graphics device. Such a device makes
it possible to analyze the judgment policies of one or more people and to
display the results immediately. The terminals have been located in public
places (shopping centers, library, retirement homes, etc.) for citizens to
record their judgments and receive immediate feedback. The program operates
with an inexpensive, computer terminal linked by telephone to a large time-
sharing network. The program, and user manual, Policy II, are available for
Corps use.

GAMES

Abstract

A simulation game is an activity among two or more decisionmakers playing assigned roles seeking to achieve role-related objectives in some limiting context. Games as tools have grown out of military strategic planning (i.e., war games) to be applied in many other areas of decision-making. They facilitate learning about the subtle consequences of actions, the development of scenarios and the assessment of policy options. Games, like other models, are limited by their ability to be sufficiently inclusive. They can be expensive to develop and run. Unique skills are required to develop and manage games.

Definition

Games are a form of simulation in which a model of reality is created, decisions on action options are made by people playing specified roles, and the outcomes of the decisions are experienced. It is the role playing which distinguishes games most clearly from other forms of simulation (e.g., system dynamics). Games as simulation involve the intellectual process of model building but go beyond that to include action in the form of participation. Good decision-making games combine the analytical, rational, technical point of view with the intuitive, artistic, seat-of-the-pants experience of decision-making in the real world.

History

Serious use of games can be traced back to war games in which battle

situations were simulated not only to gain experience, but, equally important, to test new strategies and tactics. More recently (in the 1950s) strategic planners in both the State and Defense Departments began to develop and use games. The sixties saw games spread to use in education, all levels of public policy making, and even to business. Companies, like Similie II, have been started to develop such games.

Main Uses

Games find their main use as an educational tool, a scenario generator and as a policy evaluation device. While cognitive learning about policy situations is relatively easy to come by, the affective dimension--the feel for how it really is from a variety of points of view--is not so accessible. Games can be useful in providing this feel for the more subtle higher-order consequences of contemplated actions.

Through multiple iterations of a particular game one can devise alternative scenarios for the situation under study. This is done by modifying some of the variables (e.g., initial assumptions, timing, roles, etc.) on each of the runs.

Combining these two, one can evaluate alternatives in terms of their direct effects as seen through scenarios as well as the more subtle consequences as experienced from the perspective of a particular role.

Limits and Cautions

As with other forms of modeling, there is a very important caution to be aware of: no model is ever complete. Important factors must be left out.

Reality is much more complex than our ability to model it can match. In gaming this deficit sometimes takes the form of important actors being left out either through lack of awareness or lack of resources.

While games can be obtained that are already developed, policy making in particular situations usually calls for a unique game to be designed. This can be an expensive and time-consuming process. Ideally, the participants in a game will be those directly involved in the decisions to be made. Since a game often takes several days to play this, too, can be expensive. The usefulness of a game also depends on the ability of the participants to "act" a role. For some this can be a very difficult and uncomfortable experience. In this sense a game is also dependent on a high quality of interpersonal relationships and requires a skillful leader.

Procedures

As noted earlier, games can be obtained in packaged form (e.g., Walrus, Nexus, Neverland, Fedarism, Star Power, Simsoc, etc.). If no such game is suitable then one must be designed. This involves developing a model of the situation, including the key actors, determining the rules of play, and the methods of evaluation of results. Materials for the game must be prepared and the participants selected and usually given some advance preparation. The play of the game usually involves several rounds of play, each round simulating time in a compressed form (e.g., one round equals one year). The play often stretches out over several days. Finally the results must be evaluated.

Products or Results

There are three main results. First is the learning of the participants.
The second, more concrete outputs, are alternative scenarios of the development
of the simulated situation generated through the play of the game. These can
be viewed as forecasts of alternative outcomes. These forecasts include a
particularly useful dimension in that they usually incorporate the softer,
non-quantifiable variables. The third result is the actual evaluation of
alternative actions.

Resources Needed

Games can demand significant resources if properly carried out. The
designing of a game takes considerable time and unique skills--it may often
require an outside consultant. If high-level participants are involved in the
play of the game their time can be quite expensive. Managing the play of the
game usually requires a highly trained leader.

CONTEXTUAL MAPPING

Abstract

Contextual mapping is a technique for identifying plausible sequences of development in a given field, and for relating these sequences to potential further developments of particular interest. It has been used largely in technological forecasting applications, although it holds promise in other fields as well. The method is at least as useful for provoking imaginative yet systematic conjecture as it is for predicting actual future developments. Its use requires experienced experts familiar both with the method and with the topic of inquiry.

Definition

Contextual mapping was developed for technological forecasting purposes, and is still used largely in that field, although its use for societal, economic, and other forecasts has been suggested. The principle is simple, although its application is often difficult: Any given sequence of assumed technological development will make possible certain further developments. One therefore can specify any development sequence desired and, from it, try to discover what further developments would thereby be enabled and encouraged. Or--to apply the same principle the other way round--one can specify some future technological development of interest and, working backward, try to discover how many different sequences of preceding technological development could lead up to the development of interest. EXAMPLES: 1) One might specify one or more sequence of future developments in solid-state circuitry and, for each, explore what

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devices or systems might be invented or diffused on the basis of the new technological capabilities assumed. 2) One might specify some generally desirable features for a new high-speed ground transportation system. On the basis of those specifications, one could then try to estimate how many different sequences of RDT&E could enable the development of such a system.

The method assumes that current technological developments will evolve in foreseeable directions. It is assumed that logical, plausible new "clusters" of emerging technological capabilities can be foreseen. It is assumed that the uses to which new technological clusters might be put can be foreseen. It is assumed that future technology-responsive needs can be foreseen, and can be related to emergent sequences of technological developments. It is assumed that the preceding capacities can be seen far enough ahead in sufficient detail to make contextual mapping a profitable investment in support of research and product planning, capital budgeting, etc.

History

Jantsch informs us that RAND Corporation used the earliest versions of contextual mapping in the late 1940s to forecast the best engine-airframe combinations for U.S. strategic bombers of the 1950s and 1960s. Fairchild Semiconductor relied heavily on contextual mapping in timing its highly successful entry into the integrated circuits field. Many other specific applications, past and current, can be readily found in the literature.

Main Uses

As mentioned, contextual mapping has been used largely for technological

forecasting applications. Donald Pyke, however, reports that TRW has used a modified version of the approach for product planning purposes which considers many non-technological factors, including political,. social, cultural, ethical, and ecological considerations. TRW's multilevel map also is tied to a specific time horizon, whereas earlier versions have emphasized date-free sequential maps.

Limits and Cautions

Contextual mapping requires either that its use be limited to topics-- e.g., technological development--about which firm estimates can be made or that it be used only to provoke imaginative thought (not predictive forecasts relied upon for decisions). In either case, the technique requires experts well experienced in the topics at hand who also understand the strengths and limits of the method. In many cases, topic focus must be rather narrow in order to use the method within the limits of available time, manpower, and resources.

Other Techniques

Depending on the topic of interest, multiple-regression correlation of trend curves, scenarios of various sorts, and simulation models might yield comparable results.

Product or Result

The product is one or a series of graphic displays ("maps") depicting sequential events (with or without associated dates). The maps also may

indicate what further outcomes a given sequence might be expected to yield. Map data is tied to support documents showing data sources, assumptions made, calculations performed, etc.

Level of Detail of Results

Where extensive data and information is available about the current developments projected, logical inferences about future developments can plausibly be drawn in great detail. Where such data and information is lacking, details inferred should be regarded with extreme caution but may still be useful to stimulate imaginative conjecture.

Level of Confidence of Results

Confidence levels associated with this method are determined by the level of confidence placed in the intelligence, experience, and judgment of those who apply it. Selection of sequences, identification of potential further outcomes, timing estimates--every major facet of the method hinges on the caliber of judgmental decisions.

Communicability of Results

Where the topic is sufficiently narrow and only a few well-understood sequences are explored, results can be communicated effectively to persons having varied backgrounds and levels of training and experience. Where significant complexities must be assessed, sustained and concentrated attention is required to convey results, even between persons experienced in using the method.

Credibility of Results to Critics

If presented as a forecast of some possibilities, results from the method will generally be accepted as credible. If offered as a forecast of the most probable actualities, results are properly open to criticism, since a different set of judgmental decisions at critical points would yield substantially different results.

Span of Forecast

Typical time spans with this method vary between a few years and a few decades, largely dependent on the normal innovation cycle length in a given sector of activity.

Resources Needed

The principal resource required is one or more persons trained and experienced in the technique. Current state-of-the-art data and information is usually needed in some detail, and in typical applications is already available and need only be compiled. A few man-months to a few man-years for a period of many weeks to several months may be required to complete one mapping sequence.

RISK ANALYSIS

Abstract

Risk analysis uses probability and statistics to generate estimates about the risks of system failure when experience is insufficient to provide such estimates from experience. The method is particularly useful for systems such as space vehicles or nuclear power plants where the system must be made reliable without waiting for failure experience.

Definition

Risk analysis is the systematic consideration by probabilistic methods of component risks in large systems. By combining component risks in logical ways, an overall equivalent risk can be derived. Techniques used include "event trees" (alternative courses of events that can be triggered by an initial event) and "fault trees" (successive serial or parallel fault combinations leading to specific failures).

History

The early history of risk analysis started before World War II with the works of Von Neumann and Morgenstern on Game Theory and of Savage and others on Statistical Decision Theory. Numerous practical applications began to be developed during World War II in military operations research; and after the war, in such commercial fields as statistical quality control and electronic reliability. Fault tree analysis is more recent; it is an outgrowth of Bell Telephone Laboratory work on Minuteman developments during the 60's.

Most recently, risk analysis has been extended to environmental studies of ecosystems and to the estimation of hazards from large technological systems. For example, the 1974 "Rasmussen Report" to the Atomic Energy Commission on hazards from nuclear electric plants (and from other hazards, such as dam failures, airplane crashes, meteorite impacts, and toxic material spills) is based on very detailed fault tree analyses.

Main Uses

The main uses for this technique are for system implementation decisions for which inadequate data is available to assess the risks of failure. Risk analysis generates and interprates such data so that better estimates of risk can be derived. These estimates are then used as inputs for such decisions as: (a) should the system be implemented, or if already operating, should it be continued, (b) what safeguards are needed, and (c) what further information is needed in order to decide on implementation of the system or its safeguards?

To justify a full-fledged risk analysis, the system under review generally will involve extreme potential hazards, as in the case of nuclear power plants. Or it may be of a nature that requires high reliability for successful performance of its mission, as in aerospace applications. Or, finally, it may simply involve such expensive alternatives that the effort of formal analysis is considered worthwhile. For example, decisions about whether or not to pursue corporate lawsuits have used risk analysis methods.

The optimum benefits of risk analysis can be realized when the system under review has numerous components that are clearly identifiable and operate relatively independently. However, if the system is too large or interacts too extensively, the solution becomes impossibly complex.

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Data available should be good for the individual components so that
accurate fault trees can be structured, but data on operation of the
system as a whole will generally be inadequate or nonexistent. (If
·such overall experience data were available, it would be both cheaper
and more reliable to use than a risk analysis.)

Limits and Cautions

A risk analysis requires a great deal of detailed data about the
system being investigated, and this data must be integrated into a
logical, cohesive package that accurately reflects the cause-effect
relationships and interactions in the system. Even after a careful
risk analysis has been completed, a residual uncertainty always remains
about whether significant hazard paths may have been missed.

Furthermore, reasonably good data on both the probabilities and
the consequences of failure must be available for all of the significant
components of the system. "The analysis is only as strong as its weak-
est link."

Because component relationships are so crucial to the analysis,
only "one-time" systems, such as expendable space boosters or missiles
and "static" systems whose component relationships are stable (such as
river systems, power systems, or nuclear-electric plants), can be con-
veniently handled. "Dynamic" systems, such as urban development, military
forces, or investment portfolios, are not very amenable to risk analysis
methods; and even for static systems, correct assumptions have to be built
in about the degree of maintenance, system load, management skill, and
other quasi-dynamic considerations.

Also, component relationships must be expressible in logical terms,
which generally requires that outcomes be of an "either-or" nature rather
than cover a full spectrum of possible endpoints. This limits the rich-
ness of variation in deriving overall solutions.

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Finally, the overall risk outcomes must be expressible in terms of some simple set of outcomes, such as expected money loss or life loss. Risk analysis does not directly provide a very wide range of information on the total impacts of a particular risk.

Other techniques

Risk analysis differs from the more conventional techniques of actuarial analysis that are used in the insurance industry because it uses inductive methods to arrive at an overall risk on the basis of data about the constituent components; whereas, actuarial analysis uses deductive methods to determine individual risks from known comparable past experiences.

Both, of course, are closely related to the statistical decision theory and to statistics and probability in general. Risk analysis utilizes logical concepts from Boolean algebra and set theory to formulate event trees, fault trees, and decision trees. Its probabilistic models use concepts of statistical inference, both "Bayesian" (subjective) and "non-Bayesian" (objective), and of stochastic "random walks" to combine data.

"Failure analysis" is another closely associated technique used to examine questions of reliability, time before failure, etc., but without use of the event tree or failure tree model.

Procedures

The "tree" method of analysis requires that an "event tree" be constructed to show the course of events that can happen following a specific type of initial failure called the "initiating event". The possible failure of various protective devices or dependent components

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will thus form a branching network of possible accident sequences. A particular sequence is called an "event path".

A "fault tree" is constructed similarly, except that it uses a somewhat more complex logic to describe the probabilities of a given fault leading to various consequence types and severities.

Results

The result of "tree" analyses is in the form of a branching probability network, known as the "extensive" form. The extensive probabilities can be reduced to an equivalent single outcome or "normal" form. Equally important are to account for the necessary qualifications and assumptions surrounding the quantitative work.

Resources

The most distinctive requirement for risk analysis is to find experts with a sophisticated understanding of the logic, data needs, and limitations of the method so that the problem can be formulated in a meaningful yet feasible way. Technical experts, such as engineers, scientists, and operators of the system under review, are also necessary to assure that the event paths are realistic and as comprehensive as possible. From a practical standpoint, perhaps the most difficult inputs to find are detailed data on component failure rates and consequences. Risk analyses are often most vulnerable to criticism on the basis that their input probability estimates are too uncertain to be of value for analysis. A fourth required resource, easy to obtain in this computer age, is the calculating capability to carry through the laborious calculations of an extensive fault tree analysis. Standard computer programs are available for this task.

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Comment

Risk analysis is a natural extension of the engineering approach
to problem-solving, and has the advantages and disadvantages that can
be expected in that approach. The major advantage is that risk analysis
utilizes to the utmost the type of reliability data that may be available
on the components of a system. It combines such data in a logical and
formal manner to derive a quantitative conclusion about the reliability
of the overall system. Its major disadvantages are its dependence on
(a) reliable data about the components, and (b) the logic of its assump-
tions about component interrelationships and the operating environment
of the system. When these inputs are incomplete or incorrect, the over-
all credibility of the method becomes suspect.

MISSION FLOW DIAGRAMS

Abstract

Mission flow diagrams are a sophisticated, detailed, costly method of detailing how a given (usually large-scale) mission may best be accomplished. As such it is a planning and control technique rather more than a forecasting method. The approach is useful chiefly in situations where costs, risks, and difficulties of carrying out a mission can be fairly accurately assessed.

Definition

Mission flow diagramming is as much a planning and control method as it is a forecasting method. Using the method, one specifies in detail the mission to be accomplished. A sequence of functions or activities necessary to complete the mission is developed. For each function, a set of existing or attainable means is specified, singly or in various combinations. For each means or combinations of means listed, costs, risks, and difficultires are assessed. On the basis of this assessment, normative (goal-specific) forecasts are developed, showing what must be done by when if the mission specified is to be completed in the manner designated. EXAMPLE: Martino cites the example of planning a new airport-to-downtown ground transportation system.

The method assumes that the mission can be clearly specified, and that it can be carried out with resources which are or will be available as required. It is further assumed that all the most suitable means of performing the mission can be identified, and that the "best" (most cost-effective, for instance)

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combination of means can be identified by assessing costs, risks, and diffi-culties. Further, it is assumed that the knowledge and resources to develop selected means which do not yet exist will be adequate to develop those means before they are needed in performing the mission.

History

In its simplest form, this is an ancient method going back at least to when Sumerian armies planned their campaigns. In elaborated forms, mission flow diagrams evolved from World War II operations research and the rise of systems analysis in the 1940s, 1950s, and 1960s.

Main Uses

As its title suggests, the method was developed for and has been used largely by the military for many years. More recently, NASA and other large organizations executing complex, large-scale projects over large areas and long time intervals have made good use of such methods, including the Corps of Engineers.

Limits and Cautions

Mission flow diagramming is best used when the mission requires no innova-tion, the mission environment is stable, and the flow of resources is assured. When the environment is unstable or the mission planners rely on means asso-ciated with difficulties, uncertainties, or resources beyond their direct control, caution must be used in relying on the method's outputs.

Other Techniques

Mission flow diagramming might be regarded as the general name for a family of closely related methods, including CPM, PERT Charting, Decision Trees, etc.

Procedures

First the mission is specified. Then a systematic inventory is made of the functional sequence required to complete the mission. For each functional sequence an inventory of potential means is made. Any desired number of alternative combinations of means to complete the functional sequence are identified. Each combination is then assessed in terms of its costs, difficulties, risks, benefits, etc. Finally, one or a few combinations are selected for implementation, with one combination designated preferable and the others designated as back-ups.

Product or Result

The product is a series of flow graphics identifying the functional sequence required to complete the mission. For each sequence, other charts and supporting data describe and assess one or more alternative combination of means which could be used to complete the sequence. Summary graphics and written data report general procedures followed, findings, recommendations and (ultimately) the course of action selected.

Level of Detail of Results

Because mission flow diagramming is used for project planning, management, and evaluation, extensive detailed data (often regularly updated) is usually

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essential and is provided.

Level of Confidence of Results

In most instances, mission flow diagramming will be used only if there
is confidence that the desired results can and will be attained. Used as a
normative forecast, the diagram represents anticipated results which are con-
fidently expected to be attained.

Communicability of Results

For persons acquainted with graphic flow communication methods, mission
flow diagramming conveys its results rapidly and efficiently, at whatever level
of detail is necessary. If the audience is unfamiliar with such methods,
mission flow diagramming may be obscure or even intimidating.

Credibility of Results to Critics

Because it involves typically more certain information and less uncertain
estimates than other forecasting methods--especially exploratory methods--
mission flow diagramming is relatively more credible than many other forecasting
methods.

Span of Forecasts

Forecast span is dependent on the scope and schedule of the mission
involved, and may range between a few weeks to several years. As a rule mission
flow forecasting does not extend to the long range.

Resources Needed

No special resources are needed which would be unavilable to managers of a typical project large and complex enough to justify the use of the method. Time and cost requirements are typically high, but the technique is generally used only for major projects where stakes also are high.

SCENARIO WRITING

Abstract

Scenario writing is best used to explore possible future conditions, given a set of assumptions. Scenario writing is not well suited either to the making or to the reporting of forecasts. The scenario is essentially the product of the yarn-spinner's art. For serious purposes, however, the assumptions on which the account is based are made explicit. Scenarios have enormous power to communicate the sense or feel of situations which do not and may never exist, a power which is at once an asset and a danger. In a sense, scenario writing is merely a softer version of the well-known modeling, simulation, and gaming methods.

Definition

Originally, scenario referred to the bare outlines of a script for a film or a stage play. As used currently, scenario also refers to an outline of what might happen, given a set of initial assumptions. Thus a scenario is the outline of one conceivable future state of affairs as seen from the perspective of certain assumptions. While scenario writing is the term in general use, perspective writing is an equally pertinent term if the word scenario is considered unclear or unacceptable.

Scenario writing assumes that the major forces or factors which will determine the future state of a given issue are known and can be specified. It also assumes that the author(s) of the scenario are competent to foresee which interactions among forces are most plausible and significant. So long

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as a scenario is NOT treated as a forecast, these assumptions are reasonable.
A scenario writer then becomes nothing more than a plausible yarn-spinner.
When the scenario IS treated as a forecast, there is little to support the
validity of the assumptions. History suggests that the future, more often
than not, will surprise us.

History

In the broad sense, stories about what will be hereafter are at least as
old as ancient religious writings. In modern times, such perspective narratives
as George Orwell's 1984 and Aldous Huxley's Brave New World have been powerful
influences on conjectures about possible futures. It is important to realize,
however, that a scenario may also be a set of numerical projections, based on
stated assumptions. EXAMPLE: The U.S. Economy--1995 might well be the title
of a scenario consisting of little more than tables of economic, financial,
and manufacturing data.

Main Uses

The most appropriate use of scenario writing is in the situation where
it is important to get a feel for what could happen, as opposed to a prediction
of what will or may happen. Assume that the Corps of Engineers is suddenly
abolished. How would the U.S. be the same and how would it be different ten,
twenty, thirty years hence? Often it is difficult to get into a society
depicted on the basis of a bare set of assumptions. One needs to play with
how the various assumptions relate to and affect each other. Scenario writing
is excellent in this application.

Limits and Cautions

As mentioned above, scenario writing can be misleading and counterproductive when it is employed or accepted as an account of the most probable future, rather than as an account of one plausible, conceivable future. Many people who need to know or are interested in knowing what the future will actually be like are too eager to impute an unwarranted confidence in a given scenario. If the yarn-spinner is a skilled craftsman, he may all too easily tap that "willing suspension of disbelief" which is familiar to us all when we read a good book, or view an engrossing film.

Other Techniques

The most appropriate use of scenario writing is to explore complex inter-relations among many factors. In that application, perspective writing is most closely related to cross-impact analysis, modeling, simulating, and gaming. In these, too, a major purpose is to learn by experiment, to see how and where and when one change results in other changes elsewhere.

Procedures

Scenario writing is much more an art or a craft than it is a standardized, systematic methodology. For that reason, procedure varies greatly from one application to another. It is fair to observe that scenarios typically are developed by one or at most by a few persons, rather than by large teams as may be the case in, say, survey research methodologies. It is also generally required that the scenario writing begin with a vague, overall image of the

situation he wishes to explore. On that basis the writer determines which assumptions he should make, and then selects the nature or the setting of his assumptions. Past that point, statements or components are drafted, reconciled with others, and redrafted, until the final scenario has been completed.

Product or Result

The result is a narrative which may be heavily text, largely numerical-graphic, or a judicious mixture of both. The extent of the scenario statement may range from a few paragraphs to multiple volumes.

A scenario--like a model--must be restricted to deal with only a very few components and interrelations out of many possibilities. The statement therefore typically contains rich detail with respect to the important inter-relations among the few components selected for treatment. Other components and details are often ignored or only touched upon in passing.

Level of Confidence of Results

As emphasized throughout in this discussion, scenarios are most appro-priately used to explore possibilities, and not to make or express predictions or forecasts. This being the case, the question of confidence in the result is restricted. The only substantive issue concerns whether or not the inter-relations described are truly the important ones, and whether they are both logically and plausibly dealt with in the statement.

Communicability of Results

In this regard, scenarios fare very well compared with other methods. Most people have a great deal experience reading stories, and thus are able

to deal easily with complex descriptions of hypothetical future conditions.

Credibility of Results

The issue here is a familiar one: How credible is this story? Placed in a literary context, we see at once that credibility of a scenario depends on a number of factors. There is the reader's familiarity with the subject matter. There is the writer's experience and level of craft. There are all the emotional values--accepting and hostile--which attach themselves to the story. Credibility in this case, in short, is largely in the eye of the beholder. It is for this reason among many others that a perspective statement's use is best limited to suggesting and exploring possibilities, rather than to estimate the probabilities.

Span of Forecasts

As already indicated, scenarios are not well suited to the making or reporting of forecasts. Setting that aside, they are readily adaptable to whatever future time-span interval may be needed. After all, narratives can be and have been written covering micro-seconds at one extreme and many aeons at the other.

Resources

The primary resources required here are those of the imaginative craftsman. The one or few people charged with developing a scenario need to immerse themselves in a rich fund of pertinent information. They need to accept for exploratory purposes a wide range of exotic and improbable possibilities. They need to be sensitive to complex and evasive interrelations, and they must have

the ability to set these forth clearly and compellingly. Ideally, the scenario

will incorporate and be based logically on a great deal of valid data about

the current state of pertinent matters.

SURPRISE-FREE AND CANONICAL PROJECTIONS

Abstract

These terms were introduced by Herman Kahn and Anthony Weiner in their 1967 book, The Year 2000. The concepts have long been used in statistical analysis. One selects a set of trends believed to describe or characterize an economy, a society, etc. For each trend, one finds and compiles a historic data base showing how the trend has varied within a range of values in the past. This range of variation is then projected into the future for some specified period. For selected future dates, one then examines the projected values for each trend, and tries to interpret or describe the state of the economy, etc., as it would be if the projections represented future actualities. Readers should be particularly careful to recognize that a projection is not a forecast, until and unless the forecaster argues and demonstrates that the projected state also represents the actually expected state.

Definition

A projection is an extension of one or more present trends to some future date. It is not necessarily a forecast, since a projection indicates merely what would be if present trends continue to develop at present rates. The forecaster can project a so-called Standard World by projecting, interrelating, and interpreting a set of trends. If he projects these trends according to his best expectations about how they will probably evolve,

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the result is a surprise-free projection. Sometimes, different expectations--or several combinations of the same expectations--seem to the forecaster to be equally probable. In this case, he can project each of these equally likely probability, referring to each set as a canonical projection, with his initial Standard World as his point of reference.

These approaches assume that the dominant trends of the present will also be the dominant trends at some future date. It is assumed that the rate and direction of trend evolution can be projected with acceptable accuracy. It is assumed that the Standard World is not necessarily a forecast of the actual future, so much as a point of reference indicating what the future as a direct extension of the present might be like. It is assumed that no major surprises, breakthroughs, or discontinuities need be considered. It is assumed that the primary alternative variations in trend developments can be identified and described.

History

These concepts were introduced and widely diffused by Herman Kahn and Anthony Weiner in their 1967 work, The Year 2000. Since then, these concepts have been used essentially unchanged in the thought and writings of many other futurists.

Main Uses

Properly used, the Standard World with its Surprise-Free and Canonical Variations are excellent frameworks for conjecture. The nature, direction, and extent of variation from present norms can be explored by contrast with this basic framework. Regretfully, too many forecast readers accept these projections as forecasts, a critical distinction which purveyors of futurist studies do not always make sufficiently clear.

Limits and Cautions

These were discussed above under "main uses."

Other Techniques

Essentially, Kahn-Weiner used conventional time-series analysis techniques. Trend lines or trend curves can be fitted to a set of data points by any of many methods. Further, any of many methods may be used to delimit the boundaries of the plotted space within which individual data points or the trend curve as a whole is fitted. Which techniques are appropriate and applicable depends upon the phenomena studied, the amount and quality of historic data available, the degree of exactitude required, etc.

Procedures

Details can be quite elaborate. In concept, one selects the phenomena to be plotted, collects historic time-series data, selects and applies one or more curve-fitting procedures, and interprets the results on the basis of some set of basic premises.

Product or Result

In barest form, the product is a set of curves describing the past and projected variation of some phenomena through a range of possible values. In fact, these curves usually are accompanied by extensive explanatory and interpretive narratives.

Level of Detail of Results

The level of detail is essentially dependent on the level of detail reported by the data used in trend-fitting. As used by Kahn-Weiner and many others, these projections tend to deal with macro-phenomena--national population growth rates, GNP, etc.

Level of Confidence of Results

Confidence in trend projections is determined by two factors: (1) the extent and quality of historic data used for projection; (2) fundamental assumptions about the stability or instability of change rates for a given phenomena. If a forecaster and his audience believe that the data base is extensive and reliable and that current change rates will persist indefinitely, then there will be great confidence in the projections as forecasts. To the extent that there is less confidence in either or both of these factors, confidence in the relation of the projections to forecasts will decline, even though in all cases the projections as projections may be equally valid, within the limits of the data provided.

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Communicability of Results

Graphic trend projections are in most cases an effective way to convey the sense of an extensive array of complex data. To interpret the projections and to convey that interpretation clearly can be extremely difficult (see next item).

Credibility of Results to Critics

Projections of present trends into the future are most acceptable to those who are relatively satisfied with the present, and least acceptable to those who wish to change the status quo. Since projections, as projections, can quickly be shown not to be forecasts—they show what would be the case if there are no fundamental changes—critics attack projections as deceptive or irrelevant while defenders argue that it is the critics who must demonstrate why present trends will not persist.

Span of Forecasts

The credible span of a forecast project is determined by the period of history for which past data is provided. The longer a time series is, the more certainly its range of variation can be estimated, and so the more statistically valid is its projection into the more distant future.

Resources Needed

One requires a clear definition of what is to be projected, and a reliable, valid source of data which can be shown to relate to the forecast topic. In most cases, surprise-free projections and canonical variations

assemble and interpret extant data--e.g., population statistics. If historic research must be done to establish data point, the effort can become prohibitively expensive and subject to severe methodological criticism. Even when existing data is used, compilation and intensive analysis of large data bases may be too costly to contemplate.

Comments

The reader should not be misled by jargon. Surprise-free projections and canonical projections are colorful words which describe long-used procedures in conventional statistical analysis.

MORPHOLOGICAL ANALYSIS

Abstract

Morphological analysis is designed to examine all possible solutions to a specified problem by juxtaposing the elements of the situation in every combination. It is, in a sense, a comprehensive and systematic type of cross-impact analysis. The approach has been used most in solving technological problems. Recently, however, the method has proved excellent for projecting alternative futures for a nation, industry, region, area, etc., under a variety of explicit assumptions. It is not primarily a method of forecasting, but is superior to any other method for examining "fans of futures," he comparative likelihood that they will come to pass, and the specific assumptions that underlie their existence.

Definition

Morphological analysis is a technique for systematically exploring all possibilities within a system. The basic principle involves identification of the sectors of a system (e.g., for an internal combustion engine, sectors would include fuel, materials of construction, operating atmosphere, etc.) and all factors or variants within each sector (e.g., factors within the fuel sector would include wood, gasoline, gas, oil, coal, electricity, nuclear energy, etc.). Sectors and factors represent the morphology or taxonomy of the system. These morphological components are next arrayed in a matrix and all possible combinations are considered

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(e.g., wood fuel with all possible materials of construction and all possible operative atmospheres, etc.; this is repeated for all other fuels, etc.). The purpose, of course, is to uncover useful workable combinations that might be overlooked in a less systematic approach.

History

In recent times the morphological method was developed by the late Fritz Zwicky, a Swiss astronomer who taught at California Institute of Technology and did much of his work at Mount Wilson and Mount Palomar. Zwicky used morphological analysis as long ago as 1942 when he was temporarily engaged in rocket research. In 1961 he established a Society for Morphological Research in Pasadena with himself as president. Zwicky has published a number of books describing the method.

Although formalized by Zwicky, the method is actually ancient. A mystic Majorcan monk named Ramon Lull devised a "Great Art" diagram in the late 1200s which employed the technique to solve all problems of philosophy and met aphysics. Lull's work was handicapped by lack of a computer. Descartes and Leibnitz consciously used Lull's technique, as did the Jesuit Kircher, inventor of the magic lantern.

Its use in generating a systematic array of alternative futures--that is, its use in social forecasting--dates from the late 1960s when a group at Stanford Research Institute used the method to develop what they called the "field anomaly relaxation method" (FARM) of projecting alternative futures.

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Main Uses

Morphological analysis is used when comprehensive coverage of an area is desired. It is especially helpful in much-worked areas (like internal combustion engines) because it forces consideration of combinations of elements in a non-traditional context.

In social forecasting, the method is used for generating scenarios of probable, plausible, possible, and very unlikely futures. It is better adapted to projecting possible lines of development than to forecasting per se. It is a method for exploring possibilities, not for forecasting what will happen. A particular virtue of the method is that it facilitates exploration of societal consequences of specific assumptions (e.g., what happens to a region with and without a specified type of waterway). Basically, the technique is a macro cross-impact device since it specifically requires consideration of interactions among sectors and factors. It can be applied in the same ways cross-impact analysis is applied.

In other fields the method has been used to seek out fresh solutions to problems in jet engine design, astronomical problems, transportation systems, warhead developments, communication systems, and even "planetary engineering."

Limits and Cautions

The successful use of morphological analysis requires that its user be able to judge what "new" combination of factors are worth probing more deeply. Clearly this is a severe limitation because the essence of blocks

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to many new ideas is incorrect acceptance of the idea that "it won't work."
Similarly, the scenario writer may incorrectly discard a line of social
evolution on grounds that "it doesn't make sense."

Leibnitz and Descartes were concerned that morphological approaches
might lead to mechanization of thought. Jonathan Swift expressed this
limit when he described a contrivance invented by a savant of Laputa that
randomly combines letters, in this way "permitting the most ignorant
person to write books without the least help of genius or study."

A worse problem is that morphological matrices give rise to astro-
nomical numbers of combinations. A simple morphological box of eight
sectors each with four factors gives rise to 65,536 different combinations.
If each combination requires half an hour to assess for feasibility,
something like 15 man years is needed. Therefore, as a practical matter,
the too-great-richness must be kept in bounds by instructing the computer
not even to consider combinations defined as clearly impossible.

Other Techniques

Cross-impact analysis is the principal competing technique. Indeed,
comprehensive and systematic cross-impact analysis is, in fact, morphological
analysis. Divergence Mapping (described elsewhere) employs morphological analysis.

Procedures

In The Morphology of Propulsive Power Zwicky describes the procedures
of his method in the following terms:

1. "An exact statement is made of the problem which is to be solved.

   For instance, we may wish to study the morphological character

   of all modes of motion, or of all possible propulsive power plants,

   telescopes, pumps communication, detection devices, and so on.

   If one specific device, method, or system is asked for, the new

   method immediately generalizes the inquiry to all possible

   devices, methods or systems which provide the answer to a more

   generalized request.

   It will be found that the task of formulating the initial

   statement or definition of the problem on hand is far more

   exacting than most investigators not acquainted with the new

   method are inclined to think. In fact, one is hard put to find

   in the existing literature satisfactory definitions even of well-

   known devices like pumps, stationary power plants, telescopes and

   so on. The exact definition of apparently simple devices like

   injectors will be found to be a most difficult task and I doubt

   whether the combined common sense and sophisticated knowledge

   of any group of men would suffice to produce such a definition.

2. The exact statement of the problem to be solved, or the precise

   definition of the class of devices to be studied will reveal

   automatically the important characteristic parameters on which

   the solution of the problem depends. For instance, in the case

   of telescopes, some of these parameters are the location of the

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telescope (medium in which it is embedded), the nature of the

aperture A, the recording device R, the nature of the changes

to which the light is subjected from A to R, the motion of the

telescope, the sequence of operations, etc. The second step

thus involves the study of all of these significant parameters.

3. Each parameter pi will be found to possess a number of ki dif-

ferent independent irreducible values pi^1 pi^2 . . . pi^k.

For instance, the parameter "motion" of a telescope may

have the independent values p^1, p^2, p^3 = translation in three

directions; p^4, p^5, p^6 = rotatory motion; p^7, p^8 . . . p^{12} =

oscillation in the first six motions, etc. These matrices are

written in the following scheme:

$$[p1^1, p1^2, \ldots p1^{k1}]$$

$$[p2^1, p2^2, \ldots p2^{k2}]$$

$$. \ldots\ldots\ldots\ldots\ldots$$

$$. \ldots\ldots\ldots\ldots\ldots$$

$$[pn^1, pn^2, \ldots pn^{kn}]$$

If one element is encircled in each matrix and all the

circles are connected, every resulting chain of circles represents

one possible solution of the origi nal problem. The above scheme

of matrices, if used to construct an n-dimensional space, leads

to a morphological box. The analysis is complete if either one

or no solution will be found in every drawer of the box.

It is exceedingly essential that up to this point no questions be asked as to what value one or the other solution may have. Such premature curiosity almost always defeats the unbiased application of the morphological method. However, once all of the solutions are found, one must know their relation to any given set of adopted performance values.

4. The determination of the performance values of all of the derived solutions represents the fourth major step in the morphological analysis.

Lest one wishes to get lost in an enormous confusion of details, the performance evaluation must be carried out on a universal, although necessarily simplified basis. This is not always an easy task.

5. The final step involves the choice of particularly desirable special solutions and their realization.

The conviction that all solutions can be realized is inherent in morphological thought. It may, of course, happen that some among the many solutions are of a relatively trivial nature."

Product or Result

When applied to social forecasting, the morphological approach yields short-hand descriptions of possible types of societies. These then can be located in time and be strung together into an almost limitless variety of scenarios.

Level of Detail of Results

Results tend to be holistic, impressionistic, and "alive" rather than detailed. The technique is designed to show the overall picture made by the stones of the mosaic, even though the totality is built up, so to speak, using stones of specified size and color.

Level of Confidence in Results

Varies enormously, depending on the acceptability of the trends and combinations of trends used to define the scenario.

Communicability of Results

Excellent. The holistic, "alive" quality of good morphologically derived scenarios is both convincing and compelling.

Credibility of Results to Critics

The comment made above under "Level of Confidence" applies here also.

Span of Forecasts

Mid to long to very long range. The method is especially well adapted to projecting (not forecasting) a generation or more ahead. It is essentially worthless for societal projections of the near-term future.

Resources

Two kinds of people are needed. First, the expert in the field is required to disaggregate the topic into appropriate sectors and factors. These must be unambiguously defined--no mean task. Second, the imaginative combiner and assesser of possibilities is required. This may or may not be the same person as the expert. Usually, a team approach is employed so that hypotheses and ideas can be discussed and resolved on the spot. Often these working discussions are taped and later become the bases for written reports.

In cases where combinations are linked via formulae, computers are used to spin out "feasible" combinations which later may be examined in group sessions.

A budget of $50,000 or more and an elapsed time of at least three months is about minimum for generating 50-year morphological scenarios for, say, a river basin. It is essential to emphasize that the result will be scenarios representing likely and plausible futures. These do not qualify as forecasts. Therefore, additional research might be

required to select and "harden" the scenario line considered most probable and convert it into a true forecast.

ALTERNATIVE FUTURES

Abstract

The identification of plausible alternative futures is a means of exploring the implications of the variety of directions in which our society might evolve. The approach focuses on alternative forecasts based on different sets of assumptions. It does this through a variety of techniques, chief among which are variations on scenario writing. Alternative futures began with Pentagon contingency planning, but find much broader application today. The method attempts to illuminate plausible alternative paths for the society in the future rather than seeking to identify a most probable forecast. The process can be time consuming and expensive, but it is very useful in the search for and the evaluation of strategic options.

Definition

Alternative Futures is a name given to a variety of approaches intended to provide multiple forecasts based on differing sets of assumptions. Usually these multiple forecasts try to bound the limits of those futures considered plausible or worth planning for. Strictly speaking, multiple forecasts of a single value, such as the U.S. population, could be considered as alternative futures. However, the term is more often applied to alternative forecasts of many aspects of a society aggregated into some form of scenario. Thus, the methods usually involve the generation of a number of scenarios each of which is based on some

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set of different assumptions and presents the consequences of/and out-
comes of these over time. To generate each scenario some form of model
is usually required. What distinguishes this from simple scenario writing
is the fact of alternative scenarios.

History

As with many other techniques, alternative futures finds its origins
in military planning, particularly contingency planning. DOD planners,
in the late forties and early fifties, began constructing alternative
scenarios by asking a series of "what if" questions. The alternative
futures constructed in this way were narrowly aimed at the study of
military and political concerns and events. Alternative futures of whole
societies aimed at broader applications really began with work funded by
the U.S. Office of Education at Stanford Research Institute and Syracuse
University. At SRI, this work led to the development of a complex
technique called the Field Anomoly Relaxation Method (FAR) for the
generation of alternative futures. Since that time many other techniques
have been developed and have been applied in a variety of contexts, both
public and private.

Main Uses

The most appropriate use of alternative futures is the exploration
of the boundaries of the plausible future and the often subtle, qualita-
tive ramifications of policy choices. In this sense, alternative futures

are a learning tool designed to illuminate the consequences of different assumptions. A careful study of alternative futures can also be very useful in identifying those points in time which seem to be key branch points--where somehow fateful choices lurk--and the kinds of decisions which might lead to one path or another actually emerging. It may also, as in military planning, be useful in contingency planning.

Limits and Cautions

As in simple scenario writing, the most important caution is not to accept one of a set of alternatives as the most probable future and therefore discard the others as of no interest. This is a common and easy error to make. It does not seem unreasonable that, if one can deduce which scenario is most likely, one can afford to ignore the others. The recent energy crisis is an excellent example of why that is not a safe assumption. A few years ago a scenario which included a cut off of oil imports would not have been considered as very probable and in fact most planning was done excluding such considerations. This, of course, only made the resulting crisis that much worse. Thus, if one has been relatively careful in devising believable alternatives then one cannot afford to ignore those scenarios which are judged to be of a relatively lower probability. This is especially true where the implications of those scenarios is particularly significant, as in the case of the energy crisis.

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Limits to this approach are severalfold. First, it takes a high degree of imagination to push the limits of plausibility. Second, the development of comprehensive alternative scenarios can take considerable time and effort, hence a high cost. Third, one will never be totally comprehensive, i.e., some things must be left out. Thus, one always runs the risk of missing important elements and interactions. Thus, it is safe to assume that no matter how much good, thoughtful effort goes into the process, the actual future will in some important way be different from any of the alternatives developed.

Other Techniques

Alternative futures is related to any of the various forecasting techniques that allow or demand alternative forecasts. For example, in a computer simulation mo 1, runs may be made using different rates or testing different policies, yielding alternative forecasts.

Procedures

The first step in generating alternative futures is the selection or construction of a model which will be used to specify the modes of the various elements of each scenario. At this point two alternative approaches are available; (1) the description of various moments in time which will be assembled into scenarios, or (2) the immediate construction of scenarios through the description of event and trend sequences. Some image must be identified which will guide the selections of the

alternatives to be considered. For example, one might select a spectrum
from most desirable to most undesirable. After the construction of alter-
native scenarios they must be studied to elicit the useful implications
for the forecasting organization.

Product or Result

The result of this effort is a series of scenarios describing the
alternative courses of development for the society and the implications
implicit in each. These may be at a very brief "sketch" level or may
contain very rich and comprehensive detail. The analysis of implications
may also be quite brief or may go so far as to analyze strategic options
by conditional probability.

Resources

Doing a reasonably comprehensive job on alternative futures can be
enormously time consuming. As with scenario writing, it demands imagina-
tive thinkers, creative writers, and skillful analysts. Both the time
and the human resources involved, imply considerable expense. A typical
project of analysis through alternative futures may take from three
months to more than a year and involve many people in the process.

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DIVERGENCE MAPPING

Abstract

Divergence Mapping is a technique for aiding management think usefully about the future and what alternative futures imply for the organization. (The method is equally valid for studying non-institutional problems.) The heart of the technique is a 2-3 day workshop in which "snapshots" of plausible futures are placed on a Divergence Map form in such a fashion that "good," "bad," and "most probable" futures can be identified. Those scenarios are then scrutinized for implications for strategic planning. A major advantage of the method is that if makes explicit the hidden assumptions of participants concerning the future.

Definition

Divergence Mapping is a soft, group consensus judgment method for considering and reaching agreement on the timing and direction of the future of a society or any other broad topic. A set of brief narratives or "snapshots," called "frames," are prepared to describe a range of societies. The conditions portrayed in these frames are selected to reflect an array of plausible conditions with respect to the critical issues for the topic being studied. These frames are then positioned on a Divergence Map Form along a timing (sooner/later) dimension. The completed map is then drawn upon to outline potential futures of concern (best, worst, most probable, etc.).

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Every member of any decision-making group has intuitive premises about the expectable future and its implications for the group's decisions. For the most part, these assumptions are unrealized and hence go unexamined by individuals and by the group as a whole. Divergence Mapping provides a relatively simple, rapid way to make implicit assumptions explicit so that they can be debated, conflicts and disagreements resolved, and a comprehensive, consistent set of assumptions about the future can then be used by all members of the group in its decision-making processes.

History

Divergence Mapping was developed in 1972-1973 by Context Corporation, Palo Alto (since dissolved). Peter Schwartz and David C. Miller--both participants on the current IWR project--were the principal developers of the method. They have since collaborated in its further development and-- singly or collectively--have been involved in its several applications with numerous clients. A transport leasing company, an insurance company, two state citizens' planning groups, and a major timber-paper company have been among the successful users of Divergence Mapping.

Main Uses

Divergence Mapping is not intended primarily as a forecasting method, although it can be so applied. Its main use--as mentioned above--is to surface and examine hidden assumptions and premises about the expected future on the basis of which the individual members of a decision-making

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group are acting. The method is also an excellent instructional device

for conveying the meaning of alternative futures,   identifying the wide

and diverse range of potential futures, and probing the implications of various

scenarios for a host of institutional decision issues.

Limits and Cautions

Divergence Mapping is essentially a small group procedure, and would

require substantial modification for use with large numbers of individuals.

Further, the method demands a great deal of general information and parti-

cipation from its members. Finally, as a soft, non-rigorous process,

successful use of the method requires coordination by skilled facilitators

experienced in using the method.

Other Techniques

The C.L.A.F. Method devised by the same authors for the Weyerhaeuser

Company is an analogous, multiple-trends-projection method. Any of a

variety of polling or survey research methods, including Delphi polling,

might also be used in place of Divergence Mapping. The generation of alternative

futures via morphological analyses   also provides similar results.

Procedures

The user group is asked to identify a few issues most critical to

the future of its organization. Drawing on these issues and other con-

jectures about the future, a set of 22 narrative frames is prepared, each

suggesting a different potential future at some unstated and unimplied

future date. Thus far, frames have been written at the level of U.S.

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society, although many other persepctives might be taken. The user group
is given advance reading assignments dealing broadly with future possibil-
ities. The main application of the method occurs in a two-to-three day
retreat workshop. Alternating between two or three small groups and the
committee of the whole, the group is assisted by workshop leaders to com-
plete the following procedures: (1) The group agrees on a description of
the present. (2) The frames are positioned on a four-tier Divergence Map
form which has one space for the Present and four, five, six, and seven
spaces respectively in tiers one, two, three, and four. Assignment of
a frame to tiers one, two, three, or four is determined by the group's
best judgment as to which frames might be realized "sooner," and which
only "later" (date unspecified at that point). (3) The group then selects
alternative "routes" through the Map from the present to tier four. Each
route represents some particular view of the future, such as "best,"
"worst," "most probable." (4) For each route, the group indicates the
earliest possible year by which each frame might be reached. (5) Finally,
the group is asked to relate its view of each future route to the organiza-
tion's most critical planning strategies.

Product or Result

When it is completed, the procedure yields a set of 22 frames, each
assigned a position on the Divergence Map form. Two or more alternative
future routes are also marked out on the form, together with supporting

explanations and discussion. Implications for long term planning strategy
are also set forth.

Level of Detail

As used to date, Divergence Mapping yields only very broad, extremely
brief accounts of possible states of future society. In principle, the
amount and level of detail can be extended indefinitely, according to the
group's needs, interests, and available resources.

Level of Confidence of Results

Divergence Mapping is designed to make explicit the premises and assumptions
about the future which members of a group already possess. As such, the
results are usually accepted with great confidence by members of the group,
although previously unsuspected differences of opinion may be revealed.
In fact, experience to date suggests that most decision-making groups have
a high degree of uniformity and optimism about the future, a consensus
probably unjustified by history.

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Communicability of Results

Divergence Mapping is designed to enable participants to learn quickly how to share their opinions about the future clearly and systematically. In presenting results to persons not familiar with the method, results are readily summarized, explained, and defended.

Credibility of Results to Critics

Divergence Mapping properly used is not represented as yielding forecasts. Critical comments are therefore best dealt with by engaging critics in use of the method, so that assumptions, agreements, and disagreements can be explored cooperatively rather than combatively.

Span of Forecasts

For exploring the future of U.S. society, a time span of 30 years into the future has been used. Depending on the topic and group interests, longer or shorter time horizons can be used, depending on the group's needs.

Resources

The decision-making group's time and energy represent the most costly resources. Consulting assistance probably will be required in preparing the frames and in conducting the retreat workshop. The cost of such consultation ranges up from about $15,000. A minimum of three months is required to prepare for and stare a Divergence Mapping workshop.

AUTHORITY FORECASTING

Abstract

In authority forecasting, a leader who must make decisions or take
actions in a situation of extreme uncertainty acknowledges or designates
an authority. The authority is consulted about the probable future
pertinent to the decision topic. His opinions and recommendations then
become all or part of the basis on which the leader makes a decision,
takes an action, or explains and justifies a decision or action. Authority
forecasting is perhaps the most ancient forecasting method still in use
and serves a purpose not readily served by other methods. A democratic
society, however, properly maintains a healthy skepticism for too-heavy
reliance on any designated authority.

Definition

This is one of the most ancient forecasting methods known. It sur-
vives in modern dress essentially unchanged. The client or forecast
consumer identifies some person or organization believed for whatever
reason to have special expertise or insight about a given topic. The
expert is queried about the future pertinent to the topic, and his/her
replies are accepted as forecasts of the most probable future.

This approach assumed that for the topic there exists a body of
factual knowledge, principles, etc. on the basis of which reliable
forecasts can be made. It is assumed that there are individuals or

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organizations who possess the pertinent facts and understand the appli-
cation of the pertinent principles. It is assumed that these experts
can be identified and accessed. Finally, it is assumed that the experts
opinions and replies are pertinent, knowledgable, and the most reliable
opinion available about the future of the forecast topic.

History

In a true sense, the history of this method is the history of leader-
ship, authority, and power in society. The ancient, Sumerian priests,
the Greek Delphi oracles, and The Hudson Institute--these and millions
of other persons and organizations, known and unknown, have been earnestly
consulted about the future and their opinions held especially credible
because of their presumed special authority. Depending on the era and
situation, the source of authority has been held to be mystic, experi-
mental, spiritual, or rational.

Main Uses

Authority forecasting has always served basic human societal needs,
usually expressed through society's leaders. A leader regularly is called
upon to make decisions and take action in situations of extreme uncer-
tainty and great risks. In such situations, social solidarity requires
that the leader be able to explain his decisions and actions on a basis
which is comprehensible and credible to his followers. In these circum-
stances the most acceptable explanation and defense is that the leader

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has consulted and accepted the highest and/or "best" opinion available--
the priest, the wise man, the scientist, the economist, etc.

Limits and Cautions

An authority is an authority only if she/he is accepted as such by
those in position to act upon or obstruct decisions based on the author-
ity's opinion. Thus, the authority of the President and the Pentagon
in the 1950s and 60s to decide what "national security" means has been
severely eroded in the 1970s. The lesson must be that leaders in posi-
tions of power must be keenly sensitive to shifts in the images and
locus of authority. In another direction, leaders and led alike are
over inclined to bestow the mantle of authority on those parties whose
opinions and recommendations appear to further immediate selfish inter-
ests. For this reason, a democratic republic is obliged to maintain a
healthy skepticism of all sources of authority, a skepticism sometimes
difficult to maintain and yet dangerous to overdo.

Other Techniques

Authority forecasting methods typically are relied upon when a
forecast seems essential and no approach superior to informed judgment
is apparent. In these circumstances, the "voice of the people," the
assumption that the future will be simply an extension of the present,
or an attitude of "let's wait and see what happens" are the major sub-
stitutes for authority forecasting. When leaders are enlightened, the

risks and limitations of all these methods are frankly acknowledged, and resources are invested to discover more adequate approaches.

Procedures

In its crudest form, the "leader"--elected or self-appointed-- asserts the definition of the problem, argues that a forecast is essential, designates the authority, and interprets the authority's findings according to his own experience, judgment, and purposes. This pure form of the method is rarely encountered, and then only in totalitarian societies. In non-absolutist societies, each of the steps noted is resolved through complex competitive and cooperative procedures among interested stakeholders. Clearly, procedures in particular organizations or societies can run the gamut from simplistic and intuitive to sophisticated and highly organized. Typically, at the level of an organization or a sector of society, authority forecasting proceeds at two levels--an elaborate, highly visible explicit level supplemented by an unacknowledge, intuitive level. Generalizations are apt to be meaningless. In-depth case examples afford the best description of the method.

Product or Result

Authority forecasting tends to be used when it is acknowledged that a decision(s) and action(s) is essential in the absence for a rational or plausible basis for it. This being so, the nominal product of an authority forecast is a description of what is likely to happen if certain

decisions or actions are or are not taken. The actual product, however,
is usually regarded by decision-makers as a defensible explanation and
justification for whatever decision or action ultimately is taken.

Forms of Output

As might be guessed from what has already been said, the form of
output of an authority forecast varies widely. The guideline principle
in most cases is the same, however: which form of output will best
meet the explanatory and justificatory needs of the leader-decision-maker.
If those who must be convinced are securities analysts, the forecast may
take the form of a financial projection. If they are members of the
House Armed Services Committee, the forecast may take the form of mili-
tary scenarios. Because authority forecasting is most often used to
provide a credible basis for action by the leadership, the leader-client
is apt to have more to say about the format of authority forecast output
than of nearly any other forecast.

Level of Detail of Results

What has been stated above about the format of an authority forecast
applies equally to the level of detail found in a given authority forecast.

Level of Confidence of Results

Those who sponsor and those who offer authortiy forecasts profess
great confidence in them, because the forecasts are used to justify
decisions and actions, past or pending. Beyond these parties, also, the

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level of confidence acknowledged in an authority forecast usually depends

on the value and views of those concerned. Where an authority forecast

serves or can be made to serve positions established on other grounds

the forecast is accepted with great confidence. Where the forecast

attacks previously established positions it is ignored, attacked, or

minimized.

Communicability of Results

Communicability is an interesting facet of authority forecasts.

On the one hand, those who sponsor or make the forecast wish their audience

to accept without question the superior insights and opinions allegedly

contained in the forecast. For this reason, the factual content of the

forecast may be minimal, or may deliberately be made difficult to under-

stand. On the other hand, an authority forecast cannot serve its intended

end unless it persuades to some extent those parties which are on record

as hostile or skeptical. In striving to meet these opposed objectives,

an authority forecast typically clearly states certain of its major

premises and all of its major conclusions while obscuring the chain of

reasoning which links the two. Examples of this abound in the literature.

Credibility of Results to Critics

What has been said above about communicability covers this matter

adequately.

Span of Forecasts

The span of authority forecasts typically is detemined by the future
time interval for which the leader-sponsor of the authority forecast
requires a prom..se of committment from his constituents, typically a
few mouths to a few years

Resources Needed

As might be guessed, the nature and amount of resources required for an
authority forecast varies from trivial to prohibitive. Where people
want to be convinced that a certain future outcome is highly probable,
simple reassurance from an acknowledged leader may be sufficient. Where
people refuse to be convinced that a given future is likuly, no forecast--
no matter how elaborate--is apt to be sufficient. Within these limits,
the estimate of resources needed typically is made by the sponsor rather
than the forecaster. The sponsor's ertimate addresses this question:
Who must be convinced ano what is the type and level of effort most
credible to them?

Comments

Much of what has been said above about the authority forecasting
method may smack of cynicism. This is not our intent. In every organi-
zation and sector of society, crises regularly arise where it is clear
that something must be done and equally clear that no one truly knows
what should be done. In these frequent painful instances, leaders must

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have some plausible basis for demanding risk and sacrifice and followers

must have some acceptable basis for complying with the leadership's

demand. In these situations, resort to the most plausible authorities

for forecasts and recommendations is not only inevitable but desirable

and productive.

SURVEYS OF INTENTIONS AND ATTITUDES

Abstract

Major classes of surveys and polls relate to what people expect to do (intentions) and their attitudes and values. Expectation data is reliable only for very near-term (3 months) forecasts. Projections based on changing attitudes and values are often long-term but tend to be global rather than detailed. Moreover, reliability is subject to dispute. Data on attitudes and values, however, are indispensable for foreseeing public reaction to controversial proposals and programs.

Definitions

Covered in this forecasting approach are consumer surveys of various types, public polls, and systematic surveys of the spending intentions of elements of the business community. Some of the best known annual (or more frequent) surveys of these types are:

Plant and equipment spending--surveys by Commerce-SEC, McGraw-Hill, Conference Board.

Consumer buying plans--surveys by Census Bureau, Commercial Credit Company, Conference Board, Michigan's Survey Research Center.

Expected sales and inventories--survey by Commerce.

Housing--surveys by Fortune magazine and Commercial Credit Company.

Personal and national hopes and fears--survey by Potomac Associates.

35 social trends--survey by Daniel Yankelovich, Inc.

Public opinions—polls on a great range of issues by The Gallup Organization, Louis Harris, Elmo Roper, Field Associates, NORC, ORC, etc.

Quality of life—surveys by Michigan's Survey Research Center.

Results of most of these surveys are available free or for various fees. (Costs range from zero in the case of government surveys, to the cost of Fortune magazine, to a subscription rate of about $15,000 per year for the Yankelovich data.)

Anticipatory surveys, such as these are often called, are used chiefly in sectorial analysis—that is, for forecasting in limited sectors of the economy rather than for more global forecasts, such as for GNP, personal income, and the like.

The rationale underlying such surveys and polls is that what people say they intend to do—or what they value—is a better indicator of what they actually will do than are trend extrapolations or outputs from various types of models. As discussed later there are things to be said both for and against this view.

History

Some systematic repeat surveys of intentions and attitudes go back as far as 1948, but many are ten or fewer years old. Public polls became famous in the 1930s with Gallup's predictions of presidential election results.

In recent years, not only have the repeated surveys become more numerous, but one-time polls and surveys have multiplied enormously in support of corporate as well as social and policy concerns.

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Main Uses

The two principal uses of surveys and polls are (1) to collect information on intentions, to serve as a basis for direct forecasting of consumer or corporate actions for the coming quarter, half year, year, or (in a few cases) several years in the future and (2) to amass attitudinal and values data which are presumed to influence personal, social, and consumption behavior.

Intentions. Surveys of consumer intentions cover such items as purchases of automobiles, appliances, homes, home improvements, household equipment, furniture, carpets, and a range of other durables. In general, less attention is paid to the services, nondurables, and savings.

Surveys of corporate intentions deal most notably with plant and equipment spending, capital appropriations, machinery orders, inventory levels, home starts, and sales expectations.

There is, of course, no reason why special surveys of intentions cannot be made on any subject of interest. The problem is that reliability is difficult, if not impossible, to assess in the absence of parallel data for past years which can be checked against subsequent history.

Attitudes and Values. As indicated earlier, a wide range of topics are covered in repeated attitudinal and value surveys such as those conducted by Potomac Associates, Yankelovich, Survey Research Center, and the polling organizations. Practically any headline news gets attention from the pollsters. In fact, proprietary services are sometimes based on sudden developments (e.g., Opinion Research Center's service dealing with public attitudes concerning energy). Moreover, the number of special attitudinal surveys conducted by

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public and private interest groups may well exceed 1000 per year.

Attitudinal and values data are essential for foreseeing public reactions to proposed programs. They are often invoked for goal-oriented forecasting ("where we want to go"), for identifying the nature of pluralistic segments of the population, and for predicting social and consumption behavior.

Limits and Cautions

Intentions. The forecasting record (out to a year ahead) for capital and equipment spending is quite satisfactory; the record is less satisfactory for other components of corporate activity and still less so for most of the consumer spending forecasts. Consumer intentions appear to provide a useful basis for forecasting only for the very near term, and even then they sometimes miss such spectacular events as the auto boom of 1968. The mixed record of surveys of expectations leads one authority to conclude: "Anticipatory surveys, even the best ones, must be used with care. They cannot be taken at face value....They should not be used as the only, or even the principal, technique. But they do represent a major forecasting input which all forecasters should use."[*]

Attitudes and Values. The usefulness of attitudinal and values data for marketing purposes must be distinguished from that for social analysis and "utopia forecasting." A very considerable body of marketing data points to

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[*] Morris Cohen, "Surveys and Forecasting," in Methods and Techniques of Business Forecasting, W. F. Butler, R. A. Kavesh, and R. B. Platt, eds., Prentice-Hall, Englewood Cliffs, N.J., 1974.

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many logical inferences and predictions that can be based on measured attitudes and values. However, most careful studies have concluded that the variance in consumer behavior is often difficult to explain via attitudinal information. Demographic and economic data often does better in this regard. The explanation seems to be either that (1) we have too little understanding of the role of values in consumer behavior, (2) values and preferences are overwhelmed by the practicalities of economic and social pressures, or (3) the art of measuring values is too primitive for the purpose of predicting consumption.

The situation is somewhat better with respect to social and normative forecasting. Surveys of attitudes toward specific programs or issues provide essential-data for anticipating public reactions. Such data can be used-- but less reliably--in trying to assess what a population "wants of the future." Tradeoff preferences can be approached this way. The differing views of various economic, social, and ethnic groups can be gauged via values surveys. Finally, a considerable body of data has been built up over the past 15 years concerning the demographics of many special concerns, hopes, fears, social trends, and assessments of what makes the good life. Such information is helpful in com- piling values-based scenarios. Values and attitudes can be organized in terms of theories of psychological growth (Maslow, Graves, etc.), images (Polak, Boulding, Markley, etc.), myths (Campbell), life ways (Morris, Mitchell), and so on. Scenarios forecast societies that would result from various national profiles of values, structured as suggested in the previous sentence. No claim can be made that such approaches are foolproof or even that they may not be misleading. We simply have no basis yet for accurate assessment. Nevertheless,

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surveying of attitudes and values appears to be the most direct and probably
the most reliable method of obtaining such vital inputs to establishing and
evaluating social goals and priorities.

Other Techniques

Expectations, attitudes, and values can be reliably compiled only through
surveys and polls. Even then data are sometimes subject to several inter-
pretations. It is possible, of course, to hypothesize trends in such factors
based on correlations with demographic, economic, and other characteristics
Public relations experts often do this sort of thing on a hunch basis.
or through various types of theoretical models./ Careful survey data shows
emphatically, however, that surmises and hypotheses in the domain of attitudes
and values are very commonly spectacularly in error.

Procedures

Surveys consist of questionnaires (sometimes very elaborate and requiring
much pretesting to develop reliability) administered by telephone, mail, or
personal interview to a sample (which may be random but usually is carefully
chosen to have known characteristics). Responses are then analyzed, often by
computer, along dimensions of interest. Demographic attributes of the sample
are usually given.

Product or Results

Survey and poll results usually appear in tables showing percentages of
respondents answering specific questions in a given fashion. If the survey
is periodic, charts are usually provided to reveal trends in responses.

Demographic data are usually given separately. Text generally highlights and interprets results.

Level of Detail of Results

Ranges from very detailed to global. Expectation studies tend to be detailed, value studies global, and attitude studies in between.

Level of Confidence of Results

As indicated earlier, some intention or expectation data provides a reliable base for near term forecasts. In the main, however, expectation data are not considered reliable for mid- or long-term forecasts.

Attitudinal and values data are often used as the basis for forecasting mid- and long-term trends, but the practice is so recent that data on reliability is inconclusive. In contrast the record of surveys and polls in forecasting public reactions to issues (especially voting) is well established and generally excellent.

Communicability of Results

Polls and surveys are well understood by everyone and hence their results are highly communicable if not treated with confusing sophistication.

Credibility

There are many observers who feel that all kinds of survey and poll results other than voting polls are too "soft" to be credible. They argue that people really don't know themselves what they expect to do or how they feel about things; moreover, critics hold that, in many cases, so much is lost between

the concept of the question, its actual statement, the response, and the interpretation of the response that one doesn't really know what a survey or poll says. Still another school of critics feels that "hard" things (especially economic concerns) so dominate expectations, attitudes, and values that forecasts are better based on them than on "soft" considerations. Despite the acknowledged validity of these criticisms in many circumstances, the overall trend is strongly toward acceptance of expectations, attitudes, and values as important components in people's behavior; hence they are gaining acceptance as indispensable elements in long-term social forecasting as well as in foreseeing public reactions to proposed programs.

Span of Forecasts

Expectation data generally refers to a year or less in advance. Trends in attitudes and values often are projected for a generation or more ahead.

Resources

Sophisticated surveys and polls require highly skilled question writers, statisticians, and trained interviewers. Informal surveys require none of these, but results are much less reliable. Computers and programmers are a must for analyzing complicated surveys.

A national probability survey of a sample of 1500 on a subject requiring the development of a new questionnaire would cost over $100,000 and might cost several times that. Six months or more would be required. In contrast, an informal spot-check of opinion on Main Street obviously could be done for the cost of a few days' time.

PANELS

Abstract

Forecasts by panels most commonly reflect majority opinion of selected experts dealing with a defined area. Less commonly panels are used to represent the views of a cross-section of the public, a discipline, or some other coherent group. Panels have often produced good results, but care must be taken to avoid bandwagon effects, blockage of unpopular viewpoints, and distortions arising from the unwillingness of experts to change previous opinions. Panels are very widely used in all kinds of organizational situations and results have the prestige that accrue to individual panel members. Delphi is one of the most effective panel forecasting techniques.

Definition

Groups of people brought together into one or more panels are frequently asked to make predictions concerning specific aspects of the future. Subject matter of such forecasts is unlimited. The panels usually are composed of experts in a given field or discipline, but may be selected to represent a cross-section of the public, of an industry, profession, etc. The common denominator is that the panel's judgment is considered valuable either with respect to forecasts or with respect to representing a defined spectrum of opinion. Most commonly, the rationale underlying selection of a panel for making forecasts is that experts have

better insight into the probable future developments in their fields of expertise than do laymen.

The Delphi technique makes use of panels as does much brainstorming. The practice of obtaining expert opinion on which to base forecasts and action is, of course, basic to all research and most decision making.

History

The use of panels is as old as human history for it is a certainty that "panels" of clan leaders always rendered the "forecasts" on which the group's actions were based. Advisors to kings and presidents qualify as panels. Staff assistants to executives often serve this function.

What is meant here, of course, is the organized use of experts to forecast future trends. President Hoover made use of such a panel in calling for a report entitled Recent Social Trends at the start of the 1930s. More recently the Armed Services have used panels with great effectiveness. Project Forecast of the Air Force and Project Seabed of the Navy are classic examples.

Main Uses

Forecasting via panels is used in two types of circumstances: (1) when expert opinion is presumed to be superior to any other source of information concerning the future, and (2) when representativeness of viewpoint is of central concern. Clearly, different kinds of panels are selected, depending upon the circumstance. Expert opinion panels predominate

by far in practice; polls and surveys are generally preferred in gathering data on representative opinion.

Limits and Cautions

With respect to panels of specialists, three kinds of cautions should be observed. First, experts are often exceedingly wrong in their forecasts. History is full of sensational examples of the "best experts" being the worst prognosticators. Second, a "bandwagon" effect often occurs in panels, so that one person's viewpoint overwhelms the opinions of others and/or plausible alternatives never get proper exposure. Third, many specialists are unwilling to revise previously expressed positions. The upshot is that free and open consideration of alternatives in the light of all data is not possible.

Other Techniques

As indicated earlier, the use of advisors is basic to much decision-making. Hence panels of varying degrees of formality are commonplace in every circumstance in which one person must make decisions affecting many. Consultants, staff assistants, "wise men," and even printed authorities (ranging from books by experts to religious pronouncements) are variants of panels. More formally, the following techniques often use panels for forecasting: Delphis, brainstorming, industry or discipline conferences, and specialty and public opinion assessment.

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Procedures

Procedures are diverse, ranging from rambling, unrecorded, round-table discussions to highly directed feed-back systems requiring specific responses to specific aspects of specific issues, all of which are summarized in a specific manner. Brainstorming represents the first procedure and Delphi the second.

Product or Result

Again, there are no set rules. Panel results come in every shape, manner, and form.

Level of Detail of Results

The range is great, but results tend to be general because they emerge chiefly from "head knowledge" as distinct from close paperwork utilizing details from the literature.

Level of Confidence in Results

This depends wholly on one's opinion of the abilities of the panel, the feasibility of forecasting in the area, and the observer's reactions concerning the methods and reasoning used by the panel.

Communicability of Results

Communicability tends to be good because the panel is at least communicating among members, suggesting a level of generality above that necessary for the "genius" to express ideas. (Example: Einstein was clear to himself

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but to only a few highly knowledgeable others; a panel report on social

trends would have to be understandable to all panel members, and would

be designed to communicate to a much wider audience.)

Credibility of Results to Critics

The same remarks apply here as were given under "Level of Confidence

in Results."

Span of Forecasts

From minutes to aeons.

Resources

The prime requirement is for a panel suitably selected to deal with

the topic. Often panels are hard to identify because the topic has no

acknowledged experts (life in a "recycle society"), the number of needed

experts overwhelms panel mechanics (definitions of "the good life"), or

representatives of differing views cannot "hear" each other, rendering

panel discussions mere arguments.

Expert panelists often command fees or honoraria, sometimes making

the approach fairly expensive. Facilities other than a meeting room

remote from interruptions are rarely required. Results from panels are

achieved rapidly--usually in a matter of days but stretching out to months

in the case of structured forecasting by panels, as in the Delphi method.

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DELPHI

Abstract

Delphi is one of the most widely known and used methods in futures fore-
casting. It is a specific application of the broader methods of opinion
polling and survey research. The method involves multi-round estimates by
designated panels of qualified experts. Experts estimate the probability,
timing, and impact of a set of possible events related to the target topic.
The method is best used in technological forecasting, for which it was ini-
tially developed. In other cases, topic definition, expert selection, and
interpretation of results may be difficult or impossible. Used for respon-
sible forecast making, Delphi is complex, time consuming, and costly. Used
for learning purposes or simply to explore possible futures, the Delphi method
is simple and inexpensive to use. This method probably represents the best-
known single facet of the whole futures research field.

Definition

The Delphi method involves the solicitation of the opinions of qualified
experts concerning the future state of affairs for some particular topic.
It is a well-known and widely used application of the broader field of opinion
polling and survey research. EXAMPLE: A panel of physicians, health adminis-
trators, insurance executives, and others might be solicited as to their
opinions about the future of health care--either in general or in some par-
ticular aspect.

The method assumes that a topic can be delineated in such a way that its boundaries and contents will be clearly and uniformly understood by those familiar with the topic. It is assumed that those having the greatest acquaintance and experience pertinent to the topic can be identified. It is assumed that a representative cross-section of these experts can be persuaded to participate in the poll. Finally, it is assumed that their ultimate collective opinion represents a more probable view of the future for that topic than would the views of persons selected on some other basis.

History

Opinion polling and survey research have been known and used for many years. Within that field, the Delphi method was developed and first used in the 1960s at RAND Corporation by Dr. Olaf Helmer and Norman Dalkey. The method is widely known and discussed. In modified form--it is doubtful that any two applications are identical in exact detail--several thousand Delphi polls have been conducted. One of the more ambitious polls published was conducted in the late 1960s by the Japan Society of Techno-Economists. Helmer is even now attempting to compile a register of major Delphi studies, and to make a comparative analysis of them.

Main Uses

Delphi was developed initially for making technological forecasts. It probably is better suited to that purpose than to topics which by their nature are more complex, unclear, or uncertain (see LIMITATIONS AND CAUTIONS). Delphi

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stuides properly conducted in appropriate circumstances can usefully predict

the need or appearance of new technologies and technological requirements.

The original work was sponsored by the Department of Defense, which finds

technological forecasts useful in establishing its R&D priorities. Similar

uses have been made by high-technology corporations.

Limits and Cautions

Three items are especially important here. (1) Delphi poll topics must

be amenable to opinion polling research methods. If the topic cannot be un-

ambiguously delimited and defined, fundamental shortcomings may result, not

always necessarily evident. EXAMPLE: If a Delphi poll were conduct on the

future of "The American Way," the results would mean little because the topic

is variously defined by various persons. (2) Even when a topic is clearly

defined, identifying and then gaining the participation of qualified experts may

be difficult. Who are the best qualified experts on "The American Way"? How

do we establish that we have a representative cross-section of such experts?

(3) Delphi polling represents the search for consensus opinions within a

particular set of persons on a particular occasion. To assume that the same

persons on a different occasion would give the same result, may be reasonable

but difficult to prove. Even if this is established, only the actual future

can demonstrate whether the consensus was in fact a more accurate prediction

of the future than other estimates made on some other basis.

Other Techniques

Delphi is best used to forecast the future of some relatively narrow,

clearly delimited technological topic. In this application it closely

resembles services often provided by a single expert consultant or consultant

team. Nor is there clear evidence that the opinion polling method will yield

better results than the experienced but intuitive judgment of one person.

The Delphi method does offer the advantage of accessing more points of view

and broader sources of knowledge. Cross-impact analysis is in many ways

parallel to Delphi, and, in fact, often asks participants to render the

identical judgments involved in Delphis.

Procedures

A typical Delphi consists of two, three, or four rounds. A topic is

selected, and a group of experts is recruited. A number of possible develop-

ments which would affect the future of the topic are identified. In polls by

mail (to preserve anonymity and to reach more qualified experts than could be

brought together) the experts estimate the probability of each development

actually occurring. Experts may also be asked to estimate when the development

may occur, and what the consequences might be. Delphi panel managers collect

estimates, translate them into a normal distribution, and return the results

to each expert. Each participant sees what the average or mean estimate was,

and how it relates to his own. He is then free to maintain or modify his

earlier estimate. And so on through the next round. At the panel manager's

discretion, explanations and defense of given estimates may be sent to the

entire panel.

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Products or Results

The result of a Delphi poll is a series of tabulations. Tabulations usually are presented in the form of a normal distribution curve. Mean estimates of probability, timing, impact are shown for each topic in each round. The final round results reveal how much or how little consensus of estimate has been established for each topic polled. The results may also include a few or many comments by individual participants, explaining and defending their individual estimates. The final round may also identify the participants, either by demographic characteristics, by name, or both.

Polling techniques rarely permit the level of detail which other forecasting methods can attain. The large numbers of persons involved, and the time-cost dimensions of survey research impose severe limits. One or a few topics may be explored in some detail if the topic is narrowly defined. Typically, poll managers in early Delphi rounds present a broad range of possible events, then zero in on many fewer topics where strong consensus or disagreement are seen to exist.

Level of Confidence in Results

In technological forecasting applications--especially in the military-- well-designed and executed Delphi polls may be treated with great respect, especially if their future time-horizon is relatively short. In other applications where topics are less clear, experts are less identifiable, and high costs cannot be borne, confidence in Delphi poll results falls off sharply. In these applications--perhaps by number the greatest fraction--Delphi is

more appropriately used (like scenario writing and simulation) to explore possibilities rather than to predict probabilities.

Communicability of Results

Delphi poll questions and results tend to make fascinating reading and are widely attended. The distribution of opinion along a normal curve is readily communicated. The significance of the distribution is often less clear and so less readily communicated.

Credibility of Results

Because they are so widely known and popular, Delphi polls provide a clear example of two types of credibility which are applicable to any forecast. Many people accept Delphi results uncritically and profess to believe in their validity. When Delphi poll recipients are placed in a position to decide or to act on the basis of Delphi forecasts, credibility falls off sharply. In a basic sense, the credibility of any forecast is heavily a product of the demands, costs, risks, and benefits the forecast implies for its recipient.

Span of Forecasts

In principle, a Delphi poll may select any time horizon whatsoever. In practice, few accept a time horizon shorter than five years and few exceed 50 years. Selection of the time horizon usually is keyed to the time span believed required or available for decisions or actions to be taken.

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Resources

Modest resources of time and effort are adequate when Delphi polls are conducted to induce learning or to explore possible futures. Used in the forecasting mode, the Delphi method is expensive and time-consuming if even credible--set aside useful--results are to be expected. Expert opinion is difficult to identify, and often expensive to access (although experts in Delphi polls are often "paid" by having access to the results). Enormous amounts of data must be held and analyzed. Thus the Delphi method used responsibly for forecasting purposes is expensive, time consuming, and may be difficult to manage.

Comments

Of all the methods, concepts, and words in the futures research field, Delphi may be best known, least understood, and most abused in practice. Anyone who wishes to gain a quick feel for the state of the art and of practice in the field might well begin by assessing the state of Delphi methodology.

LIFE WAYS/LIFE STYLES/PSYCHOGRAPHICS

Abstract

Life ways are a method of classifying people's values, needs, attitudes,
etc., usually in a typology involving 5 to 10 clusters. In the area of
societal forecasting, insight into life ways is helpful in (1) generating
alternative futures based on changing values, (2) making "soft" inputs to fore-
casts chiefly reflecting economic and technological factors, and (3) in pro-
viding a structuring framework for interpreting and generalizing results of
surveys on specific issues.

Definition

By life way is meant a person's overall pattern of inner needs, values,
beliefs, and attitudes. The theory is that this constellation of core motiva-
tions governs how the person acts, what tradeoffs appeal to him, what he strives
for, how he defines reward, what his priorities are, and every other aspect
of his individuality. Life style refers less to inner motivations than to
external behavior patterns. Thus a life way dominated by achievement drives
can be expressed in any of numerous life styles. Psychographics is a recent
term invented by market analysts to indicate the general area of correlating
psychological factors with consumer behavior.

The rationale underlying the use of psychological measures in preparing
forecasts, scenarios, or in predicting reactions (with regard to a proposed
dam, for example) is simply that what people need, value, and believe in is
a fundamental contributor to social trends and public behavior. Almost all

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long-term forecasting work incorporating life way or style factors also utilize
trends in economics, technology, demography, institutions, etc.

History

Use of values as a specific and systematic input to social or technological
forecasting is relatively recent, although spectacularly successful intuitive
applications go back as far as de Tocqueville and the Marquis de Condorcet.

The main developments in the field have emerged from two research approaches:
(1) analysis in terms of markets and consumer behavior and (2) personality
theory and how it applies to societies. These two approaches are discussed
below.

In the area of marketing research life style approaches have been used for
about 15 years. Perhaps the best known is the approach known as Activities,
Interests, and Opinions (AIO) developed jointly in the late 1960s by Wells and
Tigert of the University of Chicago, the Leo Burnett advertising agency, and
Market Facts, Inc. Other well-known market approaches include studies based
on stage of life cycle (couple with children under six, "empty nest," etc.),
life roles (homemaker, young executive, etc.), and approaches combining per-
sonality traits with demographics to define a life style ("swinger," "contented
cow," "revolutionary," etc.). Great numbers of studies have explored the
market implications of specific values and variables, such as authoritarianness,
innovativeness, or social awareness. The narrow base of such studies perhaps
disqualifies them for the forecasting methods under discussion.

Personality theorists have identified stages of individual development which can also be applied to societies. Thus a nation can be described as "achievement oriented" or "security motivated," etc., using terminology employed by such psychologists as Erikson, Graves, Kohlberg, Maslow, and McClelland. The approach can be made more sophisticated by drawing national profiles in terms of the developmental stages of growth. By tracing the probable evolution of such profiles over time, useful forecasts can be prepared of changing values, needs, and priorities.

Main Uses

With respect to the Corps of Engineers, the prime uses of life way forecasting techniques are threefold: (1) as a means of generating alternative futures reflecting changing values, (2) as an approach to making "soft" inputs to forecasts chiefly reflecting "hard" factors such as economic and technological trends, and (3) as a framework for interpreting and organizing surveys of public opinion.

Societal forecasts based on changing values usually deal with small numbers of value constellations or national profiles of life ways. Having assumed or projected a dominant value pattern for the society (e.g., achievement, security, frugal, etc.) implications for institutions, markets, and the like are hypothesized to round out the total picture.

As input to comprehensive forecasts, analyses in terms of life ways are helpful in thinking through what kinds of programs will receive support in given circumstances and what value shifts are likely to accompany changes in the external environment.

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The third use of life way typologies is as a device for clustering field attitude data into meaningful wholes. Insight into overall patterns facilitates interpretation of individual values data and provides a basis for making coherent forecasts.

Limits and Cautions

Life way analyses are uniquely useful in providing a coherent framework within which to structure the "soft" elements of society--things like people's values, beliefs, priorities, motivations and the like. But such analyses must be used with care.

In the first place, it often is not clear how much difference values and priorities make in the course of events. Their influence seems to range from decisive (prohibitions against a nuclear power plant at a specific site) to partial (reaction to energy conservation measures) to none or indeterminable. It therefore seems wise, wherever feasible, to augment life way analyses of near term events with actual surveys of the populations of interest.

This indeterminism also means that long-range forecasts based on changing values contain many uncertainties. A principal use of life ways is, in fact, to help generate alternatives around a core scenario assuming continuation of present values. Scenarios based chiefly on values, such as those by David McClelland, are necessary global rather than detailed and qualitative rather than quantitative.

Other Techniques

Value forecasting can be approached in a number of ways. Polls, panels, Delphi. and content analysis of periodicals and literature are the main sources

of quantitative specifics. Some sort of life way or life style analysis seems to be the only common way of identifying patterns of values. Literally scores of specific schemes have been suggested to describe value clusters characteristic of various nations and segments of the population.

Procedures

Development of life way typologies requires characterization of groups of people in terms of dominant value sets. Characterization can be descriptive ("swingers"), focussed on a dominant interest ("environmentalists"), demographic ("retireds"), motivational ("achievers," "changers") and so forth. What is required to qualify as a true life way is identification of correlated attributes which support the key characteristic. These correlations can range from intuitive to carefully measured. The most sophisticated life style typologies are based on careful national surveys. Perhaps the best documented typology is that of social class.

Product or Result

A life way typology consists of some limited number (usually ten or less) of groups defined in terms of some dominant feature. Associated with this core feature are secondary, supporting features which generally include demographic economic, political, attitudinal, motivational, and social characteristics. In most cases the life way typology is designed to describe a population connected by some common denominator, which may be common citizenship (all Americans), common purchase of a class of products (users of mouthwash), a common impact (residents of an area affected by a dam), or common concern with some class of issue (conservation).

Level of Detail of Results

Any life way typology is necessarily gross if only because no large, varied population can be characterized fully in a manageable number of life ways. From a statistical standpoint, however, detail relating to each type may be quite fine. Some typologies, for example, provide statistics on over 50 distinct attributes.

Level of Confidence of Results

As a heuristic--that is, as a means of stretching the mind to embrace a variety of alternative prospects--the life way approach can be counted on to enrich forecasting efforts. Its usefulness as means of ordering disparate poll results finds general but not universal agreement. As the sole device on which to base forecasts of the future, it is not reliable. As indicated earlier, it is best used in conjunction with other forecasting methods.

Communicability of Results

This is a particularly strong point. Adept naming of life way groups greatly facilitates communication of highly complex patterns in a graphic and meaningful way.

Credibility to Critics

Difficulties arise on two points. First, many people believe that people's values have little true influence on their private actions or on institutions. They argue that, "when the chips are down," basic external needs overwhelm the "higher" impulses and hence only elemental drives need be considered. Second,

many people seem to feel that almost everyone strives for the same kinds of rewards for the same reasons--that what distinguishes people are "superficial" modes of behavior. These kinds of critics--and they are numerous--are not convinced by eloquence or by survey results; they tend to think that "value successes" such as environmental legislation will be reversed if we find "we can't afford the luxury."

Span of Forecasts

Forecasts based solely on changing values have spans reaching ahead a century or more. Survey-based life way analyses can be--indeed usually are-- very short term.

Resources Needed

Forecasters interested in changing values are the prime resource requirements. A large body of published data is available; more can be had easily enough via formal or informal surveys.

A knack for characterizing and an intuitive grasp of self-consistent constellations of beliefs, values, attitudes, etc., are helpful in generating typologies. The generation of fresh typologies is a major undertaking requiring months of effort. Lesser efforts are required for applying life ways in cross-impact analyses or in structuring survey data.

Special Comments

Planners deeply concerned with public reactions to public programs would do well to extend their knowledge of public surveying techniques to include

life way kind of thinking. Life ways and life styles provide a structuring

framework essential to generalizing from specific poll data.

SYNECTICS

Abstract

Synectics is a well-tested method for developing creative solutions
to problems in business, government, technology, and people situations.
It could probably be used in conjunction with other techniques to generate
alternative futures, forecast trends, and enrich cross-impact analyses.
Courses are offered in the technique which enable organizations to explore
the applicability of Synectics to classes of issues of concern to the
organization.

Definition

Synectics is described by its developers as a technique for "dynamic
group problem solving." The name is a Greek word meaning the joining
together of different and apparently unrelated elements into a synergistic
whole. The total process is a means of applying structured creativity to
a huge array of technical, business, governmental, and people problems.
In a Synectics session a specific problem is defined. The group (usually
less than ten) includes a trained Synectics leader, an expert in the
problem area under study, and random others who hopefully possess reason-
ably unfettered minds. Under the guidance of the leader, the group develops
and discusses analogies to the problem. Having done so in depth, the
leader restates the initial problem and a "force fit" is achieved between
the problem and the analogy. The basic purpose is to force people into

fresh viewpoints based upon (often far fetched) analogies to the problem

calling for solution and in this fashion apply information stored in

corners of the conscious and subconscious mind to the issue at hand.

(Further details appear later under "Procedures.")

History

Synectics as a problem-solving technique was developed in the 1950s

by W. J. J. Gordon. In 1961 he presented his basic approach in a book

called Synectics. A company, Synectics, Inc., was founded in 1960 in

Cambridge, Massachu..... to exploit the approach. Since then a great

diversity of problems .. ..g for creating solutions have been tackled.

Much of this work--including fascinating transcripts of many actual

seasons, some successful and others not-- is described in The Practice of

Creativity by George M. Prince (Harper & Row, 1970). Mr. Prince is

president of Synectics, Inc.

Main Uses

Synectics has been applied in areas ranging from new-product hardware

problems, to business process problems, to people-oriented process problems.

The list below cites specific examples in these areas:

New-Product Problems--Hardware-Oriented

Devise a more efficient fuel cell.

Invent an easier way of applying paint.

Invent a better means of closing a Thermos bottle.

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Devise an instant, portable radio antenna thirty feet tall
that travels in a small package.

Devise a profitable use for a waste by-product.

Expand an interesting piece of technology into a commercial
product line.

Conceive of a new home appliance that fulfills a need that
no one is now aware of.

Discover how to measure the oil content per unit of stone
in a deep formation.

In one model of an army personnel carrier, land mines tend
to trigger a gasoline explosion in the fuel tanks. How
can this be prevented without major alteration?

Process Problems--Business Oriented

Devise a continuing education program in a company--one that
will keep employers interested and alert and will avoid
obsolescence.

Conceive of a more effective method for acidizing oil-bearing
limestone strata.

How can we inexpensively add one pound of chemical to two
tons of grain and have each grain get its fair share?

Devise a new market strategy for a dying brand.

How can a manager in a technical area be most helpful when
a subordinate has a technical problem?

Devise a system for presenting ideas that gives them a
maximum possibility for constructive consideration.

Devise an idea-incentive system that will encourage involve-
ment on the part of everyone from janitor to vice-president.

Process Problems--People-Oriented

How can a bored clergyman renew himself?

How can we make the visiting-physician program in Vietnam
produce more lasting benefits for Vietnamese physicians?

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How can an individual reduce his prejudices?

Conceive of the physical facilities of a new architectural
    school that satisfies the needs of the interested parties
    (students, faculty, townspeople, etc.)

Devise an economical system in which both a slow and a fast
    student can be given what each needs in the same class.

How can we persuade those in power in the --- to pass this
    power downward in an orderly fashion?

Conceive a meaningful way to involve people in the democratic
    process from childhood on.

On a personal level, people familiar with the techniques of Synectics

often claim to be better able to deal with everyday problems of living,

as well as with work-oriented issues.

Limits and Cautions

As in any creativity endeavor, results are unpredictable. In

Synectics, the "forced fit" between analogy and problem (e.g., between

the way a cat acts and a deep oil-bearing stratum) results in what is

called a "viewpoint," which sometimes points to a spectacular solution

to the problem and is sometimes a dud. Proponents of the system like to

refer to Synectics as "dependable creativity," but this is certainly

putting it rather strongly.

In theory anyway, Synectics can be applied to any area of interest,

provided there is such a thing as an "expert" to state the problem and

evaluate the feasibility of viewpoints arising from "forced fits." For

purposes of forecasting alternative futures, conducting cross-impact or

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KSIM analyses, or for projecting trends in specific areas, it seems

possible that some kind of amalgamation of Delphi and Synectics principles

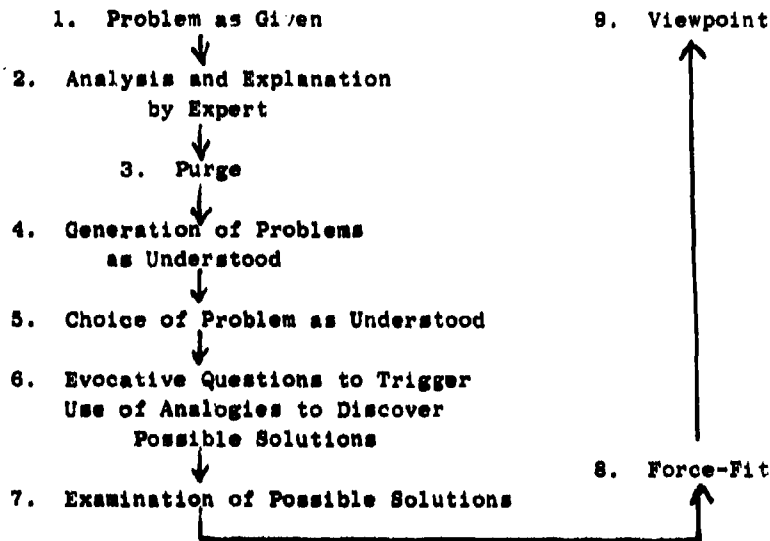would help overcome shortcomings of both approaches.

Other Techniques

Many other techniques strive for creativity. These include brain-

storming, case methods, hypothetical situations, morphological analysis,

value engineering or value analysis, attribute listing, bionics, forced

thinking in specified channels, life way analysis, "genius" scenarios,

utopian or "what if" thinking, and many more.

Procedures

Synectics sessions can be as brief as an hour or several days in

length. As indicated earlier, the group is generally limited in size and

requires the presence of a leader trained in Synectics and of a subject

matter expert. As Gordon, the principal developer of the approach, says,

"The synectics leader is primarily responsible for keeping the investigation

of the problem within the confines of the synectics flow chart and ensuring

the most efficient generation, development, and use of analogical material.

Which analogical route to take is an important decision. It is made by

the leader on the basis of the criterion of constructive psychological

strain. In a people-oriented problem, this means that the leader would

seek analogies from the exact sciences. In a mechanical problem, he might

look to biological models."

Constructive psychological strain can be observed as the participant

stretches himself out of his familiar territory to come up with analogies.

The steps in the Synectics process are depicted below:

1. Problem as Given   9. Viewpoint

2. Analysis and Explanation
        by Expert

        3. Purge

4. Generation of Problems
        as Understood

5. Choice of Problem as Understood

6. Evocative Questions to Trigger
   Use of Analogies to Discover
        Possible Solutions
                                             8. Force-Fit

7. Examination of Possible Solutions

1. Brief explanation of the problem as given. A general statement

is made of the problem to be solved as it may have been given to the group

members by an outside source or as generated by themselves. Some examples:

    Invent a wheelchair that will go upstairs.

    Design a nonfogging bathroom mirror.

    Build an anchor that will have more holding power
        per pound of weight than anything now available.

    Develop a charcoal that will ignite faster.

    Compress food.

    Close openings more effectively.

    Discover new stimulants for the healing process.

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2. Analysis. An explanation of the problem is presented by the most expert in the group, making the strange problem familiar. Enough detail is given about the problem to permit the group to go to work. The expert is a participant. He does not need to try to make everyone as knowledgeable as he is.

3. Purge. The most usual solutions are voiced, evaluated, and purged. Getting these immediate solutions out for an airing permits progress toward more unique and more valuable solutions.

4. Generation of problems as understood. After the given problem has been explored, each participant writes a restatement of the problem as he sees it or a goal he believes would be desirable. It is considered useful to write several versions of the problem which imply different approaches to it.

5. Choice of problem as understood. A momentary agreement is reached by the group on an understanding of the problem.

6. Use of evocative questions. The leader employs evocative questions to stimulate the employment of the analogical operational mechanisms.

7. Examination. A possible solution stemming from stage six is selected by the group for examination. The cycle continues, using evocative questions to stimulate the use of imagination to come up with other solutions and then the examination of these solutions.

8. Force-fit. The solutions produced by the foregoing process are forced into fitting the nature of the problem originally posed. The

attempt to fit the tentative solutions to the problem may result in the problem itself being seen differently and may suggest new lines of speculation.

9. Viewpoint. From the material arising in the force-fit stage, a new viewpoint of the problem is reached, and many potential solutions may arise. One of the basic differences between the Synectics method of operation and traditional problem solving methods is that the latter seek solutions more directly. Synectics seeks new lines of speculation, and these, in turn, lead to potential solutions by means of the force-fit.

Product or Result

The upshot of the Synectics process is a new way of looking at the initial problem. These are as diverse as ideas and can be presented in as many ways.

Level of Detail of Results

Synectics produces a viewpoint--an approach--rather than an "operative answer." In most cases operational details remain to be worked out, although they may be almost self-evident. For example, Synectics hit upon the idea of compressing Kleenex to reduce shipping costs, of freezing cores prior to lifting to study in situ oil conditions, of coating tire rims with epoxies to prevent leakers (a problem because slow leaks caused closely parked cars to fall against each other and be damaged in transit). In each case many technical details had to be worked out following the initial insight arrived at through Synectics.

Level of Confidence of Results

In advance of a Synectics meeting, one can only hope for "breakthrough" results. Viewpoints resulting from a meeting range from self-evidently workable to 99+% certainty that the solution won't work.

Communicability of Results

Usually excellent because the central results of Synectics tend to be non-technical universals understood by everyone. This, of course, does not apply to descriptions of the nature of the problem (often highly technical) or to implementation of Synectics-based solutions (again often technical).

Credibility of Results to Critics

Many people trained in the exact disciplines are uncomfortable with creativity techniques and hence tend to downgrade Synectics. These same critics, however, would certainly admit that Synectics has produced some highly useful results, although many might argue the result could have been arrived at (perhaps faster and with greater assurance of success) through conventional channels.

Span of Forecasts

As applied to social or technological forecasting (perhaps in collaboration with Delphi methods), the forecast span would tend to be mid-range or longer.

Resources

Resources are wholly in the form of people, although a recorder is usually used to tape sessions.

Key personnel are the Synectics leader, the subject expert, and others selected for high energy levels, broad job and/or educational backgrounds, and openness of thinking mode.

Sessions devoted to a major problem typically take two or three days from start to finish. Costs are chiefly for time.

Comments

Organizations interested in installing their own Synectics group can attend intensive one-week courses given at Synectics, Inc. Cost is under $1,000 per attendee.

Synectics, Inc. also offers a three-day "Management Synergism" course (cost about $500). The firm also will direct three-day "Management Synergism" course (cost about $500). The firm also will direct three-day seminars on specific company problems at a cost of $3,000 and up.