WORKING PA

ALFRED P. SLOAN SCHOOL OF MANAG

MASSACHUSETTS
INSTITUTE OF TECHN
50 MEMORIAL DRI
CAMBRIDGE, MASSACHUSE

(NASA-CR-129592) AN EXPERIMENT WITH INTERACTIVE PLANNING MODELS Working Paper J. Beville, et al (Massachusetts Inst. of Tech.) Dec. 1970 30 p CSCL

N73-13986

Unclas
05AG3/34 49556

30P

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

2

AN EXPERIMENT WITH INTERACTIVE PLANNING MODELS

James Beville
John H. Wagner
Zenon S. Zannetos

December, 1970 503-70

NTIS: HC $3.50

This paper is part of a continuing research effort of the Managerial Information for Planning and Control Group at the Sloan School of Management at M.I.T.. The support of the Army Material Command, the Land Education Development Grant, NASA, and the I.B.M. Grant to M.I.T. for Computation support is gratefully appreciated.

I. Introduction

In the past, management scientists have mainly focused their attention on the design of decision systems aimed at the solution of programmable and recurring problems. Such areas as inventory control and refinery scheduling can now be managed almost automatically by computer driven mathematical models. Although such models may require extensive as well as complicated mathematical manipulations, yet in their normal use they are rather simple in that the fundamental relationships encompassed by these models are well prescribed. Martin Starr (Starr 1966) refers to problem situations which can be depicted by such deterministic planning and control models as "fully-constrained,"[1] because their associated environments, although these may be evolving, they are considered to be perfectly predictable and all sequences of events are known with certainty.

Next in terms of complication come planning models which are probabilistic in nature either in their inputs (both data and assumptions), or in the fundamental mathematical relationships among the variables incorporated into these models.[2] These planning models which one may classify as partially constrained (Starr 1966), lead to tentative consequences requiring the value judgment of the decision maker before a

---

[1]We will use Starr's, 8, terminology for classification of planning models.

[2]As the reader may have already observed, we are classifying these models on the basis of the structure chosen by the decision maker in his effort to choose a course of action and not on the basis of how these decision situations <u>could have</u> been structured. Obviously fully constrained models could be set up as probabilistic models. With the exception of pointing this out we shall not delve into the question of the factors affecting choice of models, nor in the evaluation of the degree of comprehensiveness of such.

choice is made. Finally, in extreme cases, planning problems may be depicted by threshold-constrained systems (Starr, 8) in which the sequence of events is speculative, the environment must be forecasted, and some potential outcomes may be catastrophic.

The problem used in our experiments was of the "partially constrained" type. We wanted to find out how executives could deal with capital investment and competitive pricing decisions under conditions of uncertainty.

Many writers have pointed out the value of formal planning[3] and also stressed the necessity of using structured situations as a stepping stone to higher level (unstructured) planning. Of course this is easier said than done, and the average manager partly because of necessity but mainly for escape finds himself spending proportionately much more time on operational than on planning problems. This relative aversion toward planning is due both to psychological as well as methodological reasons. No doubt planning enforces self discipline, requires persistent effort, provides standards which can be potentially used by superiors for control and accountability, exposes errors and as such decreases privacy, enforces integration and cooperation across organizational functions and activities, with all their human-behavior consequences; and finally demands a resolution of the inherent conflict between the specific plan as a <u>secure</u> basis for implementing action and the plan as a temporary mechanism for measuring deviations, learning from experience and then updating the underlying planning model.[4]

---

[3]Among others, see Ackoff, R. L., 1, Ansoff, H. I., 2, Starr, M. K., 8, and Zannetos, Z. S., 10.

[4]What we are saying here is that "security" and shielding by the plan is only temporary and the manager cannot survive with either chaos or complete regimentation.

Zannetos (10 p. 13) has identified three reasons why planning problems are more difficult than operational problems. They are:

1. Absence of structure
2. Absence of many factual elements
3. Presence of uncontrolled environmental conditions

Realizing the complexity of planning problems and the difficulties associated with designing useful computerized decision systems to aid the decision maker in solving such problems, we embarked upon a research project which called for the design, implementation and experimental use of a computerized planning model. The risk analysis technique (Hertz, 4) was chosen as the basis of the model because it incorporated (1) a facility for structuring problems, (2) a methodology for utilizing subjective estimates of elements for which no factual information exists and (3) a technique for introducing risk and uncertainty through the use of subjective probability distributions. While the risk analysis technique does not eliminate the three major reasons why planning problems are difficult, it does recognize them and operates on them, and thus mitigates this onerous managerial task.

It was decided from the outset to implement the risk analysis model on an interactive graphical display computer terminal. This decision was made for the following reasons:

1) Interaction was necessary since the system operates on subjective inputs provided by the user.
2) Since planning decisions are partly based on value judgments and subjective inputs, the user must have the capability to ask "what if" type of questions and receive answers in real time. In this respect we distinguish between two classes of situations. If the "what if" question involves changing the

values of some inputs but does not involve changing basic underlying assumptions, it is defined as sensitivity testing. If it involves changing most, or all, of the values of the inputs and also changing the basic underlying assumptions, then it is defined as a new alternative. These two uses of the system will be discussed in more detail later.

3) Since the risk analysis techniques utilizes probability distributions as inputs and outputs, it was felt that graphical representation of the distributions would be more meaningful and useful than would tabular or parametric representation.

The end product of the systems development effort was a software package called the Interactive Risk Analysis Model (IGRAM) System which is available on the Compatible Time Shared System (CTSS) at MIT's Computation Center.[5]

After the IGRAM System was developed during the early part of 1970, two controlled experiments were conducted which attempted to measure the impact the IGRAM System had on a decision-making process. The next portion of this paper is devoted to a discussion of those experiments.

II. The Experiments

1) Introduction

A review of the available literature on planning reveals that it mostly centers around the need for planning models and to a much lesser extent on the implementation of models. There is, however, a dirth of literature on the observed impact these models have had on the decision making process. In an effort to fill this deficiency in the literature,

[5] For a detailed discussion of the design and implementation of the IGRAM System, the reader is referred to Beville, J., et.al., 3.

it was decided that controlled experiments should be conducted using the IGRAM System. Our objective was to gather data from experiments which could be used in analyzing the impact of the system on decision making (both the results and the process) and also in gaining insights for the design of future man-machine systems.

2) The Experimental Design

Two sets of subjects were available (business executives), so the experiment was replicated twice. The experimental design was completely randomized with two treatments, the latter being: (a) solving a complex pricing problem using manual solution techniques and (b) solving the same problem with the aid of the IGRAM System. In each replication of the experiment the subjects were assigned to two-man teams at random. Members of the odd numbered teams solved the problem with manual methods first and then solved it with the aid of the computerized IGRAM System. Members of the even numbered teams solved the problem with the aid of the IGRAM System first and then solved it with manual methods. This ordering scheme was intended to neutralize the learning effect of having to solve the problem twice. Figure 1 illustrates the sequence of steps taken by the teams during the conduct of the experiment. Copies of the referenced questionnaires are contained in Appendix A.

Figure 1

Experimental Procedure

Order of Events

Odd Numbered Teams	All Teams	Even Numbered Teams
	Answer Questionnaire #1. Receive Copy of Case Receive Hertz* Article	
Solve Case Manually Answer Questionnaire #2		
	Receive Copies of IGRAM Users' Manual Briefing on and Demonstration of IGRAM System.	
	Solve problem with IGRAM System	
Answer Questionnaire #3		Answer Questionnaire #4 Solve Case Manually Answer Questionnaire #5
	Class Discussion of Problem and IGRAM System	

*See Hertz, D. B., (4).

III. The Subjects

a) Senior Executives

The participants in the first replication of the experiment were twenty businessmen holding high level positions within their organizations and who had been attending the Spring 1970 session of the Senior Executive Program, at the Sloan School of Management at M.I.T.. The program is nine weeks long and is designed to update the senior executives' knowledge of modern management techniques and expose the participants to present research and future trends in the field of management. The executives were in their seventh week of the nine week program when the experiment started. During the program, the executives were housed in Endicott House, a suburban mansion belonging to M.I.T.. With this arrangement, the participants had unlimited opportunities for exchanging ideas. On the whole, the Senior Executives were interested in the experiment and enthusiastic about their participation, which incidentally was voluntary.

b) The Greater Boston Executives

The participants in the second replication of the experiment were twenty-five businessmen from the Greater Boston area who had been selected by their firms to participate in the Spring 1970 session of the Greater Boston Executive Program. The program is conducted by the Sloan School of Management and lasts fifteen weeks. The participants attend classes only during each Friday of the fifteen weeks, and perform their regular duties at their firms during the other four days of the work week. The four class periods each Friday are designed to update the executives' knowledge in the areas of economics, managerial planning, information and controls, labor economics and social responsibility.

This program is not as extensive in its coverage as the Senior Executive Program. Furthermore, these executives generally hold positions of lesser responsibility than do the Senior Executives, are not as mature managerially, are younger in age and comparatively less well educated than the Senior Executives. The Greater Boston Executives were in their sixth week of the program when the experiment started.

Unlike the Senior Executives (SE), the Greater Boston Executives (GBE) lived at home during the program. Practically the only contact they had with each other was during the Friday classes and during activities associated with the experiment.

IV. Expected Impacts

If we use for reference the phases of the decision making process as postulated by Simon[6]--intelligence, design, and choice--the IGRAM System was expected to affect only "design" and "choice," the intelligence, i.e., problem definition, having been taken care of by the material distributed to the subjects. In particular we were hoping that the system would help the user in the "design" phase by:

(1) Facilitating the structuring of the alternative courses of action

(2) Bringing to bear on the problem the decision-maker's subjective estimates of the values of uncertain variables.

(3) Performing the complex computations required to accomplish (2) above.

(4) Facilitating sensitivity testing.

---

[6]See Simon, H. A., 7. Other writers on the subject (especially Ackoff 1, Starr 8, and Zannetos 10) tend to look at these phases as aspects of the planning process.

As for "choice" activity, the system was not so much intended to make the choice, but hopefully aid the decision-maker in evaluating more effectively the alternatives generated by:

(1) Providing more information than do manual methods. The system accomplishes this mainly by providing a graph of the probabilistic distribution of the net present values rather than just the expected value of such which is normally provided by manual methods.

(2) Displaying information in a format which is easy to understand. The system for example provides graphs rather than tables of values or mathematical descriptions of the various probability curves.

(3) Allowing the decision-maker to comprehend the impact which his subjective estimates of risk and uncertainty have on computed expected outcomes.

(4) Making it easy for the subjects to change the values of the planning and decision variables and thus easily evaluate and choose among alternatives.

V. Hypotheses to be Tested

The hypotheses which we wanted to test were mainly as follows:

1) The subjects will tend to examine more alternative courses of action when using the computer than they will when solving the case manually.[7]

[7] Morton's work (Morton, M.S.S. 5) tends to support this hypothesis which seems to be rather widely accepted.

2) The subjects will tend to have more confidence in their computer-aided decision than in their manual decision. This proposition appears *a priori* to be reasonable for the following reasons:

(a) The system allows the subjects to bring to bear all of their knowledge--objective, subjective and risk estimates--on the evaluation of the future consequences of each alternative course of action. Thus the results will tend to appear to them as more dependable and "scientific."

(b) The system gives the subjects better knowledge of the structure of the problem, and through sensitivity testing, an idea of the relative impact exerted by the key variables on expected outcomes. They will feel therefore that they have a firmer grasp of the problem and that the computer-aided decision rests on a firmer foundation.

(c) The system carries out the calculations and gives the decision-maker additional quantitative information concerning the degree of risk and uncertainty associated with a proposed course of action. The additional information in this case consists of the graphs of the various terminal probability distributions, which is normally not available under manual methods.

(d) The system displays probabilistic information in formats, namely graphs, which are easier to understand than alternative formats, such as tables or listings of distribution parameters.

(e) Psychologically the subjects may feel insecure and tend to accept the results of manipulations they do not very well understand. Furthermore, the feeling that systems are designed by "experts" who undoubtedly store in the computer the best decision-making models known to them tends to encourage too much faith in the results of such models.

3) The decisions made with the aid of the computer, that is, the courses of action recommended, will differ from these suggested by manual methods. This is felt to be true because:

(a) The system provides the subjects with more information concerning risk and uncertainty than they will be able to generate by using manual methods.[8]

(b) When using the computerized system, the subjects will tend to rank the risk and uncertainty inherent in an alternative higher as a factor influencing their decision than they will when using manual methods. This appears logical since measures of risk even in their simplest form, e.g., variance, and general shape of the distribution of net present values, will be nearly impossible for the subjects to generate by using manual methods. They, therefore, will not tend to appreciate the significance of risk in decision making. If this hypothesis is proven then certain aspects of the educational value of the computerized system are proven also.

---

[8] The underlying assumption here is that the executives are able to comprehend and process this information. Schroder, H. M., et.al., 6, have found that beyond a certain point of environmental complexity people tend to process less information. In our case the structure provided by the system reduces the complexity so we do not believe that we will be reaching beyond the maximum information processing point.

VI. Measurement Instruments

Three types of instruments were used to collect data during the experiment. They were:

1) A set of five questionnaires.
2) Written solutions to the case which were handed in by the teams, one for manual solution and one for the computer-aided solution.
3) An informal debriefing of each set of subjects in order to obtain their reactions to the IGRAM System in particular and to the use of planning models in general. In addition, the research assistants who observed the subjects during their computer terminal sessions gathered valuable informal data.

VII. The Problem

The problem which each subject had to solve twice and which was implemented on the IGRAM System was a capital investment case study. Two basic alternative courses of action were open -- 1) discontinue producing a textile product which was a part of the firm's full line of textiles, sell off the associated equipment and inventory, and collect the associated accounts receivable; or 2) continue producing the product for the next four years (the equipment would be worn out at that time) and, given that decision, further decide upon the best pricing strategy to follow.

The problem was implemented on the IGRAM System in the form of a problem tree, as shown in Figure 2. The "Stay in Business" alternatives 1 and 2 represent two different pricing strategies over the four year time horizon. Such elements as Industry Volume and Market Share would be adjusted in each case to correspond with the particular pricing strategy chosen. For instance, a high pricing strategy might call for a smaller industry volume

and a smaller market share than would a low pricing strategy. All inputs to the elements on the end points of the tree are in the form of cumulative subjective probability distributions.[9]

VIII. Analysis of the Experimental Data

We will now analyze some of the data which were collected on the experiments and compare the odd numbered teams to the even numbered teams within each replication of the experiment. In addition, comparisons will be made between the results generated by each of the replications.

As the reader may recall, the primary difference between the odd numbered and even numbered teams, within each replication, was that the odd numbered teams solved the problem manually before solving it with the aid of the IGRAM System, while the even numbered teams first solved it with the aid of the computer system. The main difference between the two replications of the experiment was the difference in the managerial experience and education of the two sets of subjects. As we have already stated, in general the Senior Executives (SE) had more management and general education than did the Greater Boston Executives (GBE). With these differences in mind, let us now examine the experimental data.

1. The Decision Made

The case that we used for the experiments was structured so that the net expected values of the alternatives were very close together. This was done in order to elicit the value judgments of the subjects, their utility

[9] For a more complete description of the IGRAM System, the reader is referred to Beville, J., et.al., 3.

B

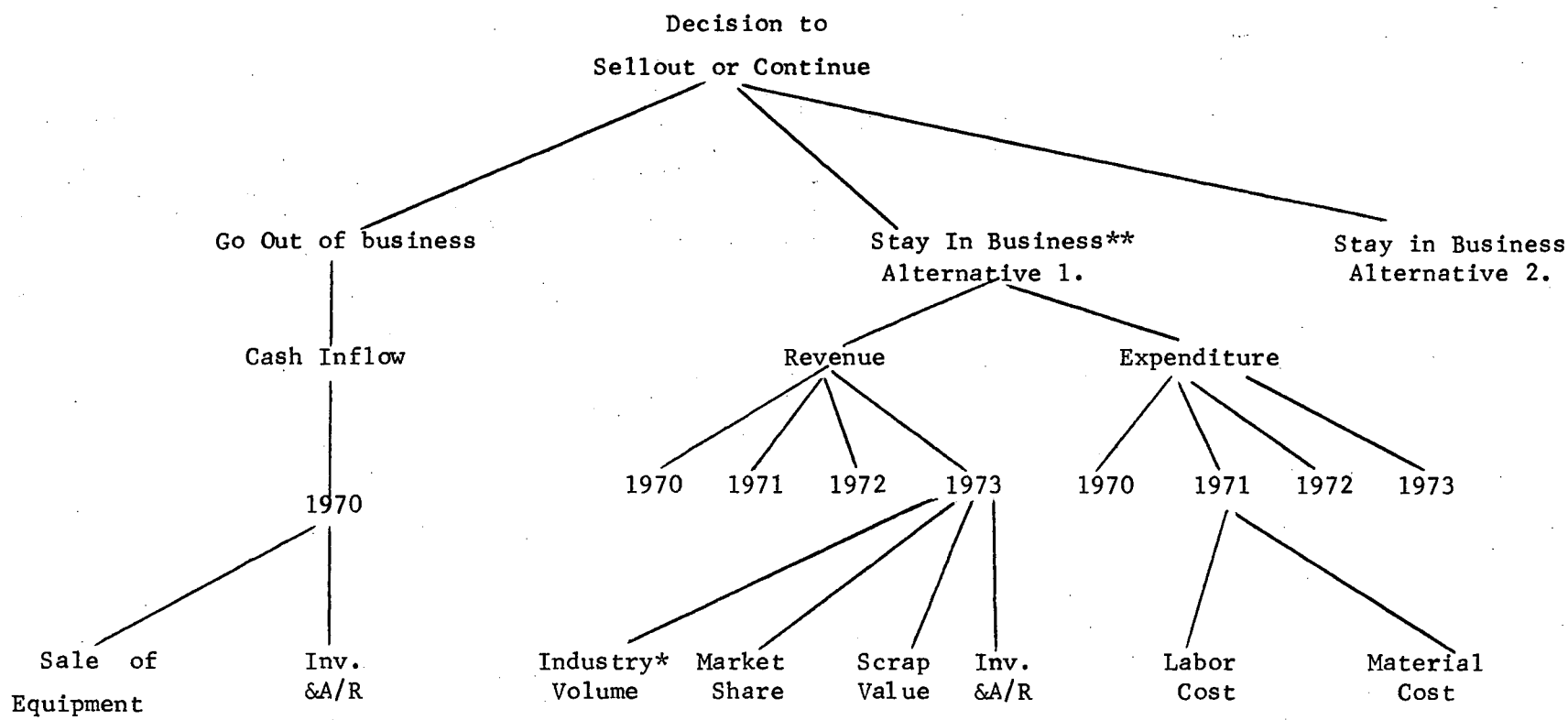

Figure 2. Structure of the Problem Tree Implemented on the IGRAM System

*Subjective probability distributions are entered at this level in the tree.

**Prices for each year and the cost of capital are entered at this level in the tree.

regarding risk and uncertainty and any other intangible elements which might creep into their decision-making process. Given the above experimental bias, the results of Table 1, which represent the number of changes in decisions after the experiments, tend to substantiate our hypothesis that decision are affected by the computer. A little further we will look into the reasons behind most of these switches, but right now let us look at the data of Table 1. In the context of the question asked, the decisions of a subject were defined as "switched" if one recommended that the company discontinue making the product, while the other decision recommended continuation of operations.

Of the sixteen Senior Executives who used the system and completed the experiments, only two reported a switch in their decision.[10] In sharp contrast nine out of twenty one Greater Boston Executives switched. This may lead us to hypothesize that the Senior Executives are possibly more conservative than the relatively younger Greater Boston Executives, or that the latter were not as mature and thorough in their original analysis and therefore learned relatively more after the first solution than did the Senior Executives. In our estimation, it is mainly the relative immaturity of the Greater Boston Executives in making high-level decisions which is manifested in the results and this is supported by evidence presented in Tables 3 and 4.

If we were to assume that all the subjects belong to the same universe then we would expect to find approximately five[11] Senior Executives switching instead of two and six Greater Boston Executives instead of nine. Also, if the "treatments" were neutral we would expect to find about five switches

---

[10] There were twenty Senior Executives in the program but only sixteen volunteered for the experiment. The respective figures for the Greater Boston Executive program were 25 participants and 21 volunteers.

[11] The figures are rounded to the nearest integer.

Table 1

Differences Between Computer-Aided and Manual Decisions

Senior Executives

	Odd Teams	Even Teams	Total
Switches	2	0	2
No change	7	7	14
Total	9	7	16

Greater Boston Executives

Switches	5	4	9
No change	4	8	12
Total	9	12	21
Grand Total	18	19	37

Note: Odd Teams solved the case first manually and then used the system while the Even Teams did the opposite.

occurring among the odd teams and six among the even teams instead of seven versus four respectively.

While we do not wish to strain the limited amount of data we have for statistical significance, it is evident to us that the data suggest that there exist differences between the Senior Executives and the Greater Boston Executives and also between the odd and the even teams.

In Table 2 we present the qualitative decision made by those who switched. The data reveal that the six of the ten subjects, for whom complete information exists, chose to continue the production of the product when they used the system and chose to discontinue its production when they solved the problem with manual methods. Five of these six subjects belonged to the odd-numbered teams which solved the case manually at first and then used the computerized system.

In order to ascertain the reasons behind the switches we asked the subjects to tell us which decision they preferred and to qualify the change of decision. Out of eleven, ten provided information and indicated that all ten would stick to their computer-aided decision. The reasons behind the "switches" are listed in Table 3.

At first glance there appears to be a discrepancy between some of the evidence contained in Tables 2, 3 and the "absolute" faith in the computerized decision shown by those who switched. Especially in view of the four switches among the even-numbered team members who, as the reader may remember, solved the probelm manually before using the computer. What the subjects are actually saying is that the data they developed manually dictated a decision opposite to the one they arrived at with the aid of the system. However, if they had to choose between the two different solutions, they would stick to their computer-aided decision.

Table 2

Differences Between Manual and Computer-aided Decisions for those subjects who Changed their Decisions

	Number Reporting	Decisions	
Senior Executives			
Odd Numbered Team Members		Manual	Computer-aided
	2	Discontinue	Continue
Greater Boston Executives		Manual	Computer-aided
Odd Numbered Team Members	4	Discontinue	Continue
	1	Continue	Discontinue
Even Numbered Team Members		Computer-aided	Manual
	1	Discontinue	Continue
	2	Continue	Discontinue
	1	No data available	

Table 3

Reasons for Switching Decisions and Occurrences

Reasons Provided	Odd Team	Even Team
Senior Executives		
The subject made errors in manual solution	1	
The assumptions were not exactly the same	1	
Greater Boston Executives		
The subject did not consider the same costs for every input required in both solutions	2	
The computer provided more data		3
The subject made errors in manual solution	1	
No reason given	2	1

The results of Table 3 further indicate that the computer system forced two of the odd numbered team members within the Greater Boston Executives to use only the relevant variable costs in the analysis of the alternatives. These subjects had used some fixed costs in their previous manual solutions, but subsequently the computer guided them to the relevant differential costs. In other words the computerized system imposed a methodological discipline. Three even-numbered team members did, however, indicate that their computer-aided decisions were based on more data than were their manual decisions. In this respect we must assume that the additional data were the graphs of the distributions of net present values since that was the only new information which was generated by the system. Unless of course the availability of easy computational power was mislabeled as "more data."

We must admit that we expected more dramatic differences between the two modes of decision making. Possibly, the limited range of differences between the manual and computer-aided decisions can be explained in part by the abstraction of realism in the experiment. A decision maker in real-life situation would no doubt possess a great deal more intuition and judgment than did the experimental subjects, and he might therefore be able to specify better probability distributions than those devised by the subjects. Also, as already explained, the expected values of the two major alternatives posed in the problem were intended to be so close together that any decision would have to be made on the basis of the differences in the shapes of the net present value distributions, "intangibles" and qualitative assumptions. When proper manual methods were used, the expected net present values for the two major alternatives--continue or discontinue--were almost identical. However, when the subjects used the system they tended to make

optimistic sales projections which tipped the scales in favor of continuing production of the item. This fact made it easy for the subjects to make their computer-aided decision without having to differentiate between the alternatives on the basis of the shape of their corresponding distributions of net present values. Both the transcript of the subjects' use of the computerized systems as well as the data of Tables tends to substantiate this explanation. As can be seen in Table 2 of the seven odd-numbered team members[12] who switched, only one decided to discontinue with the other six deciding to stay with the product.

2. The Decision Making Process

(a) The hypotheses that subjects would rank risk higher as an influence on their computer-aided decision than on their manual decision received mixed support. The Senior Executives responses supported the hypothesis while the Greater Boston Executives responses did not support it. In addition to a possibility that this hypothesis is not valid there may be two other explanations of the reaction of the Greater Boston Executives: (i) Being less mature, as managers these subjects may not have appreciated the importance of risk in decision making and (ii) the question attempted to make a ranking distinction between risk, short-term, and long-term profitability as criteria for managerial choice. It is quite probable that these subjects were unable to make such fine distinction especially since risk is not completely independent from short and long term profitability.

[12] The reader is reminded that the odd-numbered teams attacked the problem manually at first and then worked with the system.

Table 4

Number of Alternative Courses of Action Examined

SE

Computer-aided		Manual		Both	
Odd	Even	Odd	Even	Odd	Even
m=5.56[1]	m=3.43[1]	m=5.00[2]	m=2.86[2]	m=5.34[4]	m=3.14[4]
v=2.25	v=0.858	v=6.29[3]	v=0.8[3]	v=4.00[5]	v=0.508[5]
n = 9	n = 7	n = 8	n = 7	n = 17	n = 14

GBE

Computer-aided		Manual		Both	
Odd	Even	Odd	Even	Odd	Even
m=3.67[6]	m=2.66[6]	m=3.70[6]	m=2.50[8]	m=3.68[10]	m=2.58[10]
v=6.00[7]	v=0.427[7]	v=5.34[9]	v=0.455[9]	v=5.34[11]	v=0.417[11]
n = 9	n = 12	n = 9	n = 12	n = 18	n = 24

Where m=mean of the sample; v=variance of the sample; and n=sample size

1. T-test on difference means is significant at 0.1% level.
2. T-test on difference between means is significant at 5% level.
3. F-test on ratio of variances is significant at 2.5% level.
4. T-test on the differences between the means is significant at the 0.1% level.
5. F-test on the ratio of the variances is significant at the 1% level.
6+8. Difference is significant at the 10% level.
7+9+11. Ratio of variances is significant at the 1% level.
10. Difference is significant at the 5% level.

(b) The results in both replications only weakly supported the hypothesis that decision makers would examine more alternative courses of action when using the system than when using manual methods. Table 4 contains the results of the experiments.

As can be seen in Table 4, the only case where a set of teams reported examining fewer alternatives when using the computer system than when using manual methods (3.67 versus 3.70) was the odd-numbered GBE teams. All other teams reported an increase although in no case the mean differences were statistically significant. The startling result revealed by these data is that the odd-numbered team members in every instance, examined significantly more alternatives than did the even-numbered team members. In the case of the Senior Executives, the odd-numbered teams examined 5.56 computer-aided alternatives versus 5.00 manual alternatives while the even-numbered teams examined 3.43 and 2.86 alternatives respectively. The overall average number of alternatives examined was 5.34 for the odd-numbered teams versus 3.14 for the even-numbered. These data are statistically significant at the 0.1% level. Similar results are revealed by the Greater Boston Executives experiments although not as strongly. Another startling observation is the difference in the variances between the odd and the even-numbered teams, which differences are again statistically significant at the 0.1% level. The fact that the odd-numbered teams solved the problem manually first, seems to have had an important influence upon their decision on how many alternatives to examine.

A possible explanation of the results of Table 4, is that the method initially used by a decision-maker sets the style he will use in subsequent decision making including the general number of alternatives he will examine before arriving at a decision. When the odd-numbered teams first approached

the problem manually, they were possibly not very confident in their manual methods of considering risk and uncertainty. Therefore, they examined many different alternative courses of action before they made their final decisions. The even-numbered teams, however, first solved the case with the aid of the computerized system. They possibly had a high degree of confidence in the way the computer system handled risk, so they did not feel the need to examine many alternatives. The high level of confidence of the even numbered teams, therefore, may have led them to a strange sense of security which resulted in their examining fewer alternatives, on average, than did the odd-numbered teams. We presented the results to the participants without expressing our views as to the cause and they provided the same explanation.

Hence, the method first used by the decision-maker sets the style he will use in subsequent decision-making. Given their respective styles, as reflected by the number of alternatives they considered, three of the four groups did, however, examine more alternatives when they used the system than when they used manual methods. We must stress again, however, that for each group, the mean differences between the number of alternatives examined (computer-aided versus manual) were not statistically significant, contrary to widely held notions.

(c) In accordance with out previously stated hypothesis, the subjects in both replications reported that they had more confidence in their computer-aided decision than they had in their manual decision. This was reported in spite of the fact that only 11 of 37 subjects changed their decisions.[13]

[13] As we have already stressed, the subjects may have changed decisions or not simply on the basis of the output data of the method used. However, even those who switched decisions after they attacked the case manually still had more confidence in the computer-aided decision.

So, even in the cases where the manual and the computer-aided decisions were the same, (in fact even in the case where the subsequent manual method dictated a switch), the subjects had more confidence in their computer-aided decision. The causes for the higher degree of confidence in the computer-aided decisions were traced to:

(1) The subjects confidence in the "risk analysis method" of handling uncertainty.

(2) The additional information the system provided in the form of graphs of the distributions of net present values.

(3) The structure imposed on the problem by the system.

(4) The ease with which the subjects understood the graphical information.

(5) The subjects ability to perform sensitivity tests, that is, ask "what if" questions of the system.

(6) The "fact that the system was designed by experts who must have for sure incorporated in it the latest management science techniques."

The results under (b) and (c) above may also indicate another phenomenon which Schroder has observed in his experiments[14]. He found that after a certain degree of complexity in the environment the subjects tend to process less information and yet feel more confident in their decision. So it could be that trying fewer alternatives, as did the even-numbered teams, was a manifestation of an inability to cope with the complexity of the computerized case which resulted in a bias toward a lower level of information processing. These are among some challenging hypotheses which we intend to explore in the future.

---

[14] Related to one of the authors.

IX. Implications of Planning Models for Management

Based on the results of the experimental use of the IGRAM System, we feel that planning models, such as the IGRAM System, hold an exciting promise for management in the future. The following are some of the uses which we foresee:

1) As a central tool. The IGRAM System requires the user to input his subjective estimates of future states of nature, and decisions are made based on the information generated from those estimates. All of this information can be stored in machine readable form and can be quickly accessed by the user. It seems natural that managers will want to review the progress of projects which were approved with the aid of the IGRAM System or one similar to it. These reviews could be made very easily by examining the original assumptions and estimates and comparing them with later appraisals of the situation. Current data could be periodically introduced into the system to facilitate such reviews. Quick, convenient, real-time, computer-aided reviews would help the decision-maker detect problems--assumptions which are not coming true or critical estimates which are off the mark--and use the Monte Carlo simulation technique to project the consequences of these problems and evaluate alternative solutions to the problem. As the managers use the system to help control the project, they would also learn more and more about the nature of the variables which are key to the project, and eventually develop a diagnostic system rather than do post mortems.

2) As an educational tool. A system, such as IGRAM, could be used to teach new managers the procedures used in making decisions in the past--the elements considered the assumptions and estimate made--and the process through which they should progress in making future decisions. The use of

the system in this manner will undoubtedly reveal the weaknesses of past decisions as well as their strength. The use of such a system appears to be a much more efficient method of training managers than any method in use today.

3) To improve consistency in decision making. The structure and discipline imposed on problem solving should produce more consistent and efficient decision making. Within a firm, it would be possible to have the specialists in making certain types of decisions develop their own models, which models in turn can be used by other managers within the firm whenever they are faced with one of those types of decisions. Another advantage such a system would provide is that of constituting a permanent memory. Experience would not be lost when a "good" manager leaves the firm. His decision-making technique would be left behind for others to study and learn. Also the "weeding out" of obsolete methods, through automatic updating of planning models, would eliminate a lot of the inefficiencies we find in practice today.

4) To improve communications. With a system such as IGRAM, qualified people can specify the structure of the problem and then experts from the various relevant areas can enter their estimates of the variables related to their area of expertise. Methods could even be devised to reconcile the differences between the "expert opinions" of several experts on a single variable in those cases where there is disagreement.

5) A tool for consensus decision-making. If we go a step beyond the resolution of differences between expert opinions we can see how such a system could facilitate the resolution of differences between recommended courses of action in cases where there are many decision makers. Since all inputs to the system must be explicit, any differences of opinion may be traced to individual inputs, to the system, or to individually held values. In

either case, the use of the system can help to isolate the cause of the disagreement and hopefully aid in its resolution. We see interactive systems with global models as means of increasing communication and understanding of complex interrelationships.

Obviously, the surface of the field of planning model development and use has only been scratched. Much is yet to be discovered and validated. The need is for more detailed, documented experimental work using prototype models. The sooner we discover the secrets of planning models, the sooner managers will be able to harvest the fruits of their use.

Bibliography

1. Ackoff, Russell L., "Management Misinformation Systems," Management Science, Vol. 14, No. 4 (December 1967), pp. B147-B156.

2. Ansoff, H. Igor, "The Firm of the Future," The Harvard Business Review, Vol. 43, No. 5, (September-October, 1965), pp. 162-178.

3. Beville, James, John Wagner and Zenon S. Zannetos, The Development of an Interactive Graphical Risk Analysis System, Working Paper 502-70, M.I.T., Alfred P. Sloan School of Management, Cambridge, Mass, December, 1970.

4. Hertz, David B., "Risk Analysis in Capital Investment," The Harvard Business Review, Vol. 43, No. 1, (January-February, 1964), pp. 95-106.

5. Morton, M.S.S., Management Decision Systems, Division of Research, Harvard Business School, Boston, 1969.

6. Schroder, H. M., Driver, M., and Streufert, S., Human Information Processing, New York: Holt, Rinehart and Winston, 1967.

7. Simon, Herbert A., The Shape of Automation, Harper and Row, New York, 1965.

8. Starr, Martin K., "Planning Models," Management Science, Vol. 13, No. 4, (December, 1966), pp. B115-B141.

9. Wagner, John H., The Impact of an Interactive Risk Analysis Model on Decisions Under Uncertainty, S.M. Thesis, M.I.T., Cambridge, Mass., 1970.

10. Zannetos, Zenon S., Managerial Information Systems for Planning and Control, M.I.T., Alfred P. Sloan School of Management, Working Paper, 210-66, August 1966, appeared as a Chapter in Frontiers of Knowledge, (July 1966), Boston Company, Inc., pp. 231-262.