Relating Decision Theory and Interactive Planning

By Robert Bordley
General Motors Corporation

Abstract: Decision analysis and interactive planning appear to be two totally unrelated processes. As this paper shows, new results on the interpretation of utility functions and new ways of thinking about downstream decisions allows us to reinterpret interactive planning as a natural extension of decision analysis to complex organizational problems.
Key Words:Corporate Planning, Decision Analysis,Organizational studies

INTRODUCTION

(1.1) The Success of Decision Conferencing

Decision conferencing(Buede and Watson,1988) is a widely used and experimentally validated(Reagan-Cirincione & Rohrbaugh,1992;,McCartt & Rohrbaugh,1989) technique for adapting decision analysis to organizational decisionmaking. In decision conferencing(Phillips,1984), an external technical specialist helps a diverse group of decisionmakers interactively and iteratively construct a model of their shared view of the reality associated with some problem. Doing sensitivity analysis on the model identifies potential new insights for the decisionmakers as well as ways the model could be improved. The process stops when iterative development of the model no longer yields new insights.

(1.2) Ackoff's Challenges

While decision conferencing, and its variants, have accelerated the application of operations research(and especially decision analysis) in organization settings, serious problems still remain. Thus Ackoff and Gharajedaghi(1996) list four reasons why "American operations research is dead even though it has yet to be buried:"

[Problem 1] the structure and the parameters of problematic situations continuously change, particularly in turbulent environments. Because optimal solutions are very seldom made adaptive to such changes, their optimality is generally of short duration They frequently become less effective than the robust systems they were meant to replace…

[Problem 2] In OR's concept of optimality the value of a means is taken to lie exclusively in its efficiency for ends…the value of an end is taken to lie in the satisfaction its attainment brings…OR does not acknowledge, let alone take into account, the intrinsic value of means and the extrinsic value of ends

[Problem 3] Managers are not confronted with problems that are independent of each another, but with dynamic situations that consist of complex systems of changing problems that interact with each other…

[Problem 4] the type of model employed in OR implies a particular paradigm of problem solving. It consists of two parts:predicting the future and preparing for it. Clearly the effectiveness of this approach depends critically on the accuracy with which the future can be predicted. It helps us little and may harm us much to prepare for an ill-predicted future…The models currently employed in OR are evaluative in nature; they enable us to compare alternative decisions or decision rules that are given…The challenge is not so much to improve our methods of evaluation, but to improve our methods of design and invention(pg.324-325, BEST).

There are other concerns as well. For example, many organizational decisions never get implemented. In addition, defending the results of the decision to external groups can be difficult because experienced decisionmakers generally don't think in decision analytic terms(Lipshitz, Klein, Orasanu and Salas,2000).

(1.3) Focus of this Paper

Recent developments (real options, state-dependent utility theory, problem framing, value-focused thinking, implementation techniques, decisionmaker training programs) individually address many of these issues. As our next section illustrates, grafting these new developments on to decision analysis leads to an extension of Howard and Matheson(1978)'s dialogue decision process. Nonetheless the resulting process is fairly complex.

Ackoff(1981,1989) presented his own solution, interactive planning, which is discussed in section 3. Ackoff presents his solution as a decision process which was fundamentally different from decision analysis. The central thesis of this paper is the Ackoff's process can, in fact, be reconciled with decision analysis. To demonstrate this thesis, our fourth section reviews and extends a target-based interpretation of utility theory. Our fifth section then uses this result to develop a target-based approach toward value-focused thinking. As we show, this target-based approach toward value-focusing thinking closely parallels Ackoff's interactive planning process. Our sixth section discusses some other differences between interactive planning and the dialogue decision process and argues for some of the advantages of the interactive planning approach.

2. A Brief Summary of DDP and Interactive Planning

Both DDP and interactive planning begin by assembling two groups of people: stakeholders responsible for the decision being made and experts responsible for doing more of the detail work associated with the decisionmaking. Unlike DDP, interactive planning now begins an in-depth examination of momentum, i.e., of the consequences of the decisions likely to be made in the absence of major change.

Both processes then go into specifying the `ends' for the project. DDP does this by specifying the dimensions of important to the decisionmaker and quantify improvements on those dimensions via utility functions. Interactive planning does this by constructing an idealized alternative and then defining short-term and intermediate-term targets aim at approximating this ideal. Interactive planning also makes extensive use of goal-setting whereas DDP generally avoids goal-setting.

Both processes then focus on identifying the means to reach the ends. Ackoff's process then goes into considerably more detail on how whatever means are chosen are implemented in the organization and how those decisions are tracked.

The fundamental philosophical difference between Ackoff and decision analysis seems to lie in DA's use of utility functions and its avoidance of goal-setting and Ackoff's use of goal-setting and his avoidance of utility functions. In the next section, we show that this fundamental philosophical difference is actually reconcilable.

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After scopingframing the problem, DDP

2. A Variant of the Dialogue Decision Process

Step I-PreFraming

I(a) A decision board is constructed consisting of all the various individuals who have some control over how the decision might be made. This decision board appoints a decision team which, together with a decision specialist, does much of the work. A technical specialist(and possibly an apprentice) is assigned to the project.

I(b) The decision board is given an overview of decision analysis to familiarize them with their responsibilities as a decision board. The decision team likewise gets a much more extensive training for their responsibilities.

I(c) A timeline is organized specifying when various steps in the process occur.

Step II-Framing

II(a) A one-page vision statement is created, specifying `what the team plans to do, why it is being done and how the team will know if it is successful.' Brainstorming is used to raise issues(decisions, uncertainties, criteria, strengths, weaknesses, opportunities and threats.) For each major uncertainty, the team brainstorms the decisions that can be made before and after that uncertainty is resolved. Decisions and uncertainties are arrayed along a timeline.

II(b) Criteria are identified for evaluating any proposed solutions. A planning horizon, defining how far into the future the analysis extends, is defined. (Events and decisions occurring after the planning horizon aren't considered essential parts of the immediate decision problem.) Utility functions are defined over these criteria

II(c) Influence diagrams are used to assess which decisions and uncertainties impact achievement of those criteria

Step III-Alternatives

III(a) Experts assess optimistic, pessimistic & most likely outcomes for each uncertainty.

III(b) The team brainstorms possible alternative choices for each decision

III(c) The decision board defines the momentum strategy as a specification of what choices might be for each decision, if there were no further analysis.

III(d) A few alternative strategies are defined which are distinct and include alternatives favored by significant factions within the organization.

Step IV-Deterministic Analysis

IV(a) A model is constructed to evaluate each proposed strategies under the base-case for each uncertainty. The highest value strategy is identified.

IV(b) Sensitivity analysis is performed on the highest value strategy by varying each of the uncertainties one-at-a-time from its base-case value.

IV(b) If varying an uncertainty can cause the highest scoring strategy to become inferior to another strategy, the uncertainty is considered critical.

Step V. Probabilistic Analysis

V(a) For each critical uncertainty, more refined probabilities are estimated from actuarial data, stockmarket prices and individual opinion.

V(b) A decision tree is constructed using only the decisions and critical uncertainties.

V(c) Sensitivity analysis is performed on the highest value decision by varying each decision one-at-time to identify the critical drivers of value.

Step VI. Interpretation

VI(a) The decision board reviews how these results were reached..

VI(b) The decision board synthesizes a new recommendation which each individual member considers superior to the momentum alternative.

Step VII. Planning for Implementation

VII(a) Those involved in implementing the recommendation, both the immediate decisions and any downstream contingent decisions, are identified

VII(b) These individuals collectively work to develop a detailed implementation plan

VII(c) Budgets and training programs are explicitly set aside for the implementors.

Step VIII. Tracking Implementation

VIII(a). The progress of implementation is periodically checked. Contingencies are identified requiring changes in the implementation plan

VIII(b) Changes are made after assessing the impact and cost of these changes,

VIII(c) Personal and organizational conflicts are resolved as they arise

This process represents an ingenious mixture of brainstorming, project management and analytical analysis. But in practice, many clients view this eight-step process as fairly complex and time-consuming. Ackoff proposed an alternative, interactive planning, which is briefly summarized in the next section

3. ACKOFF's ALTERNATIVE

(3.1) INTERACTIVE PLANNING

Step I- PreFraming

I(a) Recruit Stakeholders who have an interest in the outcome of the decision, experts in the system under study and outside specialists with a broader perspective.

Step II-Formulating the Mess, i.e.,

I(a) Systems Definition: Constructing a systems model of the context in which the problems arise. Specifically Ackoff 's analysis of a system provides

- a description of what the system does…provided by use of flow charts
- the current state of the organization and a reference scenario describing the evolution of that system if it continues along its momentum path
- `the rules of the game', the behavior and practices that facilitate survival, if not thrival, of individuals in the organization (which Ackoff calls the culture)
- a disclosure of internal conflicts affecting the organization or its members
- trends that could affect the organization if they were to continue

I(b) Assessing Momentum: Evaluating what will happen to the organization if it continues its momentum course without change.

Step III-Ends-Planning

III(a): Mission Definition: Define the organization's mission.

III(b) Idealized Design: Construct an idealized version of what the system should be. As Ackoff(1981) writes, *When it comes to considering what a system ought to be…every stakeholder in the planned system can make an important contribution…because participation in idealized design is usually fun, it is usually easy to obtain….consensus arises in idealized design because it focuses on ultimate values rather than on means for pursuing them. In general, people disagree less about ideals than about shorter-range goals and the means for obtaining them…we develop stronger commitments to ideas and ideals that we have had a hand in formulating than to those that we do not. Such commitments considerably reduce the number and difficulty of problems associated with implementation of plans*.(Ackoff, 116-119)

III(c) Defining the Ideals suggested by this Idealized Design

Constructing an idealized design helps identify ideals:

the idealized design…provides a target to which the rest of the planning process tries to come as close as possible. The ideals embodied in an idealized design are the ultimate values that the design tries to approximate. It is usually worth analyzing the design to extract those ideals…Those characteristics of the design believed to be attainable…are either objectives or goals.(Ackoff, pg.125).

III(d) Defining long-term objectives and goals aimed at approaching the ideals as much as possible. Ackoff introduces the three key notions of ideal, objective and goal. (His definition of objective is totally unrelated to Keeney's notion of objective):

The goal of a purposeful system in a particular situation is a preferred outcome that can be obtained within a specific time period. The objective of a purposeful system in a particular situation is a preferred outcome that cannot be obtained within a specified time period but which can be obtained over a longer time period. Consider a set of possible outcomes ordered along one or more scales(e.g., increasing speeds of travel.) Then each outcome is closer to the final one than those which precede it. Each of these outcomes can be a goal in some time period after the `preceding' goal has been obtained, leading eventually to the attainment of the last outcome, the objective(Ackoff,pg.54-55)….An objective is an end that is attainable only in the long run. A goal, on the other hand, is an end that is attainable in the short run….In such games as football, soccer and hockey, goals are intermediate ends, winning is the objective, a longer-run end.(Ackoff,pg.81)

Ends-planning is completed when long-run objectives and short-term goals are specified.

Step IV. Means-Planning:

This step defines the means for achieving the goals and objectives:

Means-planning requires the formulation of alternative ways of completely or partially closing the gaps between the reference scenario and the idealized design. Once formulated, the alternatives should be evaluated and a choice made. In many cases, *however, none of the candidates seemed to be good enough, and even when one does, there often seems to be room for considerable improvement.(Ackoff, pg.173)*

Ackoff carefully distinguishes between one-time actions and procedures, i.e., a sequence of action taken over time. He also recognizes that one can handle uncertainty by:

(1) Partially eliminating it through controlling the causes of the uncertainty,

(2) Partially protecting against it through controlling its effects

(3) Contingency planning for actions that would be taken depending upon how the uncertainty is resolved

Step V. Resource-Planning

V(a) Planning for the Money Required

V(b) Planning for the Plant & Equipment Required

V(c) Planning for the People Required

V(d) Planning for the Materials & Supplies Required

I(e) Planning for the information and knowledge required

While a different kind of planning is required for each of these resources, three basic questions are asked in all phases

(1) How much will be required, where and when?

(2) How much will be available at the required time and place?

(3) How should each shortage or excess be handled?

Step VI. Implementation and Control

As Ackoff writes

Implementation consists of translating the means selected in means planning into instructions that specify who is to do what, where and when. Control consists of monitoring all planning decisions, including implementation decisions, to determine the validity of the assumptions associated with them and the assumptions on which these expectations are based. If the expectations are not realized, control involves determining why(diagnosis) and trying to correct the decision to take the deviation into *account(prescription.)…Those who are assigned responsibility for implementing a decision,…should have direct access to the decisionmakers.(Ackoff, pg.157)*

Ackoff stresses the need for learning and adaptation. Instead of trying to predict the future or make decisions that, on average, do well against that future, Ackoff recommends that the organization have the flexibility to adapt to the future when its current assumptions about the future prove incorrect.

(3.2) Comparison

In many ways, this process seems to be dramatically different from the dialogue decision process. One of the more fundamental differences is in ends-planning. Whereas the dialogue decision process focuses on utility assessment, Ackoff's process focuses on an idealized design, ideals, and objectives. But the next section presents a theoretical result which reconciles these theoretical differences. This paves the way for a reinterpretation of Ackoff's process as a decision analytic process.

4. A New Interpretation of Utility

(4.1)Value Functions versus Utility Functions

In most risky corporate decisions not involving high payoffs, the value of an alternative is often quantified with monetary value instead of utility functions. This use of monetary value versus utility highlights the distinction between:

(1) Value functions measuring only the strength of preference for a known consequence

(2) Utility functions which measure strength of preference and attitudes toward risk

Hence instead of directly assessing a utility function over a consequence, it's common to first quantify a value function and then define utility,u, as a function of value,v. Thus Barron, von Winterfeldt and Fischer(1984) write

Subjects evaluate the relative value of outcomes with a simple value model. Risk is taken into account by a transformation on value, not directly by a utility function over `objective' attribute scales like money…This hypothesis of a two-stage evaluation process--value first, then a risk-adjusting transformation---suggests that a direct assessment of utility functions u_i and u compounds important phenomenon of a subject's evaluation…In many instances, Edward's SMART procedure or BARRON and Person's HOPE procedure will provide good approximations of v(pg.243).

There are many ways of specifying utility as a function of the value function..

(4.2) The Value Function in the Target-Based Interpretation

In this paper, we specify a different way of relating utility to the value function, building on the target-based interpretation of utility(Castagnoli & LiCalzi(1998) and Bordley and LiCalzi(2000)):

Theorem 1: For any utility function u, there exists a non-negative value function,v, and a lognormally distributed random variable, T, such that the utility of a consequence is the probability that the value of that consequence exceeds T.

Proof: See Appendix

Let t be the mode of T. Then utility will be convex in v when $v<t$ and concave otherwise. If v were monetary value, then this would be the S-shaped utility function which Friedman and Savage(1948) postulated to explain an individual's simultaneous preference for insurance and casino gambling. This utility function, like Kahneman and Tversky(1978)'s value function, will also be asymmetric with small losses making a bigger difference to utility than small gains. (In their theory, t would correspond to the reference point[1].) Since Heath, Larrick and Wu(1999)'s experimental work in motivational psychology suggests that the reference point can sometimes be interpreted as a target, we, likewise, will interpret t as the individual's `implicit target.'

Defining e=t/T implies that the utility of consequence c is given by

$$U(c) = Pr(v(c)e > t)$$

(4.3) System Uncertainties versus Environmental Uncertainties

Recall that step II(d) of our decision process defined the problem scope, i.e., specified the decisions and uncertainties that would be explicitly modeled. Suppose we refer to the explicitly modeled uncertainties as system uncertainties and the remaining uncertainties as environmental uncertainties[2]. We will let $v_T(c)$ be the hypothetical value of the consequence defined in light of all factors. Then v(c) becomes the consequence's value when the environmental uncertainties are assumed to be at their modal values. Following Savage, we refer to v(c) as the `small world' estimate of the consequence's value. We can interpret e as the adjustment to this small world value,v(c), required to yield the actual value, $v_T(c)$, i.e.

$$v_T(c) = v(c)\, e.$$

Thus $\log[v_T(c)]=\log[v(c)]+\log[e]$ where log[e] is a Gaussian noise term. Hence our formulation presumes that the effects of neglecting the environmental in calculating a consequence's value can be represented by an additive error term[3].

(4.4) Resolving Ackoff's Second Objection

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[1] Prospect theory postulates that the reference point is manipulable whereas our model makes the mode of T a fixed characteristic of the individual's utility function.)

[2] For example, consider an individual betting on a roulette wheel. Our model might describe all the uncertainties associated with winning money off the roulette wheel. Our model might exclude uncertainties about whether the individual loses the money after leaving the roulette table.

Corollary 1: Consider a gamble X which yields consequence x with probability Pr(X=x). Let V be the corresponding random variable which yields consequences with value v with probability Pr(V=v). If V and e are independent, then the expected utility of the gamble is the probability that Ve exceeds t.

Proof: See Appendix

This corollary assumes that V and e are independent. Relaxing this assumption gives

Corollary 2: The probability of Ve exceeding t equals the expected utility of the gamble when the utility of a consequence is state-dependent.

Proof: See Appendix

Corollary 2 indicates that our utility must be state-dependent, i.e., the utility of a consequence must be allow to depend upon the state in which that consequence was received. Using state-dependent utility functions instead of the conventional utility function implies that the value attached to an action need not be solely determined by the result of that action. Hence it can address Ackoff's second criticism of operations research.

5.Value-Focused Thinking and Interactive Planning

(5.1) Resolving Ackoff's Fourth Objection

Value-focused thinking is explicitly directed at Ackoff's fourth objection and aims to

[3] Savage, of course, stresses the importance of assuming the small world was `separable' from the lather world. Bordley & Hazen(1992) showed that violations of separability would induce apparent violations of utility theory.

design alternatives that optimize our values instead of using values to choose among a prespecified set of alternatives. We now discuss how step II(b) in the dialogue decision process would be implemented using Keeney(1992)'s value-focused thinking.

A critical concept in Keeney's value-focused thinking is `objective':

An objective is a statement of something that one desires to achieve. It is characterized by three features: a decision context, an object, and a direction of preference. For example, with respect to traveling in automobiles, one objective is to maximize safety. For this objective, the decision context is automobile travel, the object is safety and more safety is preferred to less safety.(Keeney, pg.34)

Given this definition, Keeney suggests beginning II(b) by first thinking of idealized solutions which might then suggest objectives

You might ask respondents to describe a perfect alternative or a terrible alternative… then ask what makes it perfect or terrible…the reasoning should suggest possible objectives(Keeney, pg.58)"

As an example of using idealized solutions to suggest `objectives', Keeney writes

In numerous contexts involving consumption, I have heard people state that health and safety risks are unacceptable. The fact is, such risks are unavoidable. They may be reduced or minimized, but not to zero, so these unacceptable consequences suggest objectives(Keeney,pg.).

Hence Keeney's process involves generating an idealized alternative, generating objectives, specifying problem scope, and quantifying a utility function.

We now discuss how a target-based approach to value-focused thinking might proceed.

(5.2) A Target-Based Approach to Value-Focused Thinking

We begin by defining a special kind of objective called an ideal.

Definition: An ideal is defined by specifying a decision context, an object and an ideal point. The direction of preference is toward the ideal point. Thus with respect to traveling in automobiles, one ideal is the absence of harm. For this ideal, the decision context is automobile travel, the object is safety and a slight risk of harm is preferred to a greater risk of harm.

We propose to use ideals in place of objectives. In addition, we also propose replacing utility-assessment with the target-based approach (which involves specifying a value function , an error term, e and a target t.)

As a result, our target-based version of value-focused thinking involves generating an idealized alternative, generating ideals, specifying a time frame(which specifies the error term,e, in the previous section), quantifying a value function, and specifying the target, t. This, of course, is very much what Ackoff's ends-planning stage does.

6. COMPARISON

The previous section showed that ends-planning in interactive planning seems to be a natural target-based way of doing value-focused thinking. This section compares other differences between interactive planning and our decision process.

(6.1) Resolving Ackoff's 3rd Objection

In the dialogue decision process, we define the problem and criteria and generate a momentum alternative and other alternatives. These alternatives are then evaluated against a base-case scenario and uncertainty-by-uncertainty perturbations which are then evaluated. Hence the identification and evaluation of momentum is done simultaneously with the identification and evaluation of alternatives to momentum.

In the Ackoff process, momentum is identified and carefully evaluated up front along with problem identification and criteria developed. (Ackoff sometimes recommends that mess formulation and ends-planning be done by different groups so that the analysis of momentum doesn't contaminate the assessment of an idealized design.) The identification and evaluation of alternatives to momentum is deferred to the means-planning stage.

Why is this important? In most decision problems, momentum has a preferred status. A new alternative will only be implemented if enough individuals consider it preferable to momentum. In order to avoid reinforcing this bias toward momentum, traditional decision analysis treats the evaluation of momentum and other alternatives simultaneously. While this avoids reinforcing the bias toward momentum, it does nothing to eliminate it.

Interactive planning explicitly attempts to undermine the preferred status of momentum upfront by showing how the system will self-destruct under momentum.

(6.2) Resolving Ackoff's First Objection

As Howard(1996) noted, much applied decision analysis tends to focus on evaluating immediate decisions while ignoring the possibility of downstream decisions.

The emergence of real options is beginning to correct this weakness in traditional decision analysis practice. Specifically real options recommends(Luenberger,1998),

(1) Identifying when new information might appear that would cause one to second-guess any decision made now.
(2) Examining ways of creating more future opportunities to collect information (like experiments.)
(3) Exploring ways of decomposing the decision into stages with the ending of each stage coinciding with a point where new information becomes available.
(4) Analyzing the decision as a multi-stage decision.

In theory, this means that an individual trying to solve a decision at time zero needs to specify, in advance, what would be done at later times, depending upon the outcome of various future uncertainties. In some cases, for example, in drug development, it may indeed be possible to specify whether or not drug development will continue at later times as a function of how well the drug passes various future tests.

In other cases, specifying the decision that one would do at later times is frequently difficult because unforeseen uncertainties also emerge at later times. Thus in the automotive sector, changes in market demands, government regulations and corporate priorities can intervene at any time to affect a company's downstream decisions on product development. Hence it can be difficult to ensure that an individual implements downstream decisions at later times in exactly the way anticipated initially.

But as Trigeorgis(1999) and others emphasize, using real options valuation techniques presumes that downstream decisions will, in fact, be implemented as initially presumed.

One possible solution to this problem is the following procedure:

(1) As suggested by real options theory, identify the optimal downstream decisions that should be made given the possible outcomes of various future uncertainties For example, suppose our future uncertainty is the result of a marketing study. If the study is positive, then the optimal downstream decision, from the perspective of the present. is to escalate production. If the study is negative, then the optimal downstream decision is to discontinue production.

(2) Identify the observable contribution which each decision makes toward the long-run objective. Thus escalating production might lead to high profit. Cutting production likewise might lead to low profit..

(3) Define these observable impacts to be the `goal' associated with that uncertainty. Thus the goal associated with a positive result from the marketing study is high profit. The goal associated with a negative result from the marketing study is low profit.

(4) Instead of mandating implementation of the downstream decisions, as planned at

time zero, mandate achievement of the goals.

(5) If unforeseen uncertainties have caused the goals to be grossly unachievable, then have downstream implementers signal the need to rethink the entire decision

This procedure for implementing real options offers downstream managers freedom in making downstream decisions while still holding them accountable for making decisions whose payoffs are consistent with what the original real options analysis had anticipated..

Ackoff's Step II likewise mandates specifying goals as interim steps toward the objective. Hence if these goals are set as suggested above, Ackoff's process will be able to reflect real options Ackoff's Step VI likewise mandates having implementers signal when goals are unachievable and the base decision needs to be rethought.

Using goals---instead of specifying downstream decisions---also has a further motivational benefit. As Locke and Latham(1990,pg.95) observe,

Goals motivate individuals to persist in their activities through time. Hard goals ensure that the individual will keep working for a longer period of time than would be the case with vague or easy goals. Hard or challenging goals inspire the individual to be tenacious in not settling for less than could be achieved.

In addition,the fact that goal-setting is already widely used in organizations(Simon,1978), means that they're likely to be easy to communicate.

7.Extensions: Using the Techniques of Robust Design

Ackoff[4] has suggested that much of the dialogue decision process might be applicable in his means-planning stage. Thus we could potentially graft many of the techniques of deterministic and probabilistic analysis into Ackoff's means planning stage. But since

[4] Personal communication

Ackoff's process is focused on robust design, it seems appropriate to review the deterministic and probabilistic analysis phases of the dialogue decision process in light of common practice in robust design.

As our second section noted, deterministic analysis in the dialogue decision process proceeds by estimating the value of an alternative using base-case levels for each uncertainty and then analyzing how that value changes when each uncertainty is set to its optimistic(or pessimistic) level with all other uncertainties set at their base-values. This simple procedure is generally inconsistent with accepted principles of robust design. As Gunst & McDonald[1996] note:

One-factor-at-a-time experiments & similar `common sense' design strategies continue to be prevalent in industrial experiments in spite of the strong emphasis in statistics courses that these design strategies should be avoided. In justifying the avoidance of such design strategies, technical criteria such as design efficiency and confounding are usually stressed ...Cox(1958, chap.1) lists the following requirements for a good experiment: absence of systematic error, sufficient precision, conclusions that have a wide range of validity, designs and analyses that are as simple as possible, and the ability to assess the uncertainty in the conclusions. The wide variety of statistical designs available permit these requirements to be satisfied to the greatest extent possible within the constraints of time, budget, equipment, and personnel that are imposed by the nature of the experiment. OFAT experiments place a premium on only the simplicity requirement. Cox's requirement of the absence of systematic error, a wide range of validity and the ability to assess the uncertainty in the conclusions cannot be ensured with OFAT experiments.

It's also been recognized that these techniques are applicable to systems dynamic modelling(Clemson, Tang, Pyne and Unal,1993):

The traditional process for conducting a sensitivity analysis is...pick the parameter that seems most likely to be important and, while holding everything else constant, run the model under a full range of different values for that parameter. Repeat the previous step for the next parameter that seems likely to be important. Repeat the previous two steps until patience, money or the list of parameters is exhausted. The difficulty with this one-variable-at-a-time approach is that patience and money are likely to run out before the list of parameters is fully identified. Furthermore parameter interaction sensitivities cannot be identified. As an alternative, Taguchi methods of experimental design[DOE] may provide the analyst with a systematic & efficient way to conduct experimentation for sensitivity analysis...Taguchi methods...allow us to determine with a manageable number of trials, the degree to which a model is sensitive to each of its parameters.

A second objection to the standard approach to deterministic analysis is its inconsistency with the notion of evaluating potential decisions in light of carefully articulated alternative scenarios(Schoemaker,1995). In essence, the dialogue decision process defines its base scenario by having all the uncertainties at their base-case values. Alternative scenarios are defined by allowing only one of these uncertainties to vary from its base-case value. Hence the implicit scenarios used in deterministic analysis could be overly conservative.

Now by construction, DOE leads to scenarios which differ from one another over several uncertainties. However simple allowing DOE software to choose scenarios mechanically leads to scenarios which may not particularly make any intuitive sense. In practice, this problem can be resolved by having:

(1) Experts specify some alternative `titles' or `themes' for scenarios

(2) Using DOE to generate possible scenarios which are then matched to these themes.

(3) Iterating between steps(1) and (2) until we develop scenarios which are both statistically efficient in the sense of DOE and intuitively meaningful

Hence properly used, a DOE approach does allow for more robust design than is likely to come from the conventional approach.

This same `robust design' approach could in theory, also be used for the generation of strategies. In the dialogue decision process, decision board members specify themes for alternative strategies and decision team members `fill in' the possible choices for each decision which seem most consistent with this theme. The technical specialist, of course, urges team members to construct strategies which are `as different as possible.'   But clearly DOE provides a more rigorous way of  ensuring that the strategies are `as different as possible.'   DOE could be used to `fill in'  alternative strategies in the same process suggested for `fleshing' out the scenarios.

The dialogue decision process customarily reports its sensitivity analysis using `tornado diagrams' for the base strategy(in which each uncertainty is varied one at a time, with all other uncertainties at base-level)  and `decision sensitivity diagrams' for the `optimal strategy (in which each decision is varied one at a time with all other decisions at the levels specified by the optimal strategy.)   These charts are generated by computing upper and lower bounds on the impact of each variable. The lower(or upper) bound is computed by calculating the value of the objective function when the variable is set at its pessimistic(or optimistic) level with all other variables at their base-value.

We could generate these same charts using DOE. But in DOE, the lower(or upper) bound as the value when the variable is set at its pessimistic(or optimistic) level, averaged over all possible values which might be assumed by the other variables. As Box et al[1978,pg.311-313] noted, this provides a superior description of the impact of that uncertainty on our criteria:

The main effect for each of the variables is seen to be the difference between...the average response for the plus level of the variable and...the average response for the minus level....Notice that all the observations are being used to supply information on each of the main effects... Suppose that in the above investigation, instead of a factorial arrangement, the `one-factor-at-a-time' method had been used...For such an estimate to have general relevance, it is necessary to assume that the effect would be the same at other settings of the other variables --- that, over the ranges of current interest, the variables act on the response additively. However, (1) if the variables do act additively, the factorial does the job with more precision & (2) if the variables do not act additively, the factorial, unlike the one-factor-at-a-time design, can detect and estimate interactions that measure the nonadditivity...To obtain estimates of the main effects of three variables with the same precision as is provided by the 23 factorial design, the one-factor-at-a-time method would require 24 runs --- a threefold increase. In general, for k factors, a k-fold increase would be required."

As Appendix IV notes, there are some conditions on the objective function and the base-values will make the charts created by DOE identical to those generated by the standard DOE approach.

CONCLUSIONS

More than half a century ago, various axioms of rationality established that individuals act as if they maximize utility functions. Since then, many sophisticated decision processes have emerged based on this notion of utility-maximization. But recently a new target-based interpretation---consistent with these same axioms of rationality---has emerged. This paper focuses on the kinds of decision processes that could be based on this target-based interpretation of decision theory.

We specifically argue that Ackoff's interactive planning process---long regarded as an alternative to the decision analytic paradigm----is consistent with this new target-based interpretation.. While this process has been successfully applied(Kleindorfer & Partovi(1983),Mellalieu & Hall(1983), Taboo,Raples & Teather(1980),Clemson & Lowe(1993), Ackoff(1981), Ackoff & Vergara(1981), Lahr(1983),Ackoff(1999,pg.295-315), it is not viewed as a mainstream tool in decision analysis. In part, this lack of use reflects the belief that it's fundamentally inconsistent with decision analytic principles.

This paper shows that interactive planning is consistent with a target-based Interpretation of decision analysis. In addition, it has several advantages---at least for some problems---over more standard utility-based decision processes and hence should become part of mainstream decision analysis. For example, one special advantage of interactive planning is that it is formulated in language(ideals, objectives and goals) which most decisionmakers understand. Hence it makes the decision process less esoteric.

To illustrate why esotericism is a problem, we quote Howard(1992):

I would no more expect a person with little training to complete an effective decision analysis than I would expect him to perform a successful brain operation, ...An important and fundamental difficulty of decision analysis is that it is expensive. The level of skills required assures that it will always be relatively expensive even in a world where computation is cheap…Only a tiny fraction of decisions will ever be aided by professional decision analysis; we can only hope that among them will be the most important decisions.

In other words, decision analysis is something which a trained specialist does to help a decisionmaker decide; it is not something which the decisionmaker does alone. From this perspective, the decision analyst is much like the psychotherapist(Fischhoff,1983).

We firmly believe that more than `a tiny fraction of decisions' need to benefit from decision analysis. Hence it must become less esoteric. We hope that interactive planning can help the profession in achieving this goal.

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APPENDIX

Appendix I: Proof of Theorem 1:

Scaling:

Utility is conventionally scaled so that the worst outcome,m*, is assigned a utility of 0 and the best outcome,M*, is assigned a utility of 1. We suggest a different scaling. Let c be some reference consequence. We assign it a utility of one half. Now suppose the individual is indifferent between c* versus a p chance of M* and a (1-p) chance of m*. Hence

$$0.5 = p\, u(M^*)+(1-p)\, u(m^*)$$

There are two possibilities:

(1) If p is less than one half, define M=M* and assign M a utility of one so that

$$u(m^*) = (0.5-p)/(1-p) > 0$$

We then define m to be the hypothetical consequence---which is worse than m*---such that the individual is indifferent between an even chance of m and M.

(2) If p exceeds one half, then define m=m* and assign m a utility of zero. Hence

$$0.5/p= u(M^*)< 1$$

We then define M to be the hypothetical consequence---which is better than M*---such that the individual is indifferent between an even chance of m and M.

Transformation

Let U* be a uniformly distributed random variable, scaled to lie between 0 and 1. Then for any consequence c,

$$u(c)=Pr(u(c)>U^*)$$

Let F(x) be the probability of a standard normal random variable being less than x. Thus

$$F(x) = \int_{-\infty} exp(-y^2/2)\, dy$$

Let $F^{-1}(p)$ be the inverse of F and let a and b be arbitrary constants(with b>0). Define a value function,v*, by

$$v^*(c) = a + b\, F^{-1}(u(c))$$

and a random variable W by

$$W = a + b\, F^{-1}(U^*)$$

Then

$$u(c) = Pr(v^*(c) > W)$$

Note that W is a normal distribution with mean a and variance b^2 while v(c) assigns a value of a to a consequence with utility one half and values of minus infinity and infinity to outcomes with utility zero and one. Defining v(c)=exp(v*(c)) gives

$$U(c) = Pr(v(c) > exp(W))$$

where exp(W) is now lognormally distributed. The value function now assigns a value of zero to the worst consequence and a value of exp(a) to the reference consequence.

Appendix II: Proof of Corollary 1

The expected utility of this gamble is

$$Eu(X) = \sum u(x)Pr(X=x) = \sum Pr(v(x)+T^*>t)Pr(X=x)$$

The gamble X induces a gamble V which yields consequences with value v with probability Pr(V=v). Hence

$$Eu(X) = \sum Pr(v+T^*>t)\; Pr(X=x)$$

If X and T* are independent, then Castagnoli and LiCalzi's result(1998) can be extended to imply that Eu(X)=Pr(V+T*>t). (Bordley and LiCalzi(2000) showed that this independence assumption can be partially relaxed.)

APPENDIX III: Proof of Corollary 2

Note that

$$Pr(V+T^*>t) = \sum Pr(v+T^*>t|V=v)\, Pr(V=v) = \sum u(v|V=v)\, Pr(V=v)$$

If there is a one-to-one mapping between consequences and the value function, this becomes

$$Pr(V+T^*>t)=\sum Pr(v(x)+T^*>t|X=x)Pr(X=x)=\sum u(x|X=x)Pr(X=x)$$

where the utility of the consequence, u(x|X=x) is now conditioned on the state in which that consequence arose. (Hence the value of a consequence depends upon how that consequence was achieved.)

APPENDIX IV: When DOE & DDP Correspond

As noted before, the upper(or lower) values associated with each variable in DDP is just the value of the objective function when the variable is set to its upper(or lower) value and all other variables are set to their base values. In contrast, DOE defines that value as the value when the variable is set to its upper(or lowr) value averaged over the value of all other variables.

Suppose we let $u(x_1,\ldots x_n)$ represent the value of our criterion as a function of $x_1\ldots.x_n$. Let U_k be the optimistic value for x_k, let x^0_k be the base-value and let N(k) be the number of possible values considered for variable k.. Then DDP and DOE will yield the same sensitivity analysis charts if

$$(**) \quad u(U_1,x^0_2\ldots.x^0_n) = \Sigma_{x(2)\ldots..x(n)}$$

$$u(U_1,x_2,\ldots.x_n)/[N(2)N(3)\ldots.N(n)]$$

If $u(x_1\ldots.x_n)$ satisfies the utility-independence conditions of multriattribute utility theory and if R is some subset of (1,….n), then there exist functions $u_k(x_k)$ and constants C_R such that

$$u(x_1\ldots.x_n) = \Sigma_{R \text{ in } (1\ldots.n)} \Pi_{k \text{ in } R}\, C_R \;\; u_k(x_k)$$

Suppose we also define x^0_k by

$$u(x_k^0)=\Sigma_{x(k)}\, u(x)/N(k)$$

i.e., the base-value is the certainty equivalent of a gamble with an equal chance of yielding any of the possible values of x_k. Given this specific choice of certainty equivalent, it's easy to show that (**) holds.