WORKING PAPER

ALFRED P. SLOAN SCHOOL OF MANAGEMENT
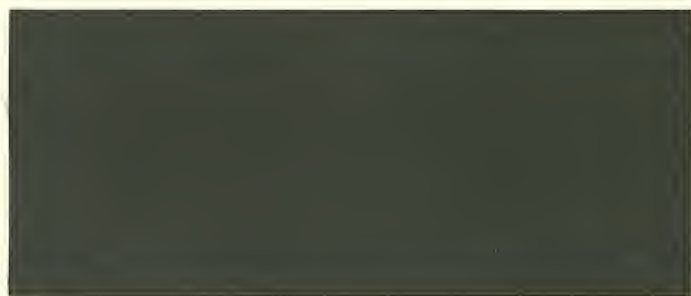
THE DEVELOPMENT OF AN

INTERACTIVE GRAPHICAL RISK

ANALYSIS SYSTEM

James Beville
John H. Wagner
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December, 1970   502-70

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I. INTRODUCTION

One of the most elusive problems faced by management today is
that of imposing structure on the decision-making process when
operating in an environment characterized by substantial uncertainty.
For example, when managers make decisions relating to activities such
as capital budgeting, choice of pricing strategies, new product develop-
ment, aquisitions, or mergers, they must somehow cope with the
uncertainty inherent in these problem areas. Hertz (1) notes that the
causes of the difficulties with these types of decision lie not in the
problem of projecting the expected return for a particular course of
action, given a set of assumptions, but in the assumptions themselves and
in accessing their impact on the decision. The reasoning is that while
each assumption has associated with it a degree of uncertainty which
singly may be manageable and possibly palatable, when taken together the
combined uncertainties can induce an uncertainty of critical proportions.

When operating in a decision environment characterized by the
aforementioned type of difficulty, assumptions in the form of point
estimates for variables such as market share, industry sales volume, etc.,
cannot be taken as factual, but must be viewed in light of the risk
involved in actually attaining them. Thus the decision maker, in
arriving at a decision must develop some form of a risk measure for
each alternative under consideration and perform some form of a trade
off between expected return and uncertainty. Typically, the decision
maker's approach might be to, (1) be overly conservative in estimating
return on investment, (2) rely on the judgement of subordinates who have
a good record for making estimates, or (3) require riskier alternatives

to meet higher criteria. Although such approaches have worked in the past, and will no doubt continue to be used in the future, for decisions which might have an important impact on the long-term profitability of the firm, a more rigorous approach to decision making would seem reasonable, especially since some methodology and tools are available for this purpose.

This paper describes the efforts of the Managerial Information for Planning and Control Group at the Sloan School of Management, Massachusetts Institute of Technology, during the 1969-1970 school year, to apply management science techniques and computer technology to this general decision-making environment. Specifically our work has focused on the use of risk analysis models and computer-driven interactive visual display devices as the major components of a management decision system. And this in order to aid the decision maker by providing him with both a framework for decision making and a means for implementing this framework.

II. RISK ANALYSIS MODELS

In general, the objective of risk analysis models is to provide structure to the problem environment by identifying the basic components of risk and assigning to each of these components probability measures for all possible outcomes. For example, for a typical business decision, the basic elements of revenues and expenditures would be first identified, then for those elements for which uncertainty is greatest further subdivisions would be made until all critical elements of the environment had been identified to the level that it is possible to specify possible ranges of outcomes and their associated probabilities of occurrence. Figure I gives a possible risk model structure for a new product decision. For each element so identified, a probability distribution describing all possible outcome states must be developed.

Figure I

Structure for a Risk Analysis Model
For a New Product Decision

Net Income
— Expenditures
— Research and Development
— Production
— Marketing

Revenue
— Industry Volume
— Market Share
— Price Per Unit

Level I   Level II   Level III

Once all of the outcome states for each of the elements of
risk have been described in the form of probability distributions,
these distributions can be aggregated by means of a Monte Carlo type
process to develop a probability distribution describing the expected
net return for the alternative being modeled.

As we have already mentioned, risk analysis models provide both
a framework for structuring decision alternatives, through the
identification of the elements of risk in a hierarchical manner, and
a methodology for analytically dealing with risk, through the use of
probability distributions and the Monte Carlo simulation. On the
negative side, however, associated with the use of risk analysis
models are the heavy computational requirements posed by the use of
the Monte Carlo process, and the problem of the development of the
probability distributions required to define the basic elements of
risk.

III. INTERACTIVE VISUAL DISPLAY DEVICES

The application of computer-driven interactive visual display
devices to the management setting is currently in its initial phases.
Some characteristics of systems based on such devices which have the
potential for having an important impact on the management decision
making process have already been identified by Morton (2,3). These
characteristics include:

1. Rapid manipulation of data through computer processing in
    a real-time environment.

2. Graphical presentation of data which, work by Morton (2,3) indicates, can be of great value in helping the decision maker to identify relationships and trends. This characteristic appears to be especially applicable to the problem of working with probability distributions, if the assumption can be validated that people conceptualize probability distributions better in a graphic rather than in tabular form.

3. Rapid, yet simple, system user interactions through devices such as light pens. This feature appears to be particularly applicable to the problem of working with probability distributions in that it provides a means for rapidly entering such distributions to models by simply drawing them on the terminal screen with a light pen. The latter also provides a simple means for interacting with the computer system through the initiation of a command by simply pointing to it with the pen.

4. Fast and quiet operation. Such devices are quiet and much faster than computer-driven teletype terminals. On the basis of our experience the realized speed of visual displays is greater than that of teletypes by a factor of approximately ten.

5. There is a certain amount of charisma associated with display devices which increases the decision maker's willingness to use them (Morton 2,3).

IV. RESEARCH PHILOSOPHY

The characteristics of risk analysis models and interactive visual

display devices indicate that these techniques could provide the basic components for a management decision system directed towards problem environments characterized as unstructured and harboring uncertainty. The risk-analysis model provides a structuring framework and a methodology for analytically dealing with risk, while the computer-driven interactive visual display device provides not only the computational power needed to run the models but also the interface between the decision maker and the modeled situation. Realizing that managers have reservations toward the use of computers in decision making and that very little has been done in the past to determine the impact of interactive systems on the quality of decisions and on managerial styles, we set as the objective of the research reported here to investigate some dimension of these questions using as a research vehicle a management decision system based on a risk-analysis model and a computer-driven interactive visual display device.

To attain the aforementioned objectives a methodology was developed which called for the design, development, and implementation of a prototype system. There are several reasons for selecting this research strategy over a purely conceptual study or simulated experiments void of an actual operating system. First, there is insufficient theoretical work available to use it as the sole basis for accessing the managerial implications of the decision-making concept we are investigating. Secondly, it was felt that the use of simulated experiments void of an operational system would require too many assumptions and therefore raise serious questions regarding the

applicability of the experimental results to actual systems. Thirdly,
it was felt, that in addition to the benefits derived from using a
prototype system as an experimental testing device, the actual process
of designing, developing and implementing a prototype system would provide
us with data relative to the costs and problems associated with the
development of systems of this type.

V. DESIGN PHILOSOPHY

The basic philosophy used in the design of the system was that
the system should be as flexible and as generalized as possible to
allow for its application to different problem environments. That is,
we were interested in the development of a generalized decision-making
tool rather than a device to aid in the solution of one specific
problem. We of course realized at the outset that substantial
progress in system design comes, more often than not, after a primitive
prototype is developed and used as a basis for subsequent iterations.
In order that the latter occur, however, flexibility for subsequent
adaptations must be among the design objectives of the prototype,
otherwise one will have a dead-end system.

The particular operational assumptions underlying the design
decision were the following:

1. For economic justifiability, the system must have the
    capability to use the same basic system core and with only
    limited additional resources be adaptable to specific problems.
2. There is a need for flexibility so that the system can
    be adapted to suit the decision-making style of the individual
    user as it evolves.

3. The system must be viewed as an integral part of a
   generalized decision-making framework and be capable to
   respond to particular problem environments.

Simon's (6,7) decision-making framework was selected as the basis
for the system design because of its wide acceptability. Simon's
framework is based on an iterative process composed of three phases --
an intelligence, or problem searching phase, a design in which
alternative problem solutions are developed, and a choice phase in
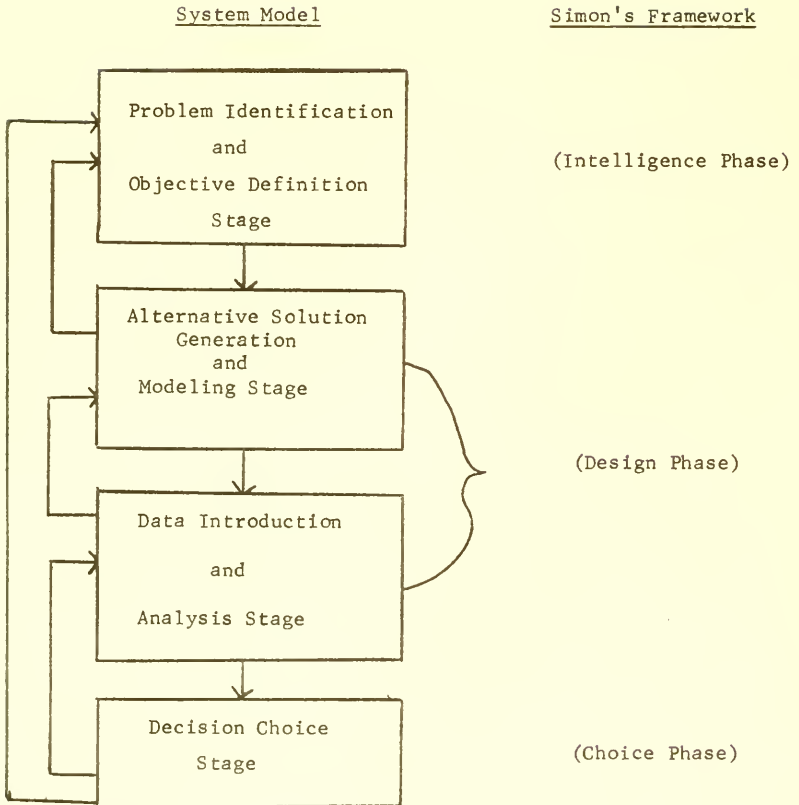which a course of action is selected.

Figure II shows the model of the decision-making process we
developed, based on Simon's framework, which served as the basis for
our prototype management decision system.

As seen in Figure II, the decision process is viewed as consisting
of four stages and being iterative in nature. By iterative it is meant
that the process of operating on one stage will tend to generate ideas
or concepts which will have implications for the other stages in the
process, and when this occurs the stages which are implicated are revisited
and reviewed.

The first stage of this process is referred to as the Problem
Identification and Objective Definition phase and is analogous to
Simon's intelligence phase. During this stage, the decision maker
defines the problem, specifies its scope, explicitly states those
assumptions he wishes to use in the decision-making process, and the
criteria which are to be used for evaluating alternative problem
solutions.

FIGURE II

DECISION - MAKING - FRAMEWORK

System Model   Simon's Framework

```
        ┌──────────────────────┐
   ┌───▶│ Problem Identification│
   │ ┌─▶│         and          │      (Intelligence Phase)
   │ │  │ Objective Definition  │
   │ │  │        Stage          │
   │ │  └──────────┬───────────┘
   │ │             ▼
   │ │  ┌──────────────────────┐
   │ │  │ Alternative Solution  │
   │ │  │     Generation        │
   │ └─▶│        and            │
   │ ┌─▶│   Modeling Stage      │
   │ │  └──────────┬───────────┘     (Design Phase)
   │ │             ▼
   │ │  ┌──────────────────────┐
   │ └─▶│  Data Introduction    │
   │    │         and           │
   │    │   Analysis Stage      │
   │    └──────────┬───────────┘
   │               ▼
   │    ┌──────────────────────┐
   │    │  Decision Choice      │      (Choice Phase)
   └────│        Stage          │
        └──────────────────────┘
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The second stage of the decision-making process is directed toward the development of a procedure for problem solution. Specifically, this stage consists of a method for generating alternative solutions and developing the general risk analysis model structure for each of the possible problem solutions. That is, for each possible solution, a model structure is developed which identifies all key elements of the solution and the relationships between these elements.

The third stage is the Data Introduction and Analysis Stage. This stage together with the previous one represents Simon's design phase in his decision-making framework. During this stage, data are entered to the models developed for each of the possible solutions being analyzed as defined in the second stage. Data which are entered to these models are of two types: (a) values of the variables which are used in the equations which define the relationships between elements in the risk model, and (b) subjective probability distributions which are used to define the possible outcomes for the independent elements of the model.

The analysis portion of this stage is based on running the alternative models, observing the results along the dimensions established in the first stage as criteria for evaluation, making desired adjustments in the input data and observing the impact on the outputs of the model to simulate possible changes in the environment.

The fourth and final stage consists of arriving at the actual decision as to which alternative course of action to take, and is analogous to Simon's choice phase. This final decision is made based

on the observed output of each of the model runs and the particular decision maker's utility function for return versus risk.

As previously pointed out, this entire process is viewed as iterative in nature and thus many passes through this process might be made before a final decision is reached. The actual hardware/ software system with the man/machine interactions used to implement this decision-making process is what we refer to as a management decision system.

VI. GENERAL SYSTEM DESIGN

To implement the proposed decision-making system a number of design objectives, some of which later on will be classified as hypotheses for testing, were established.

1. Interactive. In order to optimize the decision maker's time and also provide flexibility for changes, it appeared advantageous to provide an interactive capability to the decision maker during the Data Introduction and Analysis Stage of the decision-making process. It is during these stages that the manipulative capabilities of the system are required and also the greatest call for the application of the decision-maker's judgement is made. During these stages, it is highly desirable for the decision maker to be able to formulate new hypotheses relative to the input data and immediately test the effect of such on the outcome of the model.

It was felt that for the initial system and in view of the added expenditures involved, that there was not a strong enough requirement

for placing the alternative modeling stage of the decision-making framework in an interactive mode. The following amplify somewhat further on the reasons which influenced our choice in this respect.

(a) Basic model structures for problem solutions are subject to much fewer changes during the decision-making process than changes in the data used in each model. Thus in attempting to take our first steps, and optimize the decision maker's time, we felt no pressing need for placing the Modeling Stage in an interactive mode and instead concentrated our efforts on the Data Introduction and Analysis Stage.

(b) The costs involved in placing the Modeling Stage in an interactive mode would have approximately doubled the system development costs.

Thus the decision was made to carry out the Alternative Solution Generation and Modeling Stage in a batch-type mode of computer operation, in which instructions defining the model structures to the system are entered in a non-interactive manner using a macro instruction-type language.

2. Response Time. In order to maintain the decision maker's span of attention during the interactive mode of operation with the system, we felt that a real-time response to a user's request was necessary. We defined "real time" to be any response of less than 15 seconds. There were no time constraints placed on the batch mode, as the decision maker was not actively involved in the decision-making process while the models were being placed on the system.

3. <u>Adaptive</u>. It was hypothesized that as a user became more familiar with the operation of a system, he would request additional system options. Thus an adaptive capability was deemed necessary to allow easy modification of the system to satisfy user requests.

4. <u>Generalized</u>. There was also a need for using risk-analysis models of different hierarchical forms in order to provide the manager with the capability to deal with different problem environments.

5. <u>Simple to Use</u>. As the system was primarily directed towards top management personnel, it was necessary that it be easy to interact with, and not require the user to learn a programming language, or an elaborate set of instructions. In addition, the learning period on how to operate the system had to be short.

6. <u>Graphical Presentation of Data</u>. Since probability distributions were to be the primary format for both input and output data, graphical presentation of data was critical. To aid in understanding and developing subjective probability distributions, and because experience was needed before one could determine which was more relevant, the dual capability was specified for displaying both cumulative probability distributions and probability density functions.

7. <u>Modular Design</u>. For ease of development, and to insure an ability to easily modify the system, a method of decoupling the system was necessary. A modular design, which allowed the system to be decomposed into a number of subsystems, each of which could be developed independently, provided the mechanism for accomplishing this objective.

VII. DETAILED SYSTEM DESIGN

In line with the objectives specified in the previous section, the system was designed to facilitate two types of interactions -- problem solution structuring, and data introduction and analysis activities.

The models permitting structuring of the problem for solution were designed to be non-interactive, that is to say, they were entered in to the system in a batch-type operation. Each model, or problem tree was hierarchical, composed of elements and levels. For example, the risk model structure shown in Figure II has nine elements organized into three levels. The lowest-level elements represent the independent variables on which subjective probability distributions are imposed by the user.

All elements at higher hierarchical levels in the model are dependent on and calculated from the elements directly below them. A Monte Carlo simulation process is used to develop probability distributions for all higher-level elements.

Thus the decision maker specifies the shape of the problem tree in terms of levels, elements at each level, and relationships between elements. For each element, he specifies the data needed to be entered by the user, and, or, data to be taken from other elements, and the relationship for developing the probability distribution describing the element.

As the system was initially designed, up to four separate model structures could be implemented on it at one time. To facilitate

movement between these models, a System Directory level was established.
When moving from one model structure to another, one always returns to
the directory level. Furthermore, to enable comparisons among like
dimensions of different models, we provided an Alternative Comparison
level where output graphs from different models could be displayed
simultaneously. Thus, if the dimension of comparison was "net return
after taxes," moving up to this level would allow the user to display
the probability distributions for net return after taxes for every
model entered into the system.

 Figure III shows the basic system structure.

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FIGURE III

SYSTEM STRUCTURE

</div>
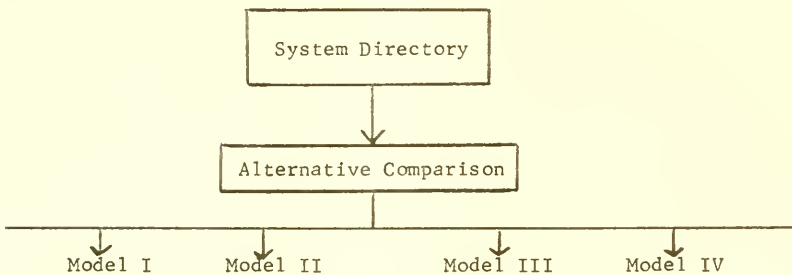
The data introduction and analysis activities are accomplished in an on-line mode of operation. During this activity three types of data can be entered into the alternative model structures.

1. Probability Distributions. This type of information is used to describe the outcome states of the independent elements of the model. In arriving at a design decision several alternatives were considered relative to both the type of probability description and the method for entering the probabilities into the model. As regards the probabilistic description, it was felt that while the probability density function was conceptually easier to understand than the cumulative distribution, it was more difficult to specify in that the area under it must always equal one. For this reason the cumulative probability distribution was selected as the means for describing the independent variables.

The methods considered for entering the cumulative probability distributions into the models were mainly two: (a) specify the distribution in terms of the coordinates of enough points on the function to describe the shape of the curve, or (b) enter the function by drawing it on the screen face with a light-pen. The use of the light-pen method was discarded because of the possibility of technical problems and because of the feeling that during the initial research phase, where the objective was to access the usefulness of the concept of a system of this type, the capability for light-pen input was not critical.

To standardize procedures for entering the coordinates of probability distributions, the user is required to enter values for the 5, 10, 25,

50, 75, 90, and 95 percentiles. After these values are specified, the system displays a cumulative probability distribution which is formed by joining these points with line segments. In addition to the cumulative distribution function, the probability density function is derived and displayed.

2. Model Parameters. This term is used for data which are expressed as point estimates, rather than described by probability distributions. These model parameters are part of the relationships which are used to develop the dependent elements of the problem solution.

3. Functional Data. Data of this type are non-probabilistic and are expressed as a function of some independent variable. An example would be the cost of producing an item, assuming that the cost is a function of the volume produced and there is no uncertainty associated with the cost figures. Data are entered in the same manner as the probability distributions.

The normal procedure for entering data in the interactive mode is to first enter all the parameter and functional data associated with each of the dependent elements, and then to enter the cumulative probability distributions for each of the independent elements. Once all the data required to completely specify the model of the problem solution have been entered, the model is automatically run to develop the output probability distributions for each of the dependent elements. For each of these elements, the system computes and, on command, displays the cumulative probability distribution, the probability density function, the mean of the distribution and the standard

deviation of the distribution.

For illustrative purposes, an example of a problem environment was implemented. Figure IV shows the system layout for this problem, including the models developed to describe the possible problem solutions. The problem environment as described in Appendix III is that of a company which is faced with a decision to either continue producing a particular product line or sell out to a competitor. There are two uncertainties associated with the company leaving the business: (a) how much the present equipment could be sold for, and (b) how much would be recovered from the liquidation of the remaining inventories and the accounts receivable. Thus the model, or problem tree for this alternative consists of two levels, the lower level containing the independent elements for the expected return to the company on the sale of the equipment, and for the liquidation of the inventory and accounts receivable. The top level contains one element which describes the total expected return to the company if it sells out, and is calculated by taking the sum of independently selected values from the distributions of the two independent elements of the model and adding a tax allowance based on the difference (loss) between the book value of the equipment and the actual sale price. The actual distribution for the total expected return to the company for leaving the business is calculated by iterating through this process a number of times, each time using a different set of random numbers for selecting values out of the distributions of the independent elements.

FIGURE IV

SYSTEM STRUCTURE FOR THE ATHERTON CASE
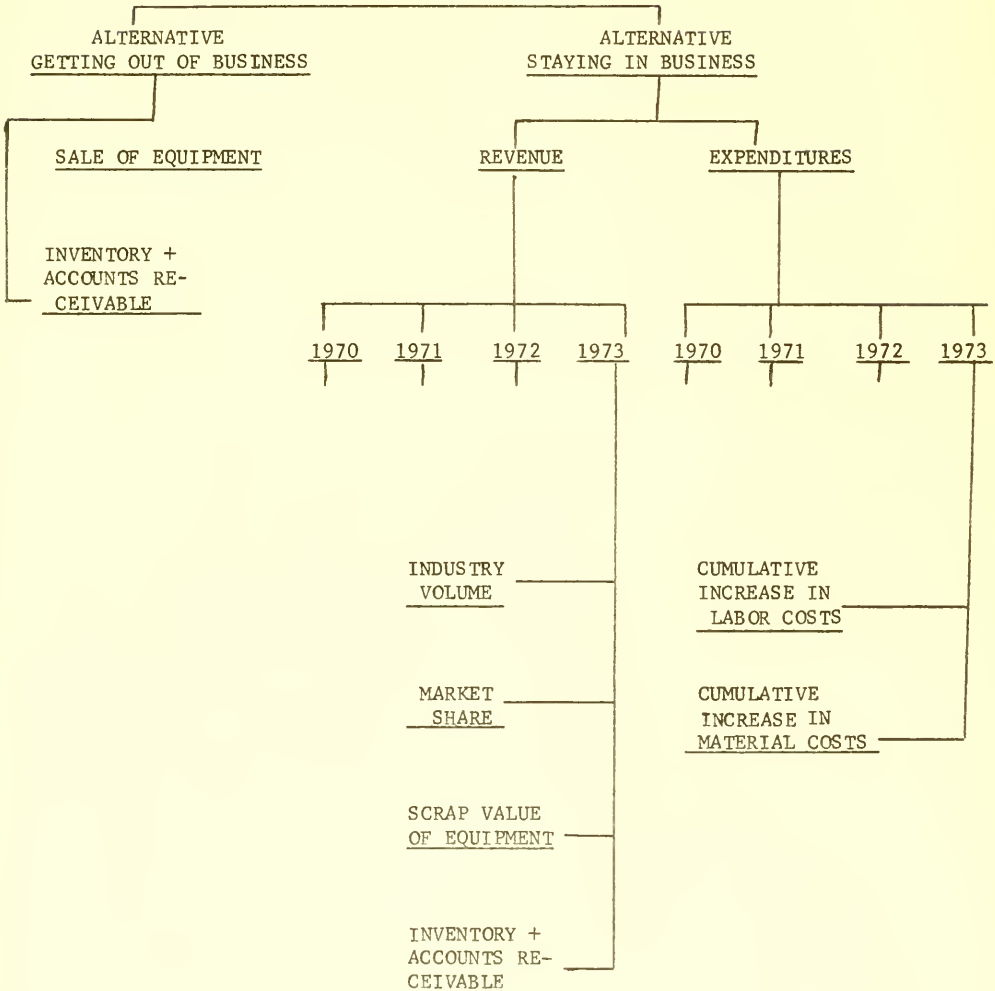
The alternative model for staying in the business is based on a four-year analysis, four years being the projected life span of the present equipment. The problem tree or model associated with this alternative contains four levels. The top level contains one element which describes the distribution for the total net present value (after taxes) to the company for staying in the business for the four year period. It is calculated by taking the discounted after tax difference between expenditures and revenues for the four years. It is at this level that the parameters are entered for the price charged per item for each of the four years and the cost of capital used by the firm in discounting cash flows. In addition, functional data are entered for labor cost per item, material cost per item, and power and supply cost per item, each as a function of the total volume produced.

The next level contains two elements, one for revenue and another for expenditures. Revenue is calculated by summing the discounted revenue cash flows for the four years. Likewise, the total expenditure element is calculated in the same manner by discounting and summing the cash flows for expenditures for the four years.

On the revenue side of the problem tree, at the lowest level are the independent elements for each year for industry volume and market share. In addition in 1973, which is the last year of the analysis, elements are provided for subjective estimates for the expected scrap value of the equipment and the expected return to the company for the liquidation of its remaining inventory and accounts receivable.

The revenue generated from product sales for each year is calculated by multiplying the sales volume for each year by the price charged for the product. Total volume of sales for the company for each year is developed by multiplying values independently selected from the industry volume element and the market share element. A probability distribution is developed for revenue for each year by repeating this process a number of times, each time using a different random number for selecting values from the industry volume elements and the market share elements.

In the final year of the analysis, in addition to the revenue generated from product sales, revenue is obtained from selling the production equipment for scrap and from liquidating the remaining inventories and accounts receivable. Thus, values are independently drawn from the probability distributions for scrap value of the equipment, inventories and accounts receivable, and added to the sales revenue to yield the total revenue for the year.

On the expenditure side, associated with each year are elements for describing the subjective probability estimates for expected cumulative increases in labor costs, and in material costs, expressed as a percentage increase. All other product cost data are a function of volume, are known with a high degree of certainty and are specified, as previously discussed, at the top element of the problem tree. Thus once a value for the volume of sales for a year is calculated from the elements on the revenue side of the problem tree, the system uses this value to enter the cost tables to obtain the costs for labor, materials,

power, and supplies. The labor and material costs are adjusted by
values obtained from the distributions for the expected cumulative
increase in labor and material costs. Referring to Figure IV,
elements are developed using the independent revenue and expenditures
for each of the four years.

The basic mechanism for forming all of the probability distributions
for the dependent elements is a Monte Carlo process, by means of which
all calculations are iterated through a number of times using a new
set of random numbers for each iteration. One of the problems faced
in the design of the system was to determine how many iterations were
required to insure convergence of the output distributions. To allow
experimentation, a parameter was made available for varying the number
of iterations carried out in developing distributions for the dependent
elements. For the models described here, 100 iterations proved to be
sufficient.

VIII. SYSTEM COMMAND STRUCTURE

The system was designed to allow display of all commands which
are available to the user at any point in the interactive phase of
the analysis. This was done to free the user from having to remember
a long list of commands, and also to eliminate problems caused by
users giving inappropriate commands.

The command options available to the decision maker in the
interactive mode were of two types: (1) movement commands which are
used for moving the system between elements in the model structure, and
(b) functional commands which are used for interacting with a specific

element, such as entering or changing data. A complete description
of the individual commands is given in Appendices I and II.

IX. IMPLEMENTATION

A prototype system was implemented at M.I.T. during the spring
term of 1970 using the Computation Center's CTSS (Compatible Time-
Sharing System). CTSS provided the basic hardware and software needed
to support an interactive visual display device.

The interactive graphical display unit selected was an ARDS
(Advanced Remote Display System) terminal which is a storage tube type
device. The application software for the system were programmed in
the AED language, primarily because of the existence of previously
written software for supporting such visual display devices.

The software development was carried out in two phases. The
first phase, which in turn was subdivided into a number of modules,
was the system supervisor and utility routines to perform system
tasks such as displaying graphs, generating random numbers, etc..
These modules represented the heart of the system and provided the
mechanisms for implementing specific models. Thus this phase provided
the software to support the model-building stage of the decision-
making framework discussed in a previous section.

The second phase of the software development of this prototype
system was the actual implementation of a problem environment. The
environment selected was that of the product decision previously
described. Figure IV shows the problem solution structure implemented.
There is a model structure for the alternative of getting out of the

business and a model structure for the alternative for staying in the business. The second phase consisted of detailing the model structures in terms of elements, levels, and relationships between the elements through the use of macro instructions which were developed in the first phase. In addition, labels and specific command options which would be made available to the user at each element were specified.

In terms of resources expended for the software development, the first phase required 350 hours of programming time. This phase is a "once only" type task in that the software developed can be used for any problem applications. The second phase, which must be redone for every new application, required 50 hours of programming time. It is felt that as more experience is gained with the system, model implementation programming involved in the second phase can be reduced to less than 20 hours for most applications.

The operational system conformed to all of the design objectives specified. One of the most critical variables for insuring the successful use of the system was gaged to be its response time when operating in the interactive mode. While response time was a function of the number of users on CTSS, (CTSS can accomodate up to 30 users) it never was longer than 15 seconds and normally averaged around 5 seconds.

All user interactions were carried out using the keyboard which was attached to the terminal. As noted, there are advantages to using light pen type devices for man-machine interactions. Due to resource constraints, however, only keyboard interaction was implemented in the initial design effort.

With regard to the actual computer time used during the inter-
active mode, our initial experience produced a ratio of about 3 minutes
of CPU (Central Processor) time for every hour of terminal time.

The next section will discuss the experiments carried out with
the system to obtain user response data.

X.   EXPERIMENT WITH THE SYSTEM

To simulate decision making in an actual business environment
a series of experiments were conducted involving members of the Sloan
School's Senior Executive Program, and Greater Boston Executive
Program as subjects. Most of the participants hold senior management
positions and have had many years of business experience. Due to
time constraints, the experiments concentrated on the last two stages
of the four stage decision-making process discussed, i.e., the Data
Introduction and Analysis Stage, and the Decision Stage. That is,
the participants were given a statement describing the problem and
the basic model structures for the possible solutions to the
problem. The problem environment used for all experiments was that
of the product-line decision which was described earlier, in which a
decision was required on whether or not to continue producing a
product. The basic models shown in Figure IV were implemented on the
system. To familiarize the participants with the problem environment,
a case study included in Appendix III and describing the business
situation was given to them. In addition a users' manual (see
Appendix IV) was given to them describing the system and the alterna-
tive models which were implemented on it.

Twenty-two teams of two members each participated in the experiments which simulated the last two stages of the four-stage decision-making process outlined. All experimentation was conducted in an interactive mode of operation. During the data entering and analysis stage, each team was required to enter data for both the alternative model for getting out of the business, and for the alternative model for staying in the business. Once all data had been entered for a model, sensitivity analysis could be performed by altering the entered data.

For the model for getting out of the business, data in the form of cumulative probability distributions were required for the expected sale price of the equipment and the expected revenues from the liquidation of inventories and accounts receivable. For the alternative model for staying in the business, data were required for the price that would be charged for each year of the four-year analysis and the cost of capital. For each individual year, cumulative probability distributions were required to specify the company's expected market share, total industry volume, cumulative percentage increases in labor costs, and cumulative percentage increases in material costs. In addition, for the last year of the analysis, cumulative probability distributions were required for the expected scrap value of the equipment and the expected revenues from the liquidation of the remaining inventories and accounts receivable.

Once all the data which were necessary to completely define a model were entered, the system computed the cumulative probability distributions and probability density functions for cash flows for each year, total discounted expenditures, total discounted revenues,

and net present values after taxes for the model alternative considered.

In order to familiarize the decision makers with the operation of the system, first, a presentation was given in which the operation of the system and the model alternatives which were implemented on the system were discussed. Then each team was allowed to use the system under the guidance of a member of the project group. To save console time, the individual teams met beforehand to decide on the data they wished to enter for each alternative model. This phase tended to take, on the average, two hours. The next phase involved using the system in the interactive mode for entering data, running models, analyzing results, and for performing sensitivity analysis. This phase also averaged two hours, during which data were entered for at least three alternatives, and sensitivity analysis was performed on each alternative.

Initial results from the experiments were very encouraging. Most decision makers were able, after about 15 minutes experience with the system, to grasp its operation well enough to feel comfortable in using the commands. They also showed strong indications that they understood what the system was doing and were not viewing it as a black box. On the negative side, we found that the executives did not fully adjust to the use of graphs (distributions of net present values) for comparing alternatives.

If we look at the form of the information which the decision maker could use to discriminate among alternative problem solutions, i.e., point estimates for the expected return, estimates of the mean and standard deviation of the distributions of net present values, or

graphs of the distributions themselves, the use of the system influenced the executives to discard reliance on point estimates and to use the mean and standard deviations as criteria for evaluation purposes. However, it appears that the user must be exposed to the system on a number of occasions before he attains the needed expertise and maturity to appreciate the use of probability distributions in decision making.

An analysis of the questionnaires completed by all those who participated in the experiment provided some interesting implications for decision making systems of this type (a copy of the questionnaire can be found in Appendix V).

1. In attempting to assess the usefulness of a system of this type we were impressed that the participants strongly indicated that the system maintained their interest and attention throughout the sessions. They also tended to underestimate the actual time they spent on the terminal on the average by a factor of 1/3.

2. In answer to questions related to the individual's like or dislike for the organization of the system, several important factors were apparent: (a) As the users became familiar with the models which were implemented on the system, they tended to come up with ideas for different model structures. This was in complete agreement with the hypothesized decision-making framework, in which a decision maker would, after some experience with working with a set of models, return to the model formulation stage to alter or develop new models. (b) For the most part, the users were content with the general command structure and presentation of the data. It was noted in some cases,

however, that once an individual had grasped the operation of the command structure for the system, he would begin to make recommendations for additional features he felt would be useful. This tended to verify our hypothesis for the need for system flexibility in order to individualize the system as the user gains more experience in its use and applications. Thus the system must have the capability for (i) acting as a learning device, initially presenting the user with basic, simple to use, command procedures to allow him to easily learn the basic capabilities of the system, and (ii) providing the flexibility needed to satisfy the requests of the user for additional features as he begins to think of new uses for the system.

Typical responses to the question of "what did you like about the system" were:

1. It forces the decision maker to structure the problem and consider all key elements.

2. It provides a methodology for working with risk.

3. It is novel.

4. Its speed allows sensitivity analysis, and consideration of more possible outcomes, than could be handled in a manual analysis.

5. It provides graphical presentation of data.

Responses to the question "what did you dislike about the system" were:

1. Lack of flexibility in structuring the models. As noted, the users were not allowed to specify their own models.

2. Data entering was time consuming. This, of course, is the drawback of any model in that someone must enter the data.

3. Lack of hard copy. This criticism could be easily overcome by having a program which would store all results and print them at some later time on a high speed line printer, or obtain a hard copy by photographic means.

4. Difficult to keep track of one's position in the problem tree. This problem can be attacked in two ways. (1) Provide a "Help" command which would display a figure of the tree with an arrow pointing to the position presently occupied by the program. (2) Print out the program's present position before printing each set of possible commands. In future versions of IGRAM, one or both of these aids will be implemented.

XI. CONCLUSIONS

We feel that several important points can be drawn from our experience with the development and experimentation with a management decision system based on the coupling of risk analysis models and interactive visual display devices.

1. We feel that management decision systems of this category have the potential for being very powerful decision-making tools. Specifically when used in conjunction with a decision-making framework, systems of this type provide the decision maker with a methodology for structuring problems, quantifying risk and establishing criteria for evaluation of projects.

The process of explicitly stating the decision model in terms
of events and expected outcomes provides a potentially valuable
input to the control and learning process of the organization. As
was discussed in the previous section where we described the experi-
mentation which was carried out, the process of working with models
of alternative courses of action, tends to stimulate the decision
maker to identify other key variables. Thus the system acts as a
learning mechanism.

2. One critical requirement for the successful implementation
of systems of this type is a careful attention to the education process.
The use of subjective probability distributions as an input to models
and the further use of distributions in graphical form as output, is
something which will take the decision maker some time to master.
While the learning period for an individual decision maker will be
partially dependent on his technical background, the more critical
dependency tends to be his willingness to try new ideas.

3. The costs involved in the development and operation of such
systems appear to be well within bounds if general-purpose systems
are designed. By general purpose we mean systems which can be
easily adapted to a new problem environment and a new decision maker.
The system described in this paper was general purpose in that any
model which can be defined in terms of a hierarchical structure whose
elements are defined in terms of probability distributions could be
implemented on the system through the use of macro instructions.

Probably the most valuable contribution the experiment made to
this research effort was the validation of the hypotheses that managers,

with little background in management science techniques, can grasp
the concept of the system and make use of it as a decision-making tool
in a relatively short period of time. With regard to the design of
systems of this type, experience with user reactions has indicated
that while an individual decision maker can be trained to become
comfortable with the operation of the system, and thus inferring
that there may not be a need to design a completely new system for
each individual decision maker, the capability must exist for easy
modification of the system. The reason for this requirement lies
in what might be called the "learning effect," which indicates that
as the decision maker becomes more familiar with the system he will
demand that new options be made available to him. The implication
from all this, with regard to a design strategy, may well be that the
initial system should be designed to be very simple for easy master,
but general enough to allow for adaptive growth as the user becomes
more sophisticated in the use of the system.

The experiments carried out with the system have thus far barely
scratched the surface of the potential insights into the man-machine
decision-making process which experimentation with systems of this type
can yield. We feel, however, that the work described in this paper
clearly establishes the feasibility of interactive and graphical
management-decision systems.

APPENDIX I

MOVEMENT COMMANDS

The three basic command options available for moving around the problem tree structure are:

1. <u>Move to a higher level</u>. This command is used for upward vertical movement in the problem tree. This command moves the system from its present element location to the element in the next higher level which lies on the branch of the element at which the command was given.

2. <u>Move to a lower level</u>. This command is used for vertical movement down the problem tree. After giving this command, a list is displayed of the elements in the next lower level of the problem tree. One then can command the system to move to any of the listed elements.

3. <u>Move to next sequential position</u>. This command is used for lateral movement in the problem tree along the elements in the lowest level, i.e., the independent elements. This command sequentially moves the system along all the lowest level elements of a particular problem tree and is useful during the initial introduction of data.

APPENDIX II

FUNCTIONAL COMMANDS

The functional commands which are available for interaction with elements are:

1. Re-enter data. This command is used to enter new data or to alter previously entered data. When at the independent elements, this command causes the coordinates for the cumulative probability distribution which are required to specify the distribution to be displayed. (See Figure V). If for each probability level no value has been previously entered, the system will pause and wait for the user to type one in. If a value already exists, it will be displayed. The user has the option of either typing in a new value or keeping the old value by typing "new line".

2. Examine level parameters. This command is also a data-entering command, and is used for entering model parameters, i.e., non-probabilistic model values. Figure VI shows an example of this type of data-entering capability for the price and cost of capital parameters for a model alternative.

3. Take data from another alternative. This command allows transferring to an element data which have been previously entered at another element without having to re-type the data.

4. Graph Data. This command graphs the output of the element at which the system is located. If one has previously requested the system to save a graph (this command will be described next) then the

saved graph will also be displayed in addition to the graph for the element at which the system was located when the command was given. Figure VII gives an example of the graph of an input distribution, figure VIII shows a typical model output graph for the distribution of the expected return after taxes, and figure IX shows the graphs for functional data for labor costs.

 5. Save top, or bottom graph. This command causes the system to save either the top or bottom graph which is currently being displayed and to re-display it on the bottom half of the screen the next time the "graph data" command is given.

Figure V

Entering Probability Distribution

A)   Re-enter a graph
B)   Move to next sequential position
C)   Other

Type desired option:

You are at: Sale of equipment. Go out of business

The parameters involved are

                    x if y=0.05
                    x if y=0.10
                    x if y=0.25
                    x if y=0.50
                    x if y=0.75
                    x if y=0.90
                    x if y=0.95

Parameter Name	Normal Value	Current Value	New value
x if y=0.05	NONE	NONE	80000
x if y=0.10	NONE	NONE	83000
x if y=0.25	NONE	NONE	87000
x if y=0.50	NONE	NONE	90000
x if y=0.75	NONE	NONE	94000
x if y=0.90	NONE	NONE	98000
x if y=0.95	NONE	NONE	

Figure VI

Entering Data for Model Parameters

```
A)  Revenue
B)  Expenditure
C)  Graph data
D)  Move to next sequential position
E)  Examine level parameters
F)  Other

Type desired option:     e

You are at:  Model alternative

The parameters involved are

          Price   1970
          Price   1971
          Price  1972
          Price  1973
          Cost of capital

  3 decimal digits will be retained.


Parameter                Normal              Current         New value
Name                     Value               Value           (if desired)


Price   1970             NONE                1.750              1.80
Price   1971             NONE                1.850              1.80
Price   1972             NONE                1.950              2.00
Price   1973             NONE                2.050              2.10
Cost of capital          NONE                0.100               .12


A)  Revenue
B)  Expenditure
C)  Graph data
D)  Move to next sequential position
E)  Other

Type desired option:
```
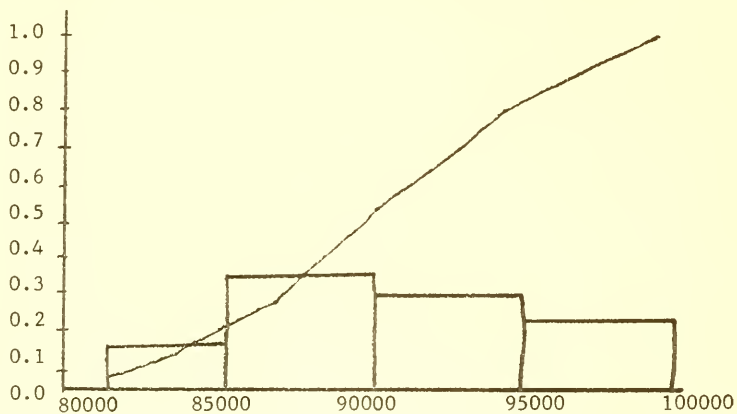
Figure VII

Graph of distribution entered for the sale of equipment element

Sale of equipment.   Go out of business

A) Save this graph
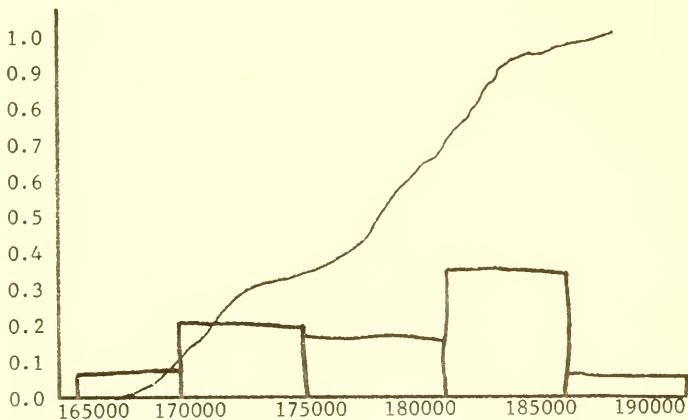B) Continue without save

Type desired option:

Figure VIII

Graph of Expected Return from the Alternative of
leaving the business

Go out of business
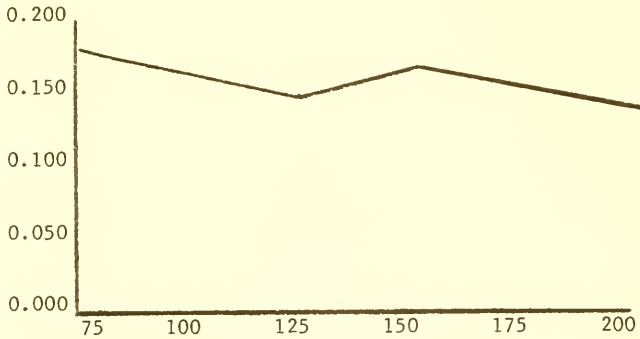   Mean = 177805. Std. deviation = 5209

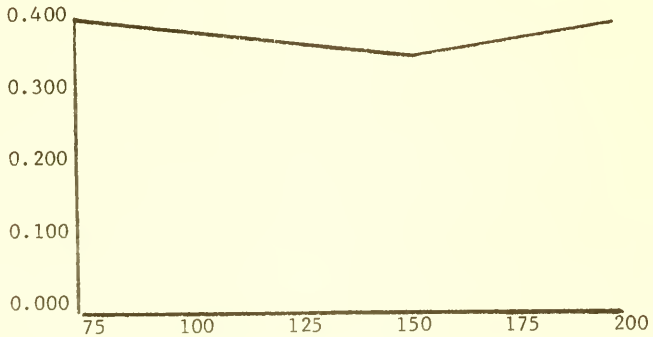A) Save this graph

B) Continue without save

Type desired option:

Figure IX

Graphs of Functional Data for Indirect Labor and
Direct Labor Costs as a Function of Volume

APPENDIX III

ATHERTON COMPANY (A)*

Early in January 1970, the sales manager and controller of the
Atherton Company met for the purpose of preparing a joint pricing
recommendation for Item 345. After the president approved their
recommendation, the price would be announced in letters to retail
customers. In accordance with company and industry practice,
announced prices were adhered to for the year unless radical changes
in market conditions occurred.

The Atherton Company, a textile manufacturer located in Maine,
was the largest company in its segment of the textile industry: its
1969 sales exceeded $6 million. Company salesmen were on a straight
salary basis, and each salesman sold the full line. Most of the
Atherton competitors were small. Usually they waited for the Atherton
Company to announce prices before mailing out their own price lists.

Item 345, an expensive yet competitive fabric, was the sole
product of a department whose facilities could not be utilized on
other items in the product line. In January 1968, the Atherton
Company had raised its price from $1.50 to $2.00 per yard. This
had been done to bring the income contribution per yard on Item 345
more in line with that of other products in the line. Although the
company was in a strong position financially, considerable capital

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*Adapted from Anthony, Robert N., <u>Management Accounting: Text and
Cases</u>, Irwin, Fourth Edition, 1970, p. 613.

would be required in the next few years to finance a recently approved long-term modernization and expansion program. The 1968 pricing decision had been one of several changes advocated by the directors in an attempt to strengthen the company's working capital position so as to insure that adequate funds would be available for this program.

Competitors of the Atherton Company had held their prices on products similar to Item 345 at $1.50 during 1968 and 1969. The industry and Atherton Company volume for Item 345 for the years 1964-1969, as estimated by the sales manager, are shown in Exhibit I. As shown by this exhibit, the Atherton Company had lost a significant portion of its former market position. In the sales manager's opinion, a reasonable forecast of industry volume for 1970 was 700,000 yards. He was certain that the company could sell 25 percent of the 1970 industry total if the $1.50 price was adopted. He feared a further volume decline if the competitive price were not met. As many consumers were convinced of the superiority of the Atherton product, the sales manager reasoned that sales of item 345 would probably not fall below 75,000 yards, even at a $2.00 price. In addition, if the current inflationary pressure remained at its then present rate, the sales manager believed the general price level across the entire industry would be forced up.

Exhibit I

ATHERTON COMPANY

Prices and Production, 1964-69, Item 345

Years	Physical Volume of Production (Yards)		Price Charged by Most Competitors	Atherton Company Price
	Industry Total	Atherton Item 345		
1964. . .	610,000	213,000	$2.00	$2.00
1965. . .	575,000	200,000	2.00	2.00
1966. . .	430,000	150,000	1.50	1.50
1967. . .	475,000	165,000	1.50	1.50
1968. . .	500,000	150,000	1.50	2.00
1969. . .	625,000	125,000	1.50	2.00

During the pricing discussion, the controller and sales manger had considered two other aspects of the problem. The controller was concerned about the possibility that competitors would reduce their prices below $1.50 if the Atherton Company announced a $1.50 price for Item 345. The sales manager was confident that competitors would not go below $1.50 because they all had higher costs and several of them were in tight financial straits. He believed that action taken on Item 345 would not have any substantial repercussions on other items in the line.

The controller prepared estimated costs of Item 345 at various volumes of production (Exhibit 2). These estimated costs reflected current (i.e., January, 1970) labor and material costs. They were based on past experience except for the estimates of 75,000 and 100,000 yards. The company had produced more than 100,000 yards in each year since 1960,

and pre-1960 experience was not applicable due to equipment changes and

increases in labor productivity.

The current inflationary trend, however, had induced a considerable

amount of uncertainty relative to material and labor costs. With regard

to material cost increases, these appeared to be closely correlated with

the general national inflationary rate. On the labor side, while

Atherton was non-unionized, it had adopted a policy of paying competitive

wages.

Exhibit 2

ATHERTON COMPANY

Estimated Cost of Item 345 at Various Volumes of Production (per Yard)

	75,000	100,000	125,000	150,000	175,000	200,000
Direct Labor	$0.400	0.390	0.380	0.370	0.380	0.400
Material	0.200	0.200	0.200	0.200	0.200	0.200
Material Spoilage	0.020	0.020	0.019	0.019	0.019	0.020
Department Expense						
Power & Supplies	0.300	0.296	0.290	0.290	0.290	0.290
Indirect Labor	0.170	0.160	0.150	0.170	0.160	0.150
Repair	0.090	0.100	0.110	0.090	0.100	0.110
Depreciation	0.400	0.300	0.240	0.200	0.171	0.150
Supervision	0.200	0.150	0.120	0.100	0.086	0.075
General Overhead[1]	0.120	0.117	0.114	0.111	0.114	0.120
Total Factory Costs	$1,900	$1,733	$1,623	$1,550	$1,520	$1,515
Selling and Aminis trative Expense[2]	0.475	0.433	0.406	0.388	0.380	0.379
	$2.375	$2.166	$2.029	$1.938	$1.900	$1.894

[1]
30% of Direct Labor

[2]
25% of Total Factory Costs

In March of 1970 one of the competitor producers of Item 345 offered
Atherton $90,000 as payment for the equipment used for Product 345. In
view of Atherton's need for funds for modernization and expansion of
other lines, this offer was rather tempting. The Controller pointed
out that a sale of the equipment would not only release the investment
in fixed assets but would also reduce the average inventory and accounts
receivable outstanding by $25,000 and $30,000 respectively. The Controller
felt that a sale would not only produce needed funds but would also
strengthen the company's "quick ratio" when it came time to enter the
market for funds. Furthermore, this was a good opportunity for Atherton
to get out of a losing venture.

The net book value of the equipment now in use for Product 345 was
$160,000 with expected salvage value of $10,000. It was originally
estimated that the economic life would expire at the end of 1974, but
now it appeared that a major rehabilitation would be needed in December 1973
if the equipment were to be used in 1974. Even though no decision was
taken on rehabilitation, Atherton decided not to change its depreciaion
policies but would write off the loss at the end of 1973 in case the
equipment were to be retired at that time.

Atherton was quite a profitable company overall (50% tax bracket),
and only Item 345 was showing losses. Their cut-off return on investment
rate was 10% after taxes, and experience has proven to management's
satisfaction that Atherton's investment evaluation techniques were sound.

Questions

1. Discuss the expected return to the company for various pricing strategies. (Hint, a time horizon of four years should be used as this is the current estimated life span of the equipment.)

2. Choose the pricing strategy which you feel offers the company the best return, taking into account the risks involved.

3. Advise the company as to whether the offer for sale of the equipment should be accepted or whether the company should stay in the 345 Product Line, clearly outlining the basis for your decision.

    NOTE: A. State any assumptions made, but avoid assumptions that may define the problem away.

             B. Please explain the procedure you used to solve the case and show all necessary calculations.

APPENDIX IV

IGRAS

Interactive Graphical Risk Analysis System

Introduction

One of the most elusive problems faced by managers today is that of imposing structure on the decision making process when operating in an environment in which large amounts of uncertainty exist. Managers are faced with this problem when they are required to make decisions concerning such things as capital investments, pricing strategies, new product development, aquisitions, etc.

When dealing with these types of problems, point estimates of such variables as market share, industry sales, etc., cannot be taken as fact, but must be viewed in light of the uncertainty involved in actually attaining these projections. Thus the manager, in arriving at a decision, must develop some form of a risk measure for the alternatives under consideration and perform some types of a trade off between return and uncertainty. Typically, the decision maker's approach might be to (1) be overly conservative in estimating return on investment, (2) rely on the judgement of subordinates who have a good record for making estimates, or (3) require riskier alternatives to meet higher criteria. Such approaches have worked in the past and will continue to work in the future, however, for those decisions which potentially have a large effect on the firm, a more rigorous approach would seem reasonable. IGRAS presents a possible approach to the problem of adding structure to problems in which there are few quantitative data, subjective projections must be made and the question which is really being asked is, "what is the probability profile of attaining the projections of the alternative under consideration?"

The basic hypothesis behind IGRAS is that the decision maker, either through his research staff, or by his own intuitive judgement, can break

a problem into basic elements and assign to each of these elements subjective probability estimates for possible outcomes. For example, in a typical business decision problem, the basic elements for revenue and expenditure would be identified. For those elements in which uncertainty is greatest. further subdivisions could be made until all basic elements of risk have been identified. Thus the problem would be broken down into a tree like structure (see Figure 1) with multiple breakdowns along those paths possessing the most uncertainty.

Figure 1

An Example of the Problem Structuring Process
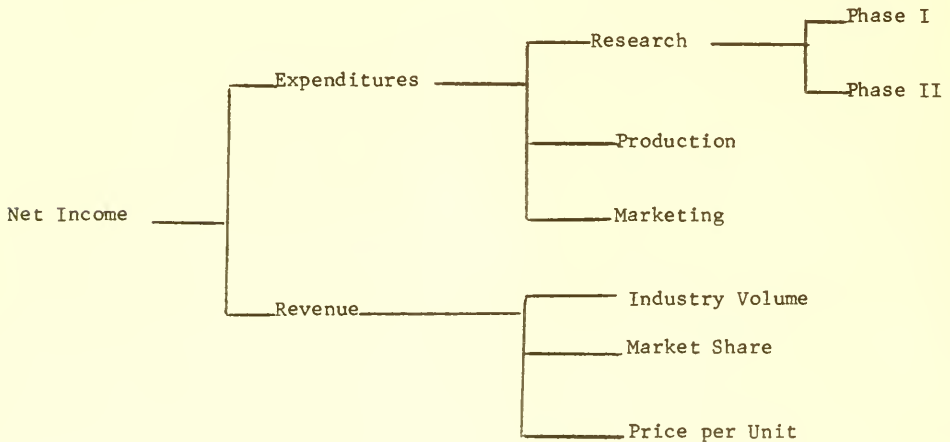
Once all the majors elements of risk have been identified, and subjective probability estimates developed for each, the tree structure can be folded back through combining the subjective probability estimate by means of a Monte Carlo type process to produce a probability profile of the total expected return on the investment. The machanism for providing the means to perform this type of an analysis is an on-line interactive visual display terminal based system (i.e., a keyboard terminal with a graphical display tube connected to a computer).

Before continuing with the description of IGRAS, four concepts of probability theory will be reviewed which are critical to the understanding of the system.

1. Frequency Distribution: A frequency distribution simply portrays for a given number of trials and a given set of outcomes, how many times each outcome occurred. Figure 2 gives an example in tabular form of a frequency distribution for the sales of product 345 for 1970 for 25 trials. In this example, since there are 25 trials, each occurrence of an outcome represents a 4% probability, i.e.,
    $$\frac{25}{100} = 4\%$$

2. Probability Density Function: A probability density function simply gives the probability that a given level will occur. This can be developed directly from the frequency distribution realizing that each outcome represents a 4% probability. Figure 2 shows the density function which is calculated by multiplying 4% by the number of outcomes at each level. This function is useful in giving one a feel for the most likely occurrence (i.e., the mode) and the skewness and variance of the expected outcomes.

Figure 2

Frequency Distribution

Sales Volume Range	Frequency	Probability
37,500 - 62,500	1	4%
62,500 - 87,500	2	8%
87,500 - 112,500	5	20%
112,500 - 137,500	7	28%
137,500 - 162,500	4	16%
162,500 - 187,500	3	12%
187,500 - 212,500	2	8%
212,500 - 237,500	1	4%
TOTAL	25	100%

Probability


Probability Density Function
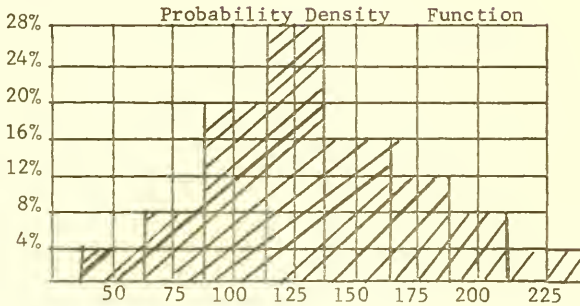
3. Cumulative Probability Distribution

This function can be derived from the probability density function and portrays the probability that an outcome will not be exceeded. Figure 3 shows a cumulative probability distribution derived from the previous example. For example, there is a sales volume of 112,500 units associated with the 32% probability point on the graph, the meaning being that there is a 32% probability that actual sales will be 112,500 or less. In operating with IGRAS you will be required to specify your subjective estimates in the form of a cumulative distribution. The system will automatically provide you with the probability density function. In describing the cumulative probability distribution you will be required to specify values at the 5%, 10% 25%, 50%, 75%, 90% and 95% probability levels.

4. Monte Carlo Method of Simulation is a method for operating with probability distributions. The process is based on the generation of a random number with values between 0 and 100, with each value having the same probability of occurrence (i.e., the generation process has a uniform probability density function). This random number is used to operate on a cumulative probability distribution by entering the graph at the probability level equal to the random number (in percent) and then picking off the value of the function associated with that probability level. For example, again referring to Figure 3, if the random number were 32, one would enter the graph at the 32% probability level and pick off the value for sales of 112,500. This value for sales is used by the system for all calculations involving sales. A new random number is then generated and the process is repeated. The results from each iteration through the process are used to form a frequency distribution, which in turn could be used to form a new cumulative distribution. Each time IGRAS runs a model it iterates through the process 25 times, thus the Monte Carlo Method provides a methodology for combining cumulative probability distributions. (Note, this concept will become clearer in the following discussion).

Figure 3

Sales Volume Range		Frequency	Probability	Cumulative Probability
37,500 -	62,000	1	4%	4%
62,500 -	87,500	2	8%	12%
87,500 -	112,500	5	10%	32%
112,500 -	137,500	7	28%	60%
137,500 -	162,500	4	16%	76%
162,500 -	187,500	3	12%	88%
187,500 -	212,500	2	8%	96%
212,500 -	237,500	1	4%	100%

Probability

Cumulative Probability Distribution

Sales Volume
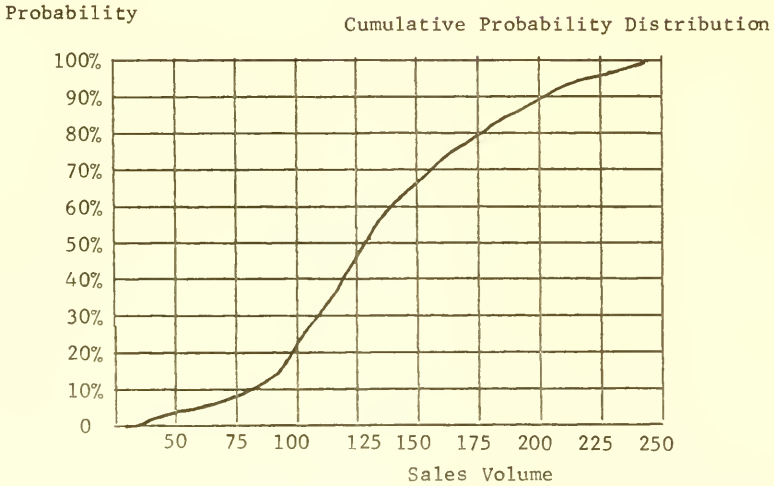
The problem environment which the present version of IGRAS addresses is that of the Atherton Company which is described in the case which has been distributed to you. The system already has placed on it the basic problem structuring tree (Refer to Figure 4). In particular, the elements of risk to which you must provide the basic inputs in the form of subjective probability distributions (i.e., cumulative probability distributions) are:

(1) Cumulative distribution of probable percentage increases in labor costs over a base cost for January 1970 for each year.

(2) Cumulative distribution of probable increases in material costs over a base cost for January 1970 for each year.

(3) Total Industry volume for each year.

(4) Atherton's market share for each year.

(5) Scrap value of equipment for the last year of the analysis horizon.

(6) The value of Inventory and Accounts Receivable for the last year of the analysis horizon.

In addition, you will be required to specify the price you intend to charge for each year and also what cost of capital will be used in the present-value calculations.

These specifications define what is called an alternative. As presently formated at the system, you can build up to four (4) different alternatives of this type in addition to the alternative of "getting out of the business." You will find on the system initially two alternatives already built, one for getting out of the business, and one pricing strategy. Thus two alternatives will already be on the system and you will have the options of modifying these two, and, or building up to three new alternatives.

Once all elements which are required to completely specify one alternative have been defined, the following models are automatically run:

1. Revenue for Each Year is calculated by use of the Monte Carlo technique which combines the cumulative probability distributions for total industry sales and Atherton's market share. The process to accomplish this is as follows: A random number is generated and is used to obtain a value for total industry sales, another random number is then generated to obtain a value for Atherton's actual sales and this value of sales is multiplied by the price for that particular year to give Revenue. The process is then repeated 25 times to form a frequency distribution for revenue for that year. The frequency distribution in turn is used to develop a cumulative distribution for revenue for that year. This process on the revenue side occurs for 1970, 1971, and 1972. In 1973, which is considered the last year for analysis purposes, values for the scrap value of the equipment and inventories and accounts receivable are also obtained using random numbers and these values are added to sales revenue for that year along with any tax advantage for loss on the sale of equipment to give total cash inflow.

2. Total Present Value of Revenues is calculated through using the Monte Carlo technique to combine the revenue curves generated for 1970, 1971, 1972, and 1973, discounting future cash flows using the present value model. Again, a frequency distribution is used to develop a cumulative probability distribution.

3. Expenditures for Each Year are calculated again using the Monte Carlo techniques and the sales figure which was generated for each iteration in calculating revenues. As there is little uncertainty associated with cost, per item cost being dependent on volume in accordance with Figure 2 of the Atherton case, the basic model for

calculating total expenditures is already on the system. Those
uncertainties which do exist are associated with labor and material
cost. Thus the calculation carried out here is the same as that
which is described in the case with the exception that labor and
material costs are adjusted by the subjective distributions developed
for expected changes in labor and materials costs, the exact per-
centage change being found for each calculation using random numbers.
Once again the process is run 25 times and a probability distribution
function is developed for expenditures for each of the years.

4. <u>Total Present Value of Expenditures</u> is an exact duplication of the
process used to calculate the present value of revenue with the
system using the Monte Carlo technique operating on the expenditures
for each year.

5. <u>Net Present Value After Taxes</u> simultaneously with the generation of
the total revenue and expense present value functions is the generation
of the net present-value function.

As present values for expenditures and revenues are calculated, the
difference between the two is calculated, tax effects are applied and
a net present value after taxes is obtained. This is repeated 25 times
and the results of these trials is displayed as the net present value
after taxes for the alternative.

This completes the introduction to the system. The next section
will describe the procedures for actually operating the IGRAS on the
ARDS Terminal.

Interactions with the System

IGRAS has been designed for operational ease and simplicity. At
each step in your analysis using the system, you will be furnished with
a list of all the options which will be available to you. For cases
where there are more than 4 options open, the command option "other"
will be listed. By initiating the command "other", the remaining options
will be listed.

The command options available at any time are of two types - movement
commands and functional commands. Movement commands are used for moving
from one node to another in the problem framework (see Figure 4) while
functional commands are used for interacting with specific nodes.

The problem framework itself is divided into 6 levels. These are:

1. Directory level
2. Alternative Comparison Level
3. Alternative Level
4. Expenditure, Revenue Level
5. Year Level
6. Model Component Level

Specifically the nodes contained in each of these levels are
used for the following purposes:

1. Directory Level: This level is where you will initially be
   when beginning your analysis. It allows you to move to any of the
   alternatives, or go to the "alternative comparison level". To move
   from one alternative to another you will always go to this level.

2. Alternative Comparison Level: This level allows you to view the
   after tax net present return functions for each of the alternatives
   entered on the system.

3. <u>Alternative Level</u>: When building a new alternative or modifying one presently on the system, moving to this level allows you to set, or change, your price per item for each year and your cost of capital.

4. <u>Revenue or Expenditure Levels</u>: You will note in Figure 4 that below the alternative level there is a fork, one side being revenue and the other expenditure. It should be noted that if you elect to move down one of these paths i.e., the expenditure path or the revenue path, to get from one path to the other, you will have to move back up the tree to the alternative node and then down the other path. This will also be true of all other forks in the tree. Thus you are limited to horizontal movement. The revenue node allows you to see a plot of the net present value of revenue versus probability for the total analysis period. Likewise the expenditure node allows you to see a plot of the net present value of expenditures versus probability for the total analysis period.

5. <u>Year Level</u>: This level allows you to look at each year's expenditure and revenues independently. Again remember if you look at expenditures for 1973 and wish then to view revenues for that year, you will have to move back up the tree on the expenditure side to the alternative level and then back down the tree on the revenue side.

6. <u>Model Component Level</u>: This is referred to as the lowest level in the SYSTEM. It is at this level that you enter your subjective estimates for the underlying model uncertainties.

   The movement command options are used to move to specific nodes in the problem tree. These commands are:

1. <u>Move to a higher level</u>: This command allows you to move up to the next higher level along the path you are presently on. Thus if you were at the (alternative - Revenue - 1973) node and gave this command, you would move to the (alternative 1 - revenue) node.

2. <u>Move to a lower level</u>: This command allows moving to the next lower level. As the structure fans out into branches, after giving this command, a list will be displayed to you of the specific nodes in the next level you can move to. You then simply type the letter associated with the node you desire to go to.

3. <u>Move to next sequential</u>: This command is used primarily for entering data at the "node component level," i.e., the lowest level of the problem tree. By giving this command it sequentially moves you along the low level nodes. Thus if you were at the (alternative 1- revenue - 1973 - industry volume) node, giving this command would move you to the (alternative 1 - revenue - 1973 - market share) node. This command moves you sequentially first on the revenue side for all model component elements for each year and then through all node component elements for each year on the expenditure side. By using this command you do not have to move up the structure to get between the revenue and expenditure sides. Thus this command allows lateral movement in level 6.

The functional commands which are available to you for interaction with a particular node are:

1. <u>Re-enter Data</u>
This command allows you to enter new data or alter old data for a distribution at the "model component level." This command causes the coordinates for the cumulative probability distribution to be printed out in tabular form one line at a time. The format of the chart is that the function value corresponding to the probability levels of - .05, .10, .25, .50, .75, .90, .95, are given one line, meaning one probability level, at a time. If no previous value has been entered, the system will pause and wait for you to type one in, if a set of values does exist, the value corresponding to the particular level will be printed, you can either type in a new value or go on to the next line by hitting the key "newline."

2. Graph Data

This command will graph the function of the node which you are presently at in the problem tree. If you have previously requested the system to save a graph (this command will be described next) then the saved graph will also be displayed in addition to the normal graph for the node you are at.

3. Save Top or Bottom Graph

This command causes the system to save either the top or bottom graph which you are viewing and to re-display it the next time you give the "graph data" command in addition to the normal graph which would be displayed. Note the size of the display tube is large enough to accomodate only two graphs at one time.

Methodology for Building an Alternative

Typically to build an alternative you would first move from the directory node (level 1) to the alternative node (level 2). At the alternative node you would specify the price you wish to charge for each year and your cost of capital (note you do not have to charge the same price for each year.)

From the alternative node you would give the "next sequential" command to move you to the industry volume 1970 level to enter your distribution. You would continue using the "next sequential" to build distributions for all "model component elements" for all 4 years for both revenue and expenditures. This requires the building of 18 distributions.

Once all the underlying distributions have been built, you are free to move to any node for that alternative, as the models will be automatically run.

Note this entire procedure will become much clearer once you get on the system.

Terminal Operating Instructions

When working with IGRAS an advisor will be present to answer any questions you may have and handle all system initiating procedures.

All commands to IGRAS are entered using the keyboard module of the ARDS terminal. In typing input to IGRAS on the keyboard if an error occurs, it may be corrected by typing a question mark (?) to cause the system to ignore ("kill") the entire line thus far, or by typing one or more quotation marks (") to cause the system to ignore ("erase") one or more immediately preceding characters.

Once you have typed either the data you desire to input, or the character describing the task you wish the system to perform, hit the "new line" key to enter it on the system. The "new line" key serves the dual purpose of acting as a carriage return and signaling the system to begin processing.

The image on the ARDS screen, whether it be text or graphics, will remain displayed for a period of several minutes, at which time if no further interactions are initiated, the ARDS terminal will automatically dim the image. To view the image again, simply push the "view" button, which is located on the upper right-hand corner of the terminal next to the display unit.

APPENDIX V

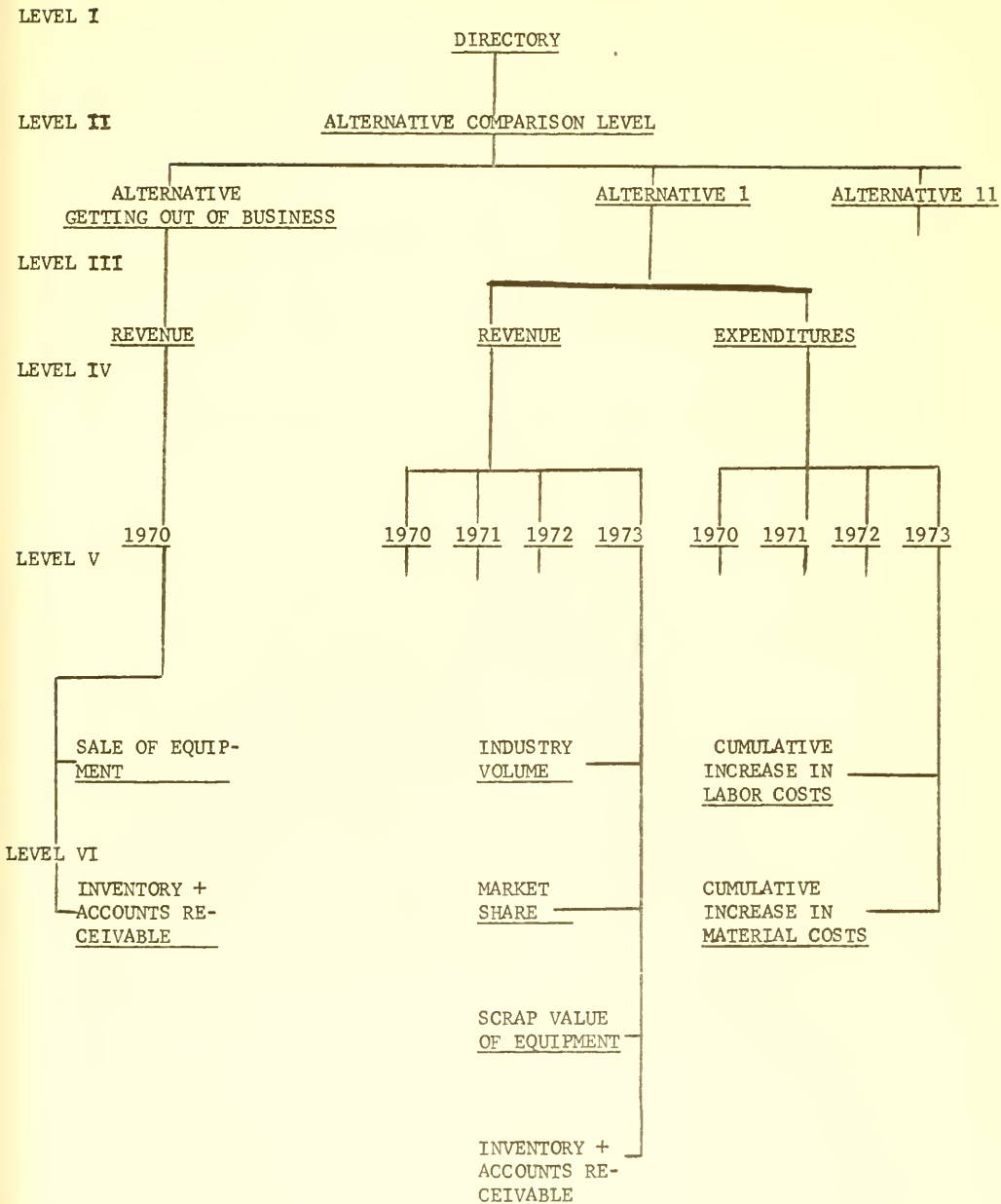### QUESTIONNAIRE

NAME_____

1. How useful in analyzing the Atherton Case was the time spent using the system?

   Very useful   1 2 3 4 5 6 7   Useless

2. How did you find waiting time between your response and system response?

   Too fast   1   2   3   4   5   6   7   Too slow

3. How did you like the organization of the system?

   Very much   1   2   3   4   5   6   7   Not at all

4. How difficult was it for you to learn how to operate the system?

   Not at all   1   2   3   4   5   6   7   Very

5. Did you feel that you were controlling the output of the system?

   I controlled   1   2   3   4   5   6   7   System controlled

6. How do you feel about the feasibility of using a system similar to this in an actual business setting?

   Very feasible   1   2   3   4   5   6   7   Not at all feasible

7. Do you feel you understood what the system was doing?

   Completely   1   2   3   4   5   6   7   Not at all

8. How do you feel about the number of subjective probability distributions you were required to enter?

   Too many   1   2   3   4   5   6   7   Not enough

9. How did you feel when using the system?

   Always interested   1   2   3   4   5   6   7   Bored

10. How long do you estimate your terminal session was?

11. Any recommendation for improvement of the system?

USER EVALUATION OF IGRAS

12. What did you like about the system?

13. What did you dislike about the system?

FIGURE 4

LEVEL I

DIRECTORY

LEVEL II

ALTERNATIVE COMPARISON LEVEL

ALTERNATIVE
GETTING OUT OF BUSINESS

ALTERNATIVE 1

ALTERNATIVE 11

LEVEL III

REVENUE

REVENUE

EXPENDITURES

LEVEL IV

1970

1970 1971 1972 1973

1970 1971 1972 1973

LEVEL V

SALE OF EQUIP-
MENT

INDUSTRY
VOLUME

CUMULATIVE
INCREASE IN
LABOR COSTS

LEVEL VI

INVENTORY +
ACCOUNTS RE-
CEIVABLE

MARKET
SHARE

CUMULATIVE
INCREASE IN
MATERIAL COSTS

SCRAP VALUE
OF EQUIPMENT

INVENTORY +
ACCOUNTS RE-
CEIVABLE

ANALYSIS FRAMEWORK FOR THE ATHERTON CASE

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