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A PILOT SURVEY OF COMPUTER PROGRAMS FOR DECISION ANALYSIS

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Decisions and Designs, Incorporated

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This report contains a survey of the state-of-the-art of computer programs for decision analysis. It is intended to provide both a useful guide for decision analysis practitioners and a tentative statement of the state-of-the-art. Existing programs are reviewed from a user's point of view with an emphasis on each program's availability, ease of use and extent of previous application. Conclusions are drawn with regard to promising

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directions for future development of such programs. This report represents an initial effort to survey decision analysis computer programs and will be revised as new material becomes available.

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A PILOT SURVEY OF COMPUTER PROGRAMS FOR DECISION ANALYSIS

1.0 INTRODUCTION

This report provides a description of computer programs to aid in decision analysis and is based on a modest amount of preliminary survey work done to date. This work is presented as a pilot study in the area and, as such, does not purport to be exhaustive. The author would welcome an ongoing exchange of information in this area, especially additional comments from users of the programs presented and information about omitted programs. This report will be revised as new material becomes available.

The objective of this study is two-fold. First, the study is designed to be a useful guide for decision analysis practitioners who wish to utilize available computer software in their work. Secondly, it is intended to provide a tentative statement on the state-of-the-art in computer applications of decision analysis techniques. For this reason, descriptions of programs that are strictly developmental or are for internal use only are included as well as those that are commercially available.

While the term "decision analysis" has connotations over a wide range of topics, a specific definition was used as a guide for this survey. As it is used in this paper, "decision analysis" refers to a general purpose prescriptive discipline for systematic evaluation of alternative actions as a basis for choice among them. Decision analysis models often include a decision tree or decision diagram. Inputs to such models can include numerical probabilities, that quantify judgments about uncertain future events, as well as numerical assessments that express the decision maker's attitudes, or the organization's policies, as regards values and risk. A model's output may include a display of the probabilities of each possible outcome for every action alternative, or a specification of the single course of action to be preferred under the assumptions of the model. This is basically the definition used by Brown, Kahr, and Peterson [4,5], Raiffa [11], and Schlaifer [14], in their books on the subject.

While this definition of decision analysis guided

the survey, focusing emphasis on programs related to decision tree analysis, several other related programs were encountered and are referred to. The search and analysis of these programs, however, was very limited.

Operating within this definition the decision analysis programs encountered could be classified as follows:

A. Decision Tree Roll-Back Programs
B. Probability and Utility Programs
C. Modeling Languages and Subroutine Packages
D. Other Special-Purpose Programs.

The most thorough research was done on the first two categories of programs. The last two categories are covered only to the extent that they were incidentally encountered. Since a number of the programs encountered do not have designated names, they are identified by developer in the discussion sections. In the case of programs which are commercially available, sources of more information are listed in Section 3.5.*

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* Informational notes and articles on all programs are on file at Decisions and Designs, Incorporated.

2.0 OVERVIEW AND CONCLUSIONS

The preliminary indications are that nearly all development of computer aids for decision analysis thus far has been as a by-product of the developer's main activity of consulting or research. Little development work on these types of programs has been done by companies that are primarily in the computer software business. For this reason, modifications and anticipated modifications to the computer aids have been largely to refine the usefulness of the programs to one particular user rather than to expand the usefulness to a wider group of potential users. Typically, the developers express the view that they are basically satisfied with their own programs and have little interest in incorporating features of other programs into their own. Also, for this reason, the programs' developers tended to be their own biggest users with the next largest user group being consulting clients of the developer.

Because of the manner in which computer programs for decision analysis have been developed, a gap exists in the type of analysis which can be readily performed by the available programs. That is, a user wishing to perform an entire complex decision tree analysis, incorporating a large user-specified decision tree combined with continuous probability distributions and utilizing a complicated utility function, cannot easily use any of the existing programs to perform the analysis. The reason for this is that programs that are designed to perform "roll-back" calculations on a user specified decision tree (such as SRI's TREE and CTREE, ADS's ADTREE and Scientific Software's TREE) are limited in the types of probability distributions and utility functions that can be easily accomodated. For instance, CTREE can easily accomodate only discrete probability distributions and utility functions exhibiting constant aversion to risk. ADTREE and TREE can handle certain classes of continuous probability distributions but cannot process utility functions. On the other hand, programs designed to process a rich set of probability and utility options, such as Manecon, DECOMP, and MUFCAP, cannot process user-specified decision trees.

Elicitation of model inputs is another area where a gap exists. Manecon and PEP provide streamlined features to aid in the elicitation of probability distributions, but cannot process a decision tree. Similarly, Manecon and MUFCAP provide for the elicitation of utility functions but do not process trees. However, no decision tree processing program provides a means for eliciting probability or utility functions. Furthermore, no programs have been developed to aid in the elicitation of the tree structure.

In conclusion, it appears that no large increment in the usefulness of computer aided decision analysis is likely to occur as long as the current trend toward special purpose refinement is continued. A shift in emphasis toward combining features of several existing programs may, however, produce such a large gain in usefulness. However, this view is by no means universally held (as evidenced by the reluctance of developers to make such moves).

3.0 DESCRIPTIONS OF PROGRAMS

3.1 Decision Tree Roll-back Programs

Programs in this group perform roll-back or folding-back calculations for user-specified trees. Programs in this group vary in characteristics from very elaborate and sophisticated to simple. The most extensively used program of this group is CTREE which receives such great use because its developer, Stanford Research Institute, uses decision trees widely in their consulting work.

3.1.1 Applied Decision Systems (ADS) (Wellesley Hills, Massachusetts) developed ADTREE as a decision tree roll-back program, but the program is not in active use (it was last used in 1971). They have found, through their consulting experience, that more productive results are obtained by presenting managers with risk profiles for options (which indicate directly the risk and return characteristics of the option) rather than a complex folded-back decision tree (see the later reference to ADS's ADPLAN in Section 3.3.2). They recommend the use of a desk calculator rather than a computer program for folding-back simple decision trees. User information for this program can be obtained from the developer (see the information in Section 3.5 of this report). This and other ADS programs are made available through several time-sharing arrangements.

3.1.2 DuPont (Wilmington, Delaware) has developed a program which is used by its analysts in batch mode to roll-back a decision tree and display the results over a high speed printer. Analysts have used this program in the area of long-range business planning, notably in the area of expansion into new business areas. This program is not available for use outside of DuPont.

3.1.3 IBM-Cambridge Scientific (Cambridge, Massachusetts) developed an experimental decision tree roll-back program utilizing interactive computer graphics. Mr. M. Schatzoff, one of the program's developers, indicated that the program was written strictly as an internal project with no plans to make it part of the commercially available software. In fact, the program is very equipment specific (IBM 1130-2250) and, since the equipment is no longer located at Cambridge, the program cannot even be run by the developer. The only available printed information on this program is an article by J. Ravin and M. Schatzoff [12] which describes the operation of the program but does not provide a guide to its use.

This program differs from others in the group in that it not only operates interactively but also provides the user with a display of the decision tree on an interactive graphic terminal. This is the only known attempt to develop a decision analysis program using interactive computer graphics and thus represents an important advancement in the state-of-the-art. Unfortunately, the program was developed strictly as an internal experimental project with no plans for public release and thus has not been subjected to extensive application and evaluation.

3.1.4 Scientific Software Corporation (Englewood, Colorado) has developed a program called TREE. This program uses simulation to both roll-back a decision tree and to give a risk profile of each option. When contacted, they indicated that the program is being used by several overseas clients and by the U.S. Department of Defense. This program is available for purchase ($15,000) or lease ($3,000/year). The program is also available for use by agencies of the U.S. Government through the U.S. Geological Survey. The developer offers a user's manual to its customers and also offers a course in the program's use.

This program differs from others in the group in that the evaluation method employed is simulation rather than the conventional mathematically defined roll-back algorithm. This program also offers a unique output option in the form of a hard copy plot of the specified decision tree in addition to a tabular summary evaluation of alternatives. When contacted, Mr. Ben Mares, Scientific Software's technical marketing representative indicated that the program is getting only limited use and that they are not actively promoting it. Scientific Software does not do a large percentage of its business in the decision tree analysis area (they are primarily petroleum consultants).

3.1.5 Stanford Research Institute (SRI) (Menlo Park, California) has developed the programs, TREE and CTREE to aid in the performance of a decision tree analysis. TREE is a highly interactive program designed to allow the user to specify small decision trees (up to 1000 nodes) in a straightforward way. CTREE is a general purpose language for specifying and processing large decision trees which may be adapted for use in an interactive or batch mode. SRI has made these programs available for outside use but they are still the program's biggest user. User Manuals are available from SRI which fully explain these programs [13,19]. Both CTREE and TREE are available through COMSHARE for a fee. In addition, CTREE is available through the G.E. and U.C.S. time sharing system or through a purchase arrangement with SRI for $15,000 (which includes the PEP Program discussed in Section 3.2.4). SRI

provides assistance in adapting the program to operate on a user's system. The cost of SRI services for adapting the the program usually runs around $10,000 to $15,000). CTREE is also available to ARPANET users through the UCLA CCBS computer.

SRI's TREE program appears to be the easiest decision roll-back program to use. It is designed to be highly interactive and to require no computer programming skills on the part of the user. Ramon Zamora of SRI indicated that modifications have been made to this program so that it is highly dependent on the COMSHARE system and not readily adaptable to other systems, a feature which may limit its usefulness. This program is also limited in the size of tree that can be accommodated and the flexibility of processing available.

CTREE is the most comprehensive and flexible of the decision tree roll-back programs. More accurately, CTREE is a specialized language that instructs the computer how to generate and evaluate complex decision tree structures. A feature of CTREE's design is that the user has the full flexibility of using FORTRAN statements as well as CTREE statements in his program, allowing a great deal of flexibility in terms of model design and output options. To provide this flexibility requires CTREE to have a much greater complexity than TREE, and a knowledge of computer programming and FORTRAN is highly useful for any CTREE user. Since SRI's Decision Analysis group is heavily engaged in the use of decision tree analysis, CTREE is the most widely promoted and most extensively used decision tree roll-back program.

3.1.6 Systemes Informatiques De Gestion (SIG) (Paris, France) has developed the program ARBRES, to aid in the performance of decision tree analysis. This program is highly interactive and is very similar to SRI's TREE program in its structure, operation, and output form. ARBRES also incorporates several unique features including a provision to perform simulation at chance nodes and a provision for a streamlined representation of multiple parallel nodes. The current version of ARBRES can only process trees with up to 450 nodes.

ARBRES has been used mainly by educational institutions (in France) and by SIG in their consulting work. Although this program is available in the United States through the Tymshare network ($32 per hour of connect time), both the interactive instructions and the user's manual [18] are in French.

3.2 Probability and Utility Programs

Programs in this group are designed to provide inputs to a decision tree model. All of these programs provide for

interactive elicitation or processing of either probability distributions or utility functions.

3.2.1 At Decisions and Designs, Incorporated (DDI) (McLean, Virginia), Rex Brown has developed the DECOMP program. This program utilizes a simulation algorithm and the method of credence decomposition to deduce the distribution of any function of random variables from the distribution of its arguments. Although this program has been used fairly extensively by its developer, it is not available for general use outside of DDI. (An earlier variant of this program, however, was originally a part of the SIMPAK programs developed at Harvard Business School [6].) Furthermore, the program is cumbersome to use and requires the user to be familiar with the method of credence decomposition, described in the developer's book, Research and the Credibility of Estimates [3]. This book also provides a listing of the program and general instructions on its use (previous attempts to use this program with only this amount of guidance, however, have proven to be very unsuccessful). This is the only program encountered that is capable of performing the very useful operation of combining distributions of random variables. The usefulness of this program is limited, though, because it is so cumbersome to use.

3.2.2 At Harvard University Graduate School of Business Administration (Cambridge, Massachusetts) Robert Schlaifer has developed the Manecon set of interactive programs designed to perform calculations of the type mentioned in his book, Analysis of Decisions Under Uncertainty [14]. The largest and most useful parts of this collection are programs that interactively elicit probability distributions and utility functions and use these elicitations to evaluate individual alternatives (the programs do not have the capacity to roll-back a user-specified decision tree). Other programs in this set perform specialized calculations of such things as the "expected net gain of sampling" and "optimal size of a sample," but these programs have not been found to be very useful. While these programs are available for purchase, indications are that they have received little use outside of Harvard Business School. Dr. Schlaifer has written a very comprehensive user's guide for these programs [15].

This highly developed, easy to use, and comprehensive collection of programs vastly reduces the computational burden involved when complicated probability distributions and utility functions must be considered. It represents the most highly developed program of this group. The very streamlined interactive features make this set easy to use by persons unskilled in computer programming. A person skilled in FORTRAN programming, though, can easily use portions of the Manecon set in his own programs. In this

way, Manecon provides a flexible resource for the skilled programmer. To most usefully use these programs, though, the user should be familiar with the concepts and terminology used by Schlaifer in Analysis of Decisions Under Uncertainty.

3.2.3 At Massachusetts Institute of Technology's Operation Research Center (Cambridge, Massachusetts), Alan Sicherman has developed MUFCAP, an interactive computer program for assessing and using multiplicative multiattribute utility functions (a computer application of the work done by Ralph Keeney at MIT [8]). This is the only known program to provide a means to evaluate multi-attributed alternatives as part of a decision tree analysis, but it is awkward to use and requires the user to be knowledgeable about both multiplicative utility theory and the specific options available in the program. It is currently planned to make the program listing and a user's guide publicly available free of charge early in 1975, (see Section 3.5 for more information) but it is not planned to make the program available through any other arrangements, such as time sharing.

The program represents an advancement in the state-of-the-art of computer programming for decision analysis in that it is the first attempt to computerize multiplicative multi-attributed utility functions. With some further refinement, this program would promise to have applications to a wide range of decision problems.

3.2.4 Stanford Research Institute (SRI) (Menlo Park, California) developed PEP, a probability encoding program, to be used in conjunction with their decision tree programs, TREE and CTREE. This highly interactive program is designed to take the place of a human interviewer to determine the user's state of information about an uncertain quantity. The user responds to a series of questions about the uncertain quantity and is then given a description of that quantity in probability terms as output. This program is sold as a package together with CTREE and is also available over the COMSHARE, G.E. and U.C.S. time sharing systems. The CTREE user's manual [19] also explains PEP.

PEP is designed to perform some of the same tasks as the probability elicitation programs in Manecon. PEP, however, does not offer the user nearly as much flexibility in the form of distributions and output available. This program is specifically designed to calculate representations of continuous distributions in a form that can be used by SRI's CTREE and TREE.

3.3 Modeling Languages and Subroutine Packages

These packages are designed to offer flexibility in model specification and are not restricted to decision tree applications. A general feature of this group is that the user must gain a programming knowledge in order to develop and use models. A. D. Little and ADS developed their generalized subroutine package and modeling language as an alternative to a decision tree roll-back language in order to more closely meet the needs of their work.

3.3.1 A. D. Little (Cambridge, Massachusetts) has developed a set of subroutines to aid in their analysis of complex problems. Their approach is to write a computer program from scratch for each problem, utilizing subroutines in their package to aid in such things a stochastic simulation or decision tree roll-back. They feel that the problems that they address are too complex for any general purpose modeling programs. Their subroutine package is not available for use outside of A. D. Little.

3.3.2 Applied Decision Systems (ADS) (Wellesley Hills, Massachusetts) has developed ADPLAN, a general planning language for probabilistic and deterministic modeling. This language allows the user to easily indicate model inputs, outputs, and the mathematical relationship between them. In the case of a probabilistic model, simulation will be performed to allow for a risk profile output (this language has no built-in decision tree features). The language has been developed and refined over the last three years on the basis of their successful use of the risk profile concept in their consulting practice. They estimate that ADPLAN is used independently by their clients as often as it is used with consulting help. The language is available for purchase or lease and a user's manual is available.

3.3.3 Bonner and Moore Associates, Inc. (Houston, Texas) have developed the PAUS system. This system provides a general purpose modeling language which enables the user to specify any input-output relationship between deterministic or probabilistic variable (with no built-in decision tree features). Further, special purpose "black box" evaluation packages which address an individual, specific problem are available. This system offers a very flexible, wide range package. PAUS is available for installation on the user's machine ($10,500 license fee per installation) and is also available over the National CSS time sharing system (on a royalty surcharge basis). Bonner and Moore indicated that PAUS is used most frequently by outside users on their own.

3.3.4 Other Modeling Languages, as well as some of the programs presented here, have been reviewed, with a slightly different emphasis, in an article by Roger W. Berger [2].

3.4 Other Special Purpose Programs

Typically, these programs are designed to be self-contained units which address a specific problem. Although they are not designed to perform a decision tree analysis or to provide inputs for a decision tree analysis, they are of a related nature.

3.4.1 At Battelle-Institut (Frankfurt, Gemany), V. Bauer, J. Meise, and M. Wegener have developed POLIS/MAUT for evaluating and displaying multi-attributed utility functions for geographic units. The program has been applied to urban planning problems in experimental workshops. More details of this program appear in the developer's forthcoming article [1].

3.4.2 General Electric (Environmental Analysis Staff, Fairfield, Connecticut) has developed a Decision and Gaming program designed to aid a decision maker who is considering the expansion of existing facilities or building a new plant for old or new products. The decision program combines features of Hertz's "Risk Analysis" [7] with certain elements of decision trees to produce a risk profile of alternatives. This program does not have provisions for processing user-specified decision trees. These programs operate on the GE-265 time-sharing system.

3.4.3 McKinsey and Company (New York, New York) have developed a number of programs strictly for internal use (used by their consultants for consulting purposes). The most widely used program is one that generates pro-forma financial statements. There are no plans to make any of these programs commercially available.

3.4.4 While at Northeastern University (Boston, Massachusetts) Warren Briggs (who is now at Bently College, Waltham, Massachusetts) developed RISKAN, a simulation model which uses the risk profile concept for evaluation of investments involving uncertainty. This program was designed for teaching risk analysis techniques but has been used in consulting situations as well. A listing of the program is available from the author free of charge, and a paper tape of the program could be obtained.

3.4.5 At Oregon Research Institute (Eugene, Oregon) Sarah Lichtenstein is currently in the process of developing a computer program to aid in the training and calibration of probability assessors. This program, which is based on her extensive research in the area, will represent a significant advancement in the state-of-the-art of programs for calibration of probability assessors. The program is now in the early stages of development.

3.4.6 At the Rand Corporation (Santa Monica, California), William Sibley developed an interactive, graphic computer program to train and calibrate probability assessors using 3-event discrete distributions [13]. A newer version which uses continuous distributions has been developed by Thomas A. Brown and Suzy Landa.

3.4.7 At the University of British Columbia (Vancouver, British Columbia), K. R. MacCrimmon and J. K. Siu have developed the ICM (Interactive Choice Mode or Indifference Curve Method) program for assessing and displaying indifference curves for two attributes. It has been experimentally applied to problems of assessing social preferences, economic policy, and alternative legal systems. A fuller description of the program's functions and applications are presented in an article by the developers [9]. A program listing is available from Dr. MacCrimmon upon request.

3.4.8 The University of Colorado Institute of Behavioral Science (Boulder, Colorado) has developed POLICY, an interactive program for externalizing, executing, and refining judgmental policy (a multi-dimensional utility model). This program has been applied to the problem of formulating Boulder, Colorado's policy for green-belt land. The program is in the public domain and available through the University of Colorado.

3.4.9 Other Special Purpose Programs - Several programs have been developed in the area of multi-dimensional scaling and are described in a book on the subject by Shepard, Romney, and Nerlove [16].

3.5 Availability of Program Information

The following people should be contacted for more information on the commercially available programs mentioned in the previous sections.

Section	Program	Contact
3.1.1	ADTREE	Dr. Stan Buchin, President Applied Decision Systems 15 Walnut Street Wellesley Hills, MA 02181
3.1.4	TREE	Mr. Ben Mares Technical Marketing Representative Scientific Software Corporation First Denver Plaza, 18th Floor Denver, CO 80202
3.1.5	CTREE, TREE	Decision Analysis Group Stanford Research Institute 333 Ravenswood Avenue Menlo Park, CA 94025
3.1.6	ARBRES	Prof. Michel Klein, Director R&D Systems Informatiques De Gestion 69, Rue Legendre 75017 Paris FRANCE
3.2.1	DECOMP	Mr. Jacob W. Ulvila Decisions and Designs, Incorporated Suite 600, 7900 Westpark Drive McLean, VA 22101
3.2.2	Manecon	Director of Computer Services Harvard Business School Boston, MA 02163
3.2.3	MUFCAP	Mr. Alan Sicherman Operations Research Center Massachusetts Institute of Technology 77 Massachusetts Avenue Cambridge, MA 02139
3.2.4	PEP	Decision Analysis Group Stanford Research Institute 333 Ravenswood Avenue Menlo Park, CA 94025
3.3.2	ADPLAN	Dr. Stan Buchin, President Applied Decision Systems 15 Walnut Street Wellesley Hills, MA 02181

Section	Program	Contact
3.3.3	PAUS	Mr. Monte G. Smith, President Bonner and Moore Software Systems 500 Jefferson Houston, TX 77002
3.4.1	POLIS/MAUT	Mr. Michael Wegener Battelle-Institut e.V. 6 Frankfurt am Main 90 Postschiessfach 900160 GERMANY
3.4.4	RISKAN	Dr. Warren G. Briggs Bentley College Waltham, MA 02154
3.4.6		Ms. Suzy Landa The RAND Corporation 1700 Main Street Santa Monica, CA 90406 or Mr. Thomas A. Brown Pan Heuristics Suite 1221 1801 Avenue of the Stars Los Angeles, CA 90067
3.4.7	ICM	Dr. Kenneth R. MacCrimmon Faculty of Commerce and Business Administration University of British Columbia Vancouver 8, British Columbia CANADA
3.4.8	POLICY	Dr. Thomas H. Smith Institute of Behavioral Science University of Colorado Boulder, CO 80302

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