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ABSTRACT

As a demonstration of the application of heuristic devices to decision-theoretical techniques, an interactive computer program known as MAUD (Multiattribute Utility Decomposition) has been designed to support decision or choice problems that can be decomposed into component factors, or to act as a tool for investigating the microstructure of a component of a decomposition problem. MAUD produces a log of decision making sessions, including a list of the MAUD-composed holistic preference values for the alternatives under consideration and a summary of the structure and basis on which these values were computed. The option of updating decision making structures is also allowed. In addition, MAUD interacts directly with clients, without the use of an intermediary decision analyst or technician. This report contains a complete user manual for the operation of the MAUD program implemented on an IBM 5110; it is noted that MAUD can be used to teach students with a variety of military decision problems to produce decisions and be more cognizant of their own values. Several examples are provided to help the user both understand the input and interpret MAUD outputs. A decision-theoretic rationale for the MAUD algorithms with special reference to multiattribute utility theory is summarized as are the programing logic and operations. Also included are a 41-item bibliography and a complete line-by-line program listing. (Author/ESR)

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Technical Report 543

MAUD: An Interactive Computer Program for the Structuring, Decomposition, and Recomposition of Preferences Between Multiattributed Alternatives

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BASIC RESEARCH

U. S. Army
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This report describes the use and operation of Multiattribute Utility Decomposition (MAUD), an interactive computer program for the structuring, decomposition, and recomposition of preferences between multiattributed alternatives.

MAUD is designed as a decision aid, helping the decision maker in any and all of the above operations. MAUD is of use in situations in which the user has an intuitive "feel" for relevant aspects of the decision-making (Continued)

Item 20 (Continued)

and problem but has not as yet uncovered its precise worth structure, or where we are interested in how the user's idiosyncratic worth structure is mapped onto the problem situation.

MAUD also finds its application within systems that are well structured at a macro level, that is, where overall act-event tree or utility hierarchy is known, but where the worth structure associated with particular utility assessments to be inserted at defined points within the main system needs investigation. In this case, MAUD does not address the decision problem as a whole but is used as a tool to investigate the microstructure of a component of the decomposition problem.

MAUD is designed for direct interfacing of client (decision maker, expert) and decision problems in a "hands on" approach. As such, it is designed to interact directly with the client, without using a decision analyst or technician as an intermediary. The decision analyst, in discussing the problem with the client before using MAUD, will wish to arrive at an agreed definition of the set of alternatives whose worth structure MAUD is to investigate and the goals under which the worth structure is subsumed. However, once these issues have been defined, the decision analyst is advised to let MAUD take over structuring decomposition and recomposition of preferences between alternatives in direct interaction with the user.

Technical Report 543

MAUD: An Interactive Computer Program for the Structuring, Decomposition, and Recomposition of Preferences Between Multiattributed Alternatives

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MAUD: AN INTERACTIVE COMPUTER PROGRAM FOR THE STRUCTURING, DECOMPOSITION, AND RECOMPOSITION OF PREFERENCES BETWEEN MULTIATTRIBUTED ALTERNATIVES

BRIEF

Requirement:

To summarize the rationale, user procedures, and program description and provide a software program listing for the Multiattribute Utility Decomposition (MAUD) decision aid.

Procedure:

The MAUD software was developed as a demonstration of the application of heuristic devices to decision-theoretic techniques; background is provided in TR 542, "Structuring Decisions: The Role of Structuring Heuristics."

Findings:

This report contains a complete user manual for the operation of the MAUD program implemented on the IBM 5110; versions are available on both tape and diskette. Several examples are provided to help the user both understand the input and interpret the outputs. A decision-theoretic rationale for the MAUD algorithms with special reference to multiattribute utility theory, as well as the programming logic and operations, is summarized. Finally, a complete line-by-line program listing is included.

Utilization of Findings:

The MAUD program is intended to support any decision or choice problem that can be decomposed into component parts or factors and for which the decision maker is able to at least tentatively identify those factors. While decision analysts are not needed to operate the program, they would be helpful in instructing the decision maker on the program rationale and output interpretation. In its present form, MAUD is designed to help a decision maker choose among alternatives for any problem; that is, it is context free, allowing users to define the problem specifics. MAUD would be particularly helpful in teaching students a variety of military decision problems to produce decisions and be more cognizant of their own values.

MAUD: AN INTERACTIVE COMPUTER PROGRAM FOR THE STRUCTURING, DECOMPOSITION, AND RECOMPOSITION OF PREFERENCES BETWEEN MULTIATTRIBUTED ALTERNATIVES

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MAUD: AN INTERACTIVE COMPUTER PROGRAM FOR THE STRUCTURING, DECOMPOSITION, AND RECOMPOSITION OF PREFERENCES BETWEEN MULTIATTRIBUTED ALTERNATIVES

1. OVERVIEW

This report describes the use and operation of Multiattribute Utility Decomposition (MAUD), an interactive computer program for the structuring, decomposition, and recomposition of preferences between multiattributed alternatives.

MAUD is designed as a decision aid, aiding the decision maker in any and all of the above operations. MAUD is of use in situations where the user has an intuitive "feel" for relevant aspects of the decision-making situation and problem, but has not as yet uncovered its precise worth structure, or where we are interested in how the user's idiosyncratic worth structure is mapped onto the problem situation.

MAUD also finds its application within systems that are well structured at a macro level, that is, where overall act-event tree or utility hierarchy is known, but where the worth structure associated with particular utility assessments to be inserted at defined points within the main system needs investigation. In this case, MAUD does not address the decision problem as a whole but is used as a tool investigating the microstructure of a component of the decomposition problem.

MAUD is designed for direct interfacing of client (decision maker, expert) and decision problems in a "hands on" approach. As such, it is designed to interact directly with the client, without using a decision analyst or technician as an intermediary. The decision analyst, in discussing the problem with the client before using MAUD, will wish to arrive at an agreed definition of the set of alternatives whose worth structure MAUD is to investigate and the goal under which the worth structure is subsumed. However, once these issues have been defined, the decision analyst is advised to let MAUD take over, structuring decomposition and recomposition of preferences between the alternatives in direct interaction with the user.

MAUD produces a log of the session that ensues,[1] and the decision analyst may well wish to assume a foreground role again in conducting a debriefing interview with the client at the end of the session to discuss the material in the log. The log will include the MAUD-composed holistic preference values for the alternatives under consideration and a summary of the structure and basis on which these values were computed.

MAUD also allows updates. The current structure elicited from the user, together with all relevant content, may be saved on a named file and recalled on any subsequent MAUD run. The user then has the options of modifying the structure, changing content within structure, and simulating the effects of changing value-wise importance weights within the original or modified

---

[1] An example of such a log is given on pages 10-12 and 15-17.

structure. Hence MAUD can be used for exploring hypotheses about new and hypothetical alternatives, simulating different users' assessments within a common structure, exploring the effects of mapping values onto different worth structures, conducting general sensitivity analyses, and so on.

Organization of the Report

Section 2 is for the user. It is self-contained and written in non-technical language. It may be separated from the rest of the report and used as a user's manual. It does not assume (or provide) any technical knowledge of decision theory, computer programming, or computer operation.

Section 3 is for the decision theorist and decision analyst who would like to know something of the theory underlying MAUD, such as why MAUD does what it does, how it does it, and how it decides when to do it. It also places MAUD in context within general Multiattribute Utility Theory (MAUT) and suggests further development.

Appendix A is for the systems analyst wishing to implement or modify MAUD on an IBM 5110, North Star Horizon, or other mini- or microcomputer. The description of the MAUD suite of programs will, however, also be of use to the decision analyst wishing to know about the detailed operations of MAUD. MAUD is modular, and so the modules can be revised, extended, and supplanted by a decision analyst who is, or has, a good systems programmer to "tune" the system to meet particular needs.

Appendix B is a complete listing of MAUD as we implemented it for the IBM 5110.

2. MAUD USER'S MANUAL

The version of Multiattribute Utility Decomposition (MAUD) described here is for an IBM 5110 system. Interaction with the user is carried out using the screen for display. MAUD is made up of three interrelated programs, stored on a 3M tape cartridge that runs on the tape unit, which is an integral part of the 5110.

To run MAUD, place the MAUD tape cartridge in the slot in the 5110 front panel, and type:

LOAD! <EXECUTE>

then RUN <EXECUTE>

What MAUD DOES

2.1 MAUD will initially ask the user for a title for the session and a generic name for all items (choice alternatives) under consideration. Amendments are allowed. The following examples are taken from a MAUD session with a campaign planner (Frances) in an advertising agency who had to choose one of four videotaped prototype advertisements for development and transmission over the commercial television network.

```
Please type in a name for this session  FRANCES SECOND SESSION
O.K.

Please type in a word describing the topic you want to
make a decision about by answering the question
"The alternatives I am thinking about could all be
described as COLA ADS

Now in singular form: Each alternative could be
described as a COLA AD
Are you reasonably happy with the words you typed? YES
```

In this and the following examples, the text has been copied from the 5110's screen, and underlines have been added to the user's responses.

2.2 The user is asked to specify choice alternatives (a minimum of 3 items, a maximum of 11). For example:

```
Please type in the name of a COLA AD
you want to consider

Its name is PARTY
```

When the user has specified all choice alternatives, MAUD will give a printout of all the alternatives under consideration and will ask if the user wants to make any changes.

MAUD allows the user to make several types of amendments:

(1) to change the name of an item,
(2) to delete an item, and
(3) to add an item.

```
You have considered 4   COLA ADS

  COLA ADS under consideration  :

  (1) PARTY
  (2) BERMUDA
  (3) HAIR
  (4) FISH AND CHIP SHOP

Do you want to change anything ? NO
```

2.3 MAUD will then help the user elicit attributes relevant to the choice alternatives under consideration by presenting triads of alternatives and asking the user to specify differences and similarities among the alternatives. Those definitions will represent the poles of the attribute dimension. MAUD will allow changes if the user is not happy about the definitions given.

```
Can you specify a way in which one of these

( 1  ) PARTY
( 2  ) HAIR
( 3  ) BERMUDA

is different from the other two in a way that matters
to you now ?          Please answer YES or NO          YES
What is the number next to the COLA AD
that differs ?  1
```

```
You have said that PARTY
is different from :
    HAIR                              and        BERMUDA

In not more than three words each time, please describe
how the three differ from each other.
First describe PARTY
PARTY                                is :
PICKUP SITUATION
On the other hand,
HAIR                               and BERMUDA                  are :
ESTABLISHED COUPLES
Are you reasonably happy with this description ?  YES
```

2.4 The user is then asked to rate all the choice alternatives on that dimension using a 7-point scale.

```
It should be possible to give each COLA AD
a rating from 1 to 9 according to its position
on the scale
PICKUP SITUATION
1                Your rating of PARTY                          is : 1
2                Your rating of BERMUDA                        is : 6
3                Your rating of HAIR                           is : 5
4                Your rating of FISH AND CHIP SHOP             is : 2
5  to            Are these ratings OK ? YES
6
7
8
9
ESTABLISHED COUPLES
```

2.5 Next, the user is asked to give an ideal point on the scale for that particular dimension.

```
Thinking only about the scale below, what position
on the scale would you like most of all for
an IDEAL COLA AD
PICK UP SITUATION
1
2
3                  Your best possible value is : 2
4
5  to
6                  Is this alright? YES
7
8
9
ESTABLISHED COUPLES
```

2.6 After two triads of alternatives have been presented, MAUD allows the user to specify poles of dimensions directly until such time as he or she runs out of ideas or has to restructure the problem (at which time MAUD returns to presenting triads in an effort to get things going again).

```
Can you think of any other way that the COLA ADS
differ from each other ? YES

In not more than three words each time, please describe
how some of them differ from the others:

Some are :  DIFFERENT SLOGAN
Whereas others are : DIFFERENT FORM OF JINGLE

Are you reasonably happy with this description ?  YES
```

MAUD will then proceed to elicit ratings on a scale between these poles, as described in steps 4 and 5.

2.7 MAUD allows the user to make several types of alterations:

(1) to change ratings of choice alternatives on the scale,
(2) to change ratings of ideal value, and
(3) to cancel the scale.

In the example in step 6, the two poles do not really lie on the same dimension. However, this is not realized until an attempt is made to elicit an ideal point on the scale between the poles, at which time the scale is canceled and replaced with a more appropriate scale.

Thinking only about the scale below, what position on the scale would you like most of all for an IDEAL COLA AD

DIFFERENT SLOGAN
1
2
3 Your best possible value is : 5
4
5 to
6 Is this alright? NO
7
8
9
DIFFERENT FORM OF JINGLE

You can

(1) Cancel this scale (and all ratings on it)
(2) Change your ratings on this scale
(3) Change the position of the ideal value

Which would you like to do?

Please type in 1, 2, or 3 : 1

Can you specify a way in which one of these

(1) PARTY
(2) FISH AND CHIP SHOP
(3) BERMUDA

is different from the other two (in a way that matters to you now)? Please answer YES or NO
What is the number next to the COLA AD that differs ? 1

You have said that PARTY
is different from :
FISH AND CHIP SHOP and BERMUDA

In not more than three words each time, please describe
how the three differ from each other .
First describe PARTY
PARTY is :
UNINTERRUPTED SLOGAN
On the other hand,
FISH AND CHIP SHOP and BERMUDA are:
INTERRUPTED SLOGAN
Are you reasonably happy with this description ? YES

... and so on. Note that MAUD returns to using triads here because the user restructured the problem by deleting a dimension.

2.8 If the preferences between choice alternatives on any two attribute dimensions are found by MAUD to be similar to each other, MAUD will ask the user if the two scales have a similar meaning. If that is the case, MAUD will ask the user to specify a new attribute dimension that will replace those two dimensions. If it is not the case, MAUD will accept the user's verdict.

Can you think of any other way that the COLA ADS
differ from each other ? YES

In not more than three words each time, please describe
how some of them differ from the others:

Some are : MORE EXCITING
Whereas others are : LESS EXCITING

Are you reasonably happy with this description ? YES

It should be possible to give each COLA AD
a rating from 1 to 9 according to its position
on the scale
MORE EXCITING
1 Your rating of PARTY is : 1
2 Your rating of BERMUDA is : 6
3 Your rating of HAIR is : 4
4 Your rating of FISH AND CHIP SHOP is : 4
5 to Are these ratings OK ? YES
6
7
8
9
LESS EXCITING

Your preferences for the COLA ADS
under consideration in terms of their ratings on the scale
ranging from UNINTERRUPTED SLOGAN to INTERRUPTED SLOGAN
seem very much the same as your preferences for the
COLA ADS in terms of their ratings
on the scale ranging from MORE EXCITING
to LESS EXCITING
Does this mean that these two scales mean similar things
to you ? NO

OK

Here MAUD found a similar pattern of preferences to those just elicited on a previously elicited dimension. However, the user decided that the two dimensions were in fact value-wise independent, and MAUD accepted this. In the next sequence, MAUD again finds two similar patterns of preferences, and this time the user decides that the relevant scales are not value-wise independent.

Can you think of any other way that the COLA ADS
differ from each other ? YES

In not more than three words each time, please describe
how some of them differ from the others:

Some are : LACKING ACTION
Whereas others are : LOTS OF ACTION

Are you reasonably happy with this description ? YES

It should be possible to give each COLA AD
a rating from 1 to 9 according to its position
on the scale
LACKING ACTION
1 Your rating of PARTY is : 7
2 Your rating of BERMUDA is : 2
3 Your rating of HAIR is : 5
4 Your rating of FISH AND CHIP SHOP is : 4
5 to Are these ratings OK ? YES
6
7
8
9
LOTS OF ACTION

Thinking only about the scale below, what position
on the scale would you like most of all for
an IDEAL COLA AD
LACKING ACTION
1
2
3 Your best possible value is : 7
4
5 to
6 Is this alright? YES
7
8
9
LOTS OF ACTION

Your preferences for the COLA ADS
under consideration in terms of their ratings on the scale
ranging from MORE EXCITING to LESS EXCITING
seem very much the same as your preferences for the
COLA ADS in terms of their ratings
on the scale ranging from LACKING ACTION
to LOTS OF ACTION
Does this mean that these two scales mean similar things
to you ? YES

MAUD then restructures the problem by deleting the offending dimensions and invites the user to replace them by a new dimension that expresses the meaning common to both the deleted ones:

Please type one or more words on the same line which could
replace both MORE EXCITING and
LOTS OF ACTION
Your new word(s) ?
INVOLVING

Now please type one or more words on the same line which
could replace both LESS EXCITING
and LACKING IN ACTION
Your new word(s) :
NOT INVOLVING

```
It should be possible to give each COLA AD
a rating from 1 to 9 according to its position
on the scale
INVOLVING
1                      Your rating of PARTY                    is : 1
2                      Your rating of BERMUDA                  is : 6
3                      Your rating of HAIR                     is : 3
4                      Your rating of FISH AND CHIP SHOP       is : 4
5  to                  Are these ratings OK ? YES
6
7
8
9
NOT INVOLVING
```

2.9 When the user has specified two or more attribute dimensions, MAUD will, if required, give a summary of progress to date.

Here is a summary of Frances' progress at the time she had specified eight attribute dimensions:

```
Would you like to be reminded of the information you
have put in so far?  YES
```

The summary is shown reduced, as it was printed out on the 5110's printer, below and on the next two pages.

```
***** SUMMARY FOR FRANCES SECOND SESSION *****

COLA ADS UNDER CONSIDERATION :
(1)  PARTY

(2)  BERMUDA

(3)  HAIR

(4)  FISH AND CHIP SHOP

ATTRIBUTE DIMENSIONS USED

(1)  PICKUP SITUATION (1)......TO........ ESTABLISHED COUPLES (9)
     IDEAL VALUE = 2
```

(2) WITH BETTER JOKES (1)......TO.......... WITH BORING JOKES (9)
IDEAL VALUE = 1

(3) DIFFERENT SLOGAN (1)......TO.......... DIFFERENT FORM OF JINGLE (9)
(RATINGS CANCELLED ON THIS SCALE)
(AFTER TRYING TO ELICIT IDEAL POINT)

(4) UNINTERRUPTED SLOGAN (1)......TO.......... INTERRUPTED SLOGAN (9)
IDEAL VALUE = 2

(5) MORE EXCITING (1)......TO.......... LESS EXCITING (9)
IDEAL VALUE = 1
(DIMENSION CANCELLED BECAUSE OF SIMILARITY WITH DIMENSION 6)

(6) LACKING ACTION (1)......TO.......... LOTS OF ACTION (9)
IDEAL VALUE = 7
(DIMENSION CANCELLED BECAUSE OF SIMILARITY WITH DIMENSION 5)

(7) INVOLVING (1)......TO.......... NOT INVOLVING (9)
IDEAL VALUE = 1

(8) APPEALING TO BOYS ONLY (1)......TO.......... APPEALING TO BOYS AND GIRLS (9)
IDEAL VALUE = 7

RATINGS OF COLA ADS ON ATTRIBUTE DIMENSIONS

COLA AD / ATTRIBUTE DIMENSION		1	2	3	4
(1)		1.00	6.00	5.00	2.00
	VALUE	.75	.00	.25	1.00
(2)		3.00	7.00	5.00	2.00
	VALUE	.80	.00	.40	1.00
(3)		5.00	5.00	5.00	3.00
(RATINGS CANCELLED)					
(4)		1.00	9.00	9.00	9.00
	VALUE	1.00	.00	.00	.00
(5)		1.00	6.00	4.00	4.00
	VALUE	1.00	.00	.40	.40
(RATINGS CANCELLED BECAUSE OF SIMILARITY TO 6)					
(6)		7.00	2.00	5.00	4.00
	VALUE	1.00	.00	.60	.40
(RATINGS CANCELLED BECAUSE OF SIMILARITY TO 5)					

```
(7)       1.00 6.00 3.00 4.00
    VALUE 1.00  .00  .60  .40

(8)       6.00 5.00 2.00 3.00
    VALUE 1.00  .75  .00  .25
```

END OF SUMMARY

2.10 Investigation of Preference Structure

When the user thinks that he or she has specified the requisite attribute dimensions in forming the preference structure, MAUD is ready to investigate the relative weights of attribute dimensions in determining preferences among lotteries. This is usually done by constructing reference gambles, or "basic reference lottery tickets" (BRLTs), which allows MAUD to determine how the user trades off values on attribute dimensions. A discussion of the theory behind this technique, and its superiority over other techniques, can be found in section 3.6. Here we present only an example of the major steps involved for Frances to determine her preference ordering of cola advertisements.

```
Do you think you have now worked through enough of the
main ways of describing similarities and differences
between the COLA ADS                         which you
think are important ? YES

Do you want to investigate your preferences among the
COLA ADS                     on the basis of the similarities
and differences you have     described so far ? YES
```

```
Would you like to assume that the various ways you have used
to describe the COLA ADS
are equally important in determining your preferences ? NO
```

MAUD now constructs and displays the BRLTs.

```
Imagine you had to choose between          OPTION B
and                                   A 90o/o chance to get a
          OPTION A                    COLA AD                    that is
                                      as WITH BETTER JOKES
A 100o/o chance to get a              as FISH AND CHIP SHOP
COLA AD that is                       and as PICKUP SITUATION
as WITH BETTER JOKES                  as FISH AND CHIP SHOP
as FISH AND CHIP SHOP                 AND a 10o/o chance to get instead
but that is also                      a COLA AD that is
as ESTABLISHED COUPLES                as WITH BORING JOKES
as BERMUDA                            as BERMUDA
          ....for sure                and as ESTABLISHED COUPLES
                                      as BERMUDA
WHICH WOULD YOU PREFER: A OR B?B
```

Option A is a compromise cola ad (best on one dimension, worst on the other). Option B represents a gamble with a 90% chance to get an advertisement that is best in both dimensions and a 10% chance to get an advertisement that is worst on both dimensions. So long as option B is preferred, the chance of best advertisement by choosing option B is adjusted progressively downward by MAUD until it becomes so unattractive that option A is preferred. For Frances, this happened at the following point:

```
Imagine you had to choose between          OPTION B
and                                   A 70o/o chance to get a
          OPTION A                    COLA AD                    that is
                                      as WITH BETTER JOKES
A 100o/o chance to get a              as FISH AND CHIP SHOP
COLA AD that is                       and as PICKUP SITUATION
as WITH BETTER JOKES                  as FISH AND CHIP SHOP
as FISH AND CHIP SHOP                 AND a 30o/o chance to get instead
but that is also                      a COLA AD that is
as ESTABLISHED COUPLES                as WITH BORING JOKES
as BERMUDA                            as BERMUDA
          ....for sure                and as ESTABLISHED COUPLES
                                      as BERMUDA
WHICH WOULD YOU PREFER: A OR B?A      ARE YOU SURE? YES.
```

Frances had five (nondeleted) dimensions in her preference structure, and MAUD had to construct four (=5-1) BRLTs in order to fully investigate her preferences. The other three BRLTs are shown next. In each case the percentages shown in option B are those at which Frances started to prefer option A.

Imagine you had to choose between and

OPTION A

A 100o/o chance to get a COLA AD that is as INVOLVING as PARTY but that is also as INTERRUPTED SLOGAN as BERMUDA ....for sure

OPTION B

A 80o/o chance to get a COLA AD that is as INVOLVING as PARTY and as UNINTERRUPTED SLOGAN as PARTY AND a 20o/o chance to get instead a COLA AD that is as NOT INVOLVING as BERMUDA and as INTERRUPTED SLOGAN as BERMUDA

WHICH WOULD YOU PREFER: A OR B?A ARE YOU SURE? YES

Imagine you had to choose between and

OPTION A

A 100o/o chance to get a COLA AD that is as APPEALING TO BOYS AND GIRLS as PARTY but that is also as NOT INVOLVING as BERMUDA ....for sure

OPTION B

A 40o/o chance to get a COLA AD that is as APPEALING TO BOYS AND GIRLS as PARTY and as INVOLVING as PARTY AND a 60o/o chance to get instead a COLA AD that is as APPEALING TO BOYS ONLY as HAIR and as NOT INVOLVING as BERMUDA

WHICH WOULD YOU PREFER: A OR B?A

Imagine you had to choose between and

OPTION A

A 100o/o chance to get a COLA AD that is as INVOLVING as PARTY but that is also as WITH BORING JOKES as BERMUDA ....for sure

OPTION B

A 80o/c chance to get a COLA AD that is as INVOLVING as PARTY and as WITH BETTER JOKES as FISH AND CHIP SHOP AND a 20o/o chance to get instead a COLA AD that is as NOT INVOLVING as BERMUDA and as WITH BORING JOKES as BERMUDA

WHICH WOULD YOU PREFER: A OR B?A ARE YOU SURE? YES

That is the end of the questions needed to investigate your preferences among the COLA ADS under consideration.

MAUD then gives the user a summary, similar to that described in section 2.9, except that value-wise importances (relative weights of attribute dimensions, calculated from the BRLTs) are included, as are the preference values for the choice alternatives. A preference value of 1.0 indicates that an alternative is at least as good as all other alternatives on all dimensions, whereas a preference value of 0.0 indicates that an alternative is at least as bad as all other alternatives on all attribute dimensions. Intermediate values may be interpreted pro rata.

The summary MAUD provided for Frances at the end of the session from which the above examples were taken is reproduced below:

```
***** SUMMARY FOR FRANCES SECOND SESSION *****

COLA ADS UNDER CONSIDERATION : -
(1)  PARTY
PREFERENCE VALUE =  .978

                                   CURRENT PREFERENCE ORDERING (FROM BEST TO
                                   WORST;PREFERENCE VALUES ARE GIVEN IN BRACKETS)
(2)  BERMUDA
PREFERENCE VALUE =  .275           BEST
                                   PARTY(  .98 )
                                   FISH AND CHIP SHOP(  .38 )
(3)  HAIR                          HAIR(  .31 )
PREFERENCE VALUE =  .307           BERMUDA(  .28 )
                                   WORST

(4)  FISH AND CHIP SHOP
PREFERENCE VALUE =  .377            ###  END OF SUMMARY  ###


ATTRIBUTE DIMENSIONS USED

(1)  PICKUP SITUATION (1)......TO.......... ESTABLISHED COUPLES (9)
     IDEAL VALUE = 2
     RELATIVE IMPORTANCE =  .026

(2)  WITH BETTER JOKES (1)......TO.......... WITH BORING JOKES (9)
     IDEAL VALUE = 1
     RELATIVE IMPORTANCE =  .079

(3)  DIFFERENT SLOGAN (1)......TO.......... DIFFERENT FORM OF JINGLE (9)
(RATINGS CANCELLED ON THIS SCALE)
(AFTER TRYING TO ELICIT IDEAL POINT)
```

(4) UNINTERRUPTED SLOGAN (1)......TO.......... INTERRUPTED SLOGAN (9)
IDEAL VALUE = 2
RELATIVE IMPORTANCE = .079

(5) MORE EXCITING (1)......TO.......... LESS EXCITING (9)
IDEAL VALUE = 1
(DIMENSION CANCELLED BECAUSE OF SIMILARITY WITH DIMENSION 6)

(6) LACKING ACTION (1)......TO.......... LOTS OF ACTION (9)
IDEAL VALUE = 7
(DIMENSION CANCELLED BECAUSE OF SIMILARITY WITH DIMENSION 5)

(7) INVOLVING (1)......TO.......... NOT INVOLVING (9)
IDEAL VALUE = 1
RELATIVE IMPORTANCE = .448

(8) APPEALING TO BOYS ONLY (1)......TO.......... APPEALING TO BOYS AND GIRLS (9)
IDEAL VALUE = 7
RELATIVE IMPORTANCE = .367

RATINGS OF COLA ADS ON ATTRIBUTE DIMENSIONS

COLA AD / ATTRIBUTE DIMENSION		1	2	3	4
(1)		1.00	6.00	5.00	2.00
	VALUE	.75	.00	.25	1.00
(2)		3.00	7.00	5.00	2.00
	VALUE	.80	.00	.40	1.00
(3)		5.00	5.00	5.00	3.00
(RATINGS CANCELLED)					
(4)		1.00	9.00	9.00	9.00
	VALUE	1.00	.00	.00	.00
(5)		1.00	6.00	4.00	4.00
	VALUE	1.00	.00	.40	.40
(RATINGS CANCELLED BECAUSE OF SIMILARITY TO 6)					
(6)		7.00	2.00	5.00	4.00
	VALUE	1.00	.00	.60	.40
(RATINGS CANCELLED BECAUSE OF SIMILARITY TO 5)					

```
(7)        1.00 6.00 3.00 4.00
     VALUE 1.00  .00  .60  .40

(8)        6.00 5.00 2.00 3.00
     VALUE 1.00  .75  .00  .25
```

2.11 When the user thinks that he or she has done enough at the session, MAUD will allow him or her to save the data.

```
Do you want to save all this information ? YES

FILE NUMBER FOR DATA?
4
```

Eight MAUD sessions can be saved on a MAUD tape. Data from each session are stored in four files. The file number for storing a session's results must be 4, 8, 12, 16, 20, 24, 28, or 32. Files may be reused at will, but each time a file is reused, the data from the session previously stored in that file are overwritten with the data from the new session.

2.12 MAUD ends.

Notes on MAUD Operation

1. Press the EXECUTE key after every entry. MAUD will begin to process information only after the key is pressed. Pressing EXECUTE indicates termination of entry.

2. When a typing error occurs before the EXECUTE key is used, the user can make corrections by using the backspace key (←); press once for every character to be deleted. The user can then proceed to overwrite the error. However, if the EXECUTE key has been used, leave the error for now and carry on; MAUD will also allow corrections at the end of every procedure.

3. MULTIATTRIBUTE UTILITY THEORY RELATING TO MAUD

3.1 Overview

This part of the report describes the rationale and operation of Multiattribute Utility Decomposition (MAUD) within the context of Multiattribute Utility Theory (MAUT). In section 3.2 we introduce MAUT as part of the multilevel decomposition-recomposition scheme used within decision-theoretic models.[2]

[2] Much of the material in this section is abridged and developed from that presented in Humphreys (1977), to which the reader is referred for further discussion of the general issues raised here.

Sections 3.3 and 3.4 review the MAUT axiomatizations of decomposition of outcomes (terminal events) within this scheme adequate for riskless and risky choice, respectively. MAUD adopts various solutions upon detection of violations of the assumptions involved in these axiomatizations, and each solution is discussed in the section reviewing the relevant assumption.

Section 3.5 discusses the mapping rules transforming the data input to MAUD by the user (ratings on attribute dimensions) into a form suitable for use in the composition rules used within MAUD.

Finally, section 3.6 provides an evaluation of the algorithms implementing the composition rules used within MAUD and gives a comparison with some algorithms not currently implemented within MAUD.

3.2 Multiattribute Utility Theory as Part of a Multilevel Decomposition-Recomposition Scheme

One way of conceptualizing a person's behavior is in terms of a sequence of identifiable acts. Each act is specified in terms of its occurrence. In the decision analytic approach, it is assumed that each act is chosen by a person, the decision maker, from a set of possible acts. The question, "On what basis was a particular act chosen?" requires, for an answer in formal terms, a decomposition under a specified axiomatic system. MAUT axiomatizes a further decomposition of the decomposition of acts into possible outcomes provided by the joint axiomatization of utility and subjective probability known as Expected Utility (EU) theory (Savage, 1954; Luce & Raiffa, 1957). MAUD is a system providing the technology required to (a) implement this decomposition in interaction with the decision maker, (b) elicit all inputs required in decomposed form, (c) check such input for possible violations of MAUT-prescribed assumptions (and take appropriate action upon discovery of a violation), and (d) apply the appropriate MAUT-prescribed composition rule in establishing holistic utility assessments. The multilevel decomposition-recomposition scheme, within which MAUD is embedded, is as follows:

Decomposition to Level 1: Choice Alternatives

The first step in this decomposition is to specify the set of choice alternatives. These are usually identified as a set of terminal acts, or consequences following from those acts (outcomes), within a decision tree (Raiffa, 1968; Brown, Kahr, & Peterson, 1974). There can be problems in the identification of such terminal acts (Brown, 1975; Humphreys, 1980), and, of course, they are not really terminal. The meaning of "terminal" here is that one is not prepared to decompose the consequences of such acts further through extension of the event-act decision tree. Utilities must now be assigned directly to all terminal acts (outcomes), and expected utilities must be computed for potential immediate courses of action through the application of the appropriate EU composition rule. There are three ways in which utilities may be assigned to consequences of terminal acts:

1. Through holistic utility assessments at level 1; that is, the utilities of the outcomes are assessed directly, without further decomposition.

2. Through the assessment of value in terms of some variable believed to have a concrete, measurable existence in the real world and to be coextensive with utility; for example, money. Value is mapped into utility through the use of a mapping rule assessed previously for that decision maker: his or her utility function.

3. Through the use of a MAUT decomposition of the utilities of the choice alternatives into multiattribute form.

MAUD will be of interest only to those who have adopted strategy 3 in assigning utilities to consequences of terminal acts.

Decomposition to Level 2: Multiattributed Outcomes

The choice alternative to be decomposed to level 2 may be specified in either of two ways: under the assumption of riskless decision making, or under the assumption of risky decision making. The technology employed in MAUD is appropriate for use in either case, but the theory is presented separately for the two cases.

Under riskless decision making, the decision maker is assumed to be able to specify with certainty the outcomes (consequences) associated with each course of action. Hence, identity rules are suitable for mapping between outcomes and choice alternatives. An example of such mapping follows:

Choice alternative: Hire an unspecified car from Rolls Royce Car Hire, Ltd., rather than from some other car hire firm.

Outcome: Drive a Rolls Royce (P = 1.0)

Under risky decision making, the decision maker is assumed to be able to specify a probability distribution over the outcomes associated with each choice alternative. Mapping between outcomes and choice alternatives requires the use of a composition rule, usually based on the expected utility principle (Fischer, 1972b, p. 10). Under this principle, if the set of choice alternatives is denoted by (A_1, A_2, A_k, A_n), and the set of outcomes under consideration by (X_1, X_2, X_j, X_m), then the EU of the kth alternative is given by the composition rule:

$$EU(A_k) = \sum_{j=1}^{m} P_{jk} U(X_j)$$

where P_{jk} is the probability of the choice of alternative A_k resulting in outcome X_j.

An example of a situation requiring such a mapping is:

<u>Choice alternative k</u>: Hire an unspecified car from General Car Hire, Ltd., rather than from some other car hire firm.

<u>Outcome</u>:	(1)	Drive a mini	(P_{1k} = 0.70)
or	(2)	Drive a VW	(P_{2k} = 0.25)
or	(3)	Drive a Jaguar	(P_{3k} = 0.04)
or	(4)	Drive a Rolls Royce	(P_{4k} = 0.01)

It is important to remember that, given the existence of a decomposition to level 1, the further decomposition to level 2 is performed on the set of outcomes, not on the set of choice alternatives. In riskless decompositions, decomposition of outcomes is identical to decomposition of choice alternatives, but in risky situations, it is not.

Fischer (1972a) and von Winterfeldt and Fischer (1975) have described in detail the decomposition to level 2 provided by MAUT from a conjoint measurement point of view. The MAUT axiomatizations of this decomposition are outlined in sections 3.3 and 3.4, together with discussions of various solutions that can be adopted in applications of MAUT when assumptions necessary under MAUT axiomatizations are found not to be met, and descriptions of the way in which MAUD implements particular solutions.

3.3 MAUT Axiomatization of Decomposition of Outcomes to Level 2 Adequate for Riskless Choice

This decomposition depends on the assumptions of connectedness and transitivity of choices (Arrow, 1952; Fischer, 1972a) fundamental to all theories of rational choice, together with certain crucial monotonicity and independence assumptions discussed next.

3.3.1 Monotonicity Assumption

Given the adoption of an ordered scaling metric describing positions of attributes on dimensions, the monotonicity assumption requires that the relevant attribute dimensions be scaled in such a way that

$$x_{ij} \succsim x_{ik} \text{ iff } f(x_{ij}) \geq f(x_{ik})$$

where x_{ij} is the i^{th} attribute of outcome X, and $f(x_{ij})$ is a numerical scale value representing the utility of x_{ij} on attribute dimension i. The $\succsim$ denotes "is preferred at least as much as," and $\geq$ denotes "is numerically greater than or equal to"; that is, on each attribute dimension, larger numerical values should imply greater utility, or part-worth, on that dimension.

Use of a scaling metric is simply a device to allow the use of numbers to represent preference orderings (Beals, Krantz, & Tversky, 1968). This device is used here to simplify the discussion of algorithms implementing composition rules in applications of MAUT. The MAUT axiomatization is concerned fundamentally with relations between preference orderings, not relations between scale values. Such scale values represent an interpretation of ordered relations.

When scaled values as obtained do not represent this interpretation, mapping techniques such as those described in section 3.5 may be employed to rescale the values in such a way that the monotonicity assumption is met.

3.3.2 Value-Wise Independence Assumption

Raiffa (1969) describes how to specify this assumption in terms of Weak Conditional Utility Independence (WCUI), which states that preferences for values on any attribute dimension should be independent of constant values on all other attribute dimensions. Such preferences are called conditional preferences. This assumption is equivalent to the single cancellation assumption in conjoint measurement theory (Krantz, Luce, Suppes, & Tversky, 1971) and, taken together with joint independence (section 3.3.3), is sometimes called preference independence (Fishburn & Keeney, 1975; Keeney, 1974; Keeney & Raiffa, 1976). It is usually tested by checking n-WCUI, that is, performing 1-WCUI checks over all n attribute dimensions, where 1-WCUI represents a check to determine if (any) one attribute is WCUI of all others (Raiffa, 1969; von Winterfeldt & Fischer, 1975). The notion of independence contained in WCUI is weaker than that contained in notions of statistical independence. Hence tests of statistical independence are too strong. However, they may be used to indicate the possibility of a violation of WCUI. Hence such a check is used by MAUD as a guide for further actions, as described next.

Failure of n-WCUI Checks in Applications of MAUT. Given failure of n-WCUI checks, one has two (legitimate) options open: (a) recognize that no total decomposition model is adequate within the existing structure and opt for a partial decomposition model, or (b) keep the total decomposition model and reorder the attribute dimension structure in such a way as to eliminate (or at least, minimize) violation of n-WCUI between the reordered attribute dimensions.

The consequence of opting for a partial decomposition model is that one has to repeatedly search for dimensions exhibiting 1-WCUI, each time substituting values of the 1-WCUI dimensions for values on all the non-WCUI dimensions (Raiffa, 1969). This procedure may require the construction of a large number of indifference curves to be able to perform the necessary substitutions.[3] The result is an exponential increase in the number of assessments required before one can bootstrap the decision maker by operating the composition rule, and, as von Winterfeldt (1975, p. 65) said, "This may be too much effort."

The alternative of keeping the total decomposition model means that an additive composition rule is still appropriate, and therefore fewer assessments

[3] See MacCrimmon and Siu (1974, p. 694) and Humphreys (1977, section 2.3.1) for details of the procedures involved.

need to be made before operating the rule. However, decision aids, such as MAUD, that opt for this approach must contain facilities for aiding the structural reordering that may consequently become necessary during an analysis.

Consider the example of a decision maker who wants to buy a car and whose multiattribute representation of the cars under consideration (Rover 2600, Citroen CX, Skoda Estelle, Renault 14) is based entirely on notions of speed, comfort, and financial disincentive. Suppose the elicitation procedure resulted in attribute values (data) on the four dimensions shown in the extract MAUD log reproduced below,

1. slow (1) .... to .... (9) fast

2. uncomfortable (1) .... to .... (9) comfortable

3. costs a little (1) .... to .... (9) costs a lot

4. makes a big hole (1) in my bank account .... to .... (9) makes a little hole in my bank account

and that the representation of his or her preference structure was as follows:

score on attribute dimension	Rover 2600	Citroen CX	Skoda Estelle	Renault 14	ideal point on attribute dimension
1	9	8	1	5	9
2	9	9	1	6	9
3	7	8	1	5	1
4	3	1	8	5	9

Checks for statistical independence would reveal that ratings on dimensions 3 and 4 are highly correlated but would also reveal that ratings on dimensions 1 and 2 are highly correlated (the faster cars under consideration were also more comfortable). The source of the latter correlation lies in the external world--the structure of the automobile industry and its marketing policies--not the internal worth structure of the individual, for whom speed and comfort are almost certainly value-wise independent.

MAUD disambiguates this situation by first using a statistical checking procedure to monitor potential failures of 1-WCUI between each new attribute dimension and every other dimension already in the structure as they are elicited from the decision maker. Should the statistical check fail, the offending pair of attribute dimensions is presented to the decision maker, and a thought experiment is then conducted between MAUD and the decision maker to see if 1-WCUI has actually been violated.[4] If it has, the decision maker is prompted to supply a new attribute dimension to replace the offending pair, and the structure is then reordered by accepting the new dimension and deleting the offending pair, providing that assessments on the new dimension subsequently pass 1-WCUI checks.

In the example, MAUD would check the correlation between ratings on dimensions 1 and 2 as soon as ratings had been elicited on dimension 2. Finding a high correlation between the two sets of ratings, MAUD would proceed with the thought experiment as shown in the following printout:

```
Your preferences for the      CARS
under consideration in terms of their ratings on the scale
ranging from  SLOW                            to FAST
seem very much the same as  your preferences for the
CARS                           in terms of their ratings
on the scale ranging from   UNCOMFORTABLE
to  COMFORTABLE
Does this mean that these two scales mean similar things
to you ? NO

OK
```

Because in each case WCUI survived (although statistically independence did not), MAUD proceeds with the elicitation of dimension 3. Ratings on dimension 3 correlate negatively with ratings on dimensions 1 and 2, so no thought experiment is performed, and MAUD proceeds with the elicitation of ratings on dimension 4. Finding a high positive correlation between ratings on dimensions 3 and 4, MAUD proceeds as follows:

```
Your preferences for the      CARS
under consideration in terms of their ratings on the scale
ranging from  COSTS A LITTLE                  to COSTS A LOT
seem very much the same as  your preferences for the
CARS                           in terms of their ratings
on the scale ranging from   BIG HOLE IN BANK ACCOUNT
to  LITTLE HOLE IN BANK ACCOUNT
Does this mean that these two scales mean similar things
to you ? YES
```

[4] MAUD's procedure has the advantage that fewer questions need be asked than in conventional 1-WCUI checking and that it leads decision makers to believe that the system is intelligent because it asks questions only in suspicious circumstances.

O.K. Please type in a word (or phrase of not more than three words) which has the same meaning as both
COSTS A LITTLE and LITTLE HOLE IN BANK ACCOUNT

Your new word(s) :
CHEAP

Now please type in a word (or phrase of not more than three words) which has the same meaning as both
COSTS A LOT and BIG HOLE IN BANK ACCOUNT
Your new word(s) :
EXPENSIVE

(MAUD then proceeds to elicit ratings of cars on the dimension CHEAP to EXPENSIVE.)

Hence dimensions 3 and 4 are deleted from the structure and replaced by dimension 3', expensive ... to ... cheap. WCUI is restored, and MAUD may now continue with the elicitation of the rest of the structure.[5]

3.3.3 Joint Independence Assumption

When n-WCUI is satisfied, a final general independence assumption must be met. This assumption is called joint independence. In formal terms, a set of attributes is said to be jointly independent of the rest if the preference ordering of outcomes, which varies only in these attributes, remains invariant for any fixed levels of the remaining attributes. Von Winterfeldt and Fischer (1975) state that violations of joint independence in conditions in which n-WCUI is satisfied are typically subtle in nature and hard to find. They give the example of someone who works in a large city and wants to rent a house or apartment. Consider this person's preferences when confronted with the two situations shown in Figure 1, differing only in whether there is a high-speed transportation system situated nearby.

In each situation, the values in the cells represent the values of the outcomes on the three attribute dimensions.

Von Winterfeldt and Fischer explain the switch in preference ordering of outcome B and C between the two situations (violating joint independence) as follows:

> Living on a farm in the country seemed to us very attractive, and the long car ride to work did not matter with the convenience of the high speed transportation system. With no high speed transportation

[5] Note also that the assessment procedure used to establish the decision maker's value-wise importance weights for attribute dimensions (described in section 3.6) is ordered by MAUD into a hierarchy in a way that minimizes the distortion introduced in any residual value-wise nonindependence that was not detected by the 1-WCUI checks.

system, the shorter ride from the apartment outweighed the benefits of living on the farm.

Situation 1 outcomes (dwellings): A	B	C	D	attribute dimensions	Situation 2 outcomes (dwellings): A	B	C	D
Fm	Fm	Ap	Ap	type	Fm	Fm	Ap	Ap
20 min	1hr	20 min	1hr	time to drive car to work	20 min	1hr	20 min	1hr
YES	YES	YES	YES	high-speed transportation system nearby	NO	NO	NO	NO
1	2	3	4	ORDER OF PREFERENCE	1	3	2	4

Figure 1. Two situations involving preferences for outcomes where the preference orderings violate joint independence (after von Winterfeldt & Fischer, 1975. Fm = Farm; Ap = Apartment).

Failure of Joint Independence Checks in Applications of MAUT. Given failure of joint independence checks, one has the same two options open as in the case of failure of n-WCUI checks: (a) recognize that no total decomposition model is adequate within the existing structure, or (b) keep the total decomposition model and reorder the attribute dimension structure in a way that eliminates the violation of joint independence.

If one retains the original structure, a total decomposition is in theory still possible. This total decomposition is described by von Winterfeldt and Fischer's (1975) model 1.3. However, such a total decomposition is inadequate because no composition rule is prescribed axiomatically for this decomposition, and an optimal solution requires a mixture of admissibility and sensitivity analyses on the application of a well-chosen selection of composition rules.

The information required to ascertain that any solution on these lines is usually not available, so MAUD opts for a different solution, that previously described by Humphreys (1977, section 2.5.2) as the "constructivist" solution.

This solution gives primacy to the MAUT axiomatization over the data and seeks to modify the output of the attribute elicitation procedure so that the modified attributes exhibit joint independence. In the example just used, the absence of a high-speed transportation system (situation 2) resulted in dimension 2, "time to drive car to work," increasing its value-wise important weight over dimension 1, "type of dwelling (farm or apartment)." Why?

Dimension 2 may be assumed to extend between these two poles:

Pole P		Dimension 2		Pole Q
long time to drive car to work	...	to	...	short time to drive car to work

For attributes to be scaled in any metric on a dimension, the pole names of that dimension must be superordinate category names, that is, refer to poles superordinate to their predictive attributes[6] or lexical entries (Bruner, Goodnow, & Austin, 1956; Katz & Fodor, 1963; Humphreys & Humphreys, 1975). For each pole, the set of lexical entries defines its meaning (Katz & Fodor, 1963; Anderson & Bower, 1974). In situation 1 in the dwellings example, pole P contains the lexical entry "but not for me," because, in this situation, the decision maker would take the high-speed transportation system. In situation 2, pole P contains instead the lexical entry "for me," because there is no option but to take the car. Hence, what is happening in this violation of joint independence is that pole P changes in meaning.

The constructivist approach would assume that in the situations described in the example, the decision maker was really construing the decision situation through the use of an attribute dimension defined in terms of these two poles:

Pole P'		Dimension 2'		Pole Q'
long time for me to travel to work	...	to	...	short time for me to travel to work

The reader is invited to verify that attributes scaled on dimensions 1 and 2' do not violate joint independence for any fixed level on dimension 3.

MAUD can pick up violation of joint independence through detecting incoherence in the resulting assessments required in the lotteries required to establish value-wise importance weights (described in section 3.6).

However, the user will often spot a dimension changing its meaning as ratings are elicited and take appropriate action in interaction with MAUD before proceeding in the development of his or her preference structure. The following is a simulated example of this action happening during a MAUD run, based on the von Winterfeldt and Fischer example:

[6] Note that these attributes define poles, not outcomes.

```
You have considered 4    DWELLINGS

   DWELLINGS under consideration  :

    1  FARM1
    2  FARM2
    3  APARTMENT1
    4  APARTMENT2
```

```
It should be possible to give each DWELLING
a rating from 1 to 9 according to its position
on the scale
HST  SYSTEM NEARBY
1                  Your rating of FARM1              is : 1
2                  Your rating of FARM2              is : 1
3                  Your rating of APARTMENT1         is : 1
4                  Your rating of APARTMENT2         is : 1
5  to              Are these ratings OK ? YES
6
7
8
9
NO HST SYSTEM NEARBY
```

```
Thinking only about the scale below, what position
on the scale would you like most of all for
an IDEAL DWELLING
HST  SYSTEM NEARBY
1
2
3                  Your best possible value is : 1
4
5  to
6                  Is this alright? YES
7
8
9
NO HST SYSTEM NEARBY
```

Can you specify a way in which one of these

(1) FARM2
(2) FARM1
(3) APARTMENT2

is different from the other two (in a way that matters to you now)? Please answer YES or NO — YES

What is the number next to the DWELLING that differs ? 2

You have said that FARM1
is different from :
FARM2 and APARTMENT2

In not more than three words each time, please describe how the three differ from each other.
First describe FARM1
FARM1 is :
SHORT DRIVE TO WORK
On the other hand,
FARM2 and APARTMENT2 are:
LONG DRIVE TO WORK
Are you reasonably happy with this description ? YES

It should be possible to give each DWELLING a rating from 1 to 9 according to its position on the scale

SHORT DRIVE TO WORK
1 — Your rating of FARM1 is : 1
2 — Your rating of FARM2 is : 9
3 — Your rating of APARTMENT1 is : 1
4 — Your rating of APARTMENT2 is : 9
5 to — Are these ratings OK ? NO
6
7
8
9
LONG DRIVE TO WORK

```
You can :

    ( 1 ) Cancel this scale (and all ratings on it)
    ( 2 ) Change your ratings on this scale.

Which would you like to do?

    Please type in 1, or 2 : 1
```

```
Can you specify a way in which one of these

( 1 ) FARM1
( 2 ) APARTMENT2
( 3 ) FARM2

is different from the other two (in a way that matters
to you now)?          Please answer YES or NO          YES
What is the number next to the DWELLING
that differs ? 1
```

```
You have said that FARM1
is different from :
    APARTMENT2                    and        FARM2

In not more than three words each time, please describe
how the three differ from each other.
First describe FARM1
FARM1                             is :
SHORT TRAVEL TIME TO WORK
On the other hand,
APARTMENT2                    and FARM2                   are:
LONG TRAVEL TIME TO WORK
Are you reasonably happy with this description ?  YES
```

3.3.4 Additive Composition Rule from Level 2 to Level 1 Under Riskless Choice

If the assumptions described in sections 3.3.2 and 3.3.3 are met, the following additive conjoint measurement model may be applied as the composition rule from level 2 to level 1 (model 1.4; von Winterfeldt & Fischer, 1975):

$$x_j \geq x_k \quad \text{iff} \quad F(x_j) = \sum_{i=1}^{n} f_i(x_{ij}) \geq \sum_{i=1}^{n} f_i(x_{ik}) = F(x_k)$$

Here, $f_i(x_{ij})$ scales the utility (part-worth) of outcome X_j on attribute dimension i. Composition from level 2 to level 1 is achieved by summing the $f_i(x_{ij})$ over all n attribute dimensions present in the decomposition at level 2. However, MAUD uses the slightly different additive composition rule described in section 3.4.4, for the reasons also discussed in sections 3.4.2 and 3.4.3.

3.4 MAUT Axiomatization of Decomposition of Outcomes to Level 2 Adequate for Risky Choice

The decomposition to level 2 described in section 3.3, while adequate for the specification of an additive conjoint measurement model under conditions of riskless choice, is, unfortunately, not sufficient to guarantee the use of an additive composition rule under risky choice. There are now two major requirements that must be satisfied in addition to those required for the axiomatization of MAUT under riskless choice. These are (a) the satisfaction of the "sure thing" principle, and (b) strengthening of the value-wise independence assumptions.

3.4.1 The "Sure Thing" Assumption

Under risky choice, each choice alternative is conceptualized as a probability distribution over a set of outcomes, that is, as a gamble. The sure thing principle, or Savage's (1954) Independence Principle, requires that preferences among gambles should not depend on the values of outcomes that are constant in a subset of events. It is essential that this requirement be met in the EU axiomatization of decomposition from level 0 to level 1.

The sure thing assumption is not a MAUT axiom in itself. However, because applications of MAUT involving risky choice require decomposition to level 1 before application of the MAUT-axiomatized decomposition to level 2, it is important to discuss the consequences of failure of sure thing checks at level 1 on attempted MAUT-axiomatized decomposition to level 2.

Failure of Sure Thing Checks in Applications of MAUT. There are three approaches to the decomposition to level 2, given failure of sure thing checks: ostrich-like behavior, reaxiomatization, and forced decomposition under an EU axiomatization.

The rationale for the "ostrich solution" is as follows: Because the specification of the outcomes to be decomposed from level 1 to level 2 depends on the structure of the decomposition to level 1, why can't we rearrange the level 1 decomposition (decision tree or whatever) in such a way that each terminal act is associated with certainty with a particular outcome? Then, the rearranged choice alternatives (terminal acts) can be decomposed (e.g., by using MAUD) under a riskless MAUT axiomatization, which does not require sure thing checks.

This ostrich-like solution consists of burying one's head in the decomposition from level 1 to level 2, so that one cannot see what is going on in the decomposition to level 1. Apart from all the problems involved in specifying terminal acts (Brown, 1975; Humphreys, 1979), choice alternatives are conceived in terms of immediate courses of action, and a composition rule based on an EU axiomatization is required to recompose terminal acts into immediate courses of action. Failure of sure thing checks at any point invalidates this composition rule and hence the whole decomposition-recomposition procedure, and the excuse, "it wasn't MAUD's fault," does not solve the problem. The consequences for applications of MAUT are both important and far-ranging. Decision analysts who think that conditions of riskless choice exist in their decompositions obtained through the use of systems such as MAUD should ask themselves carefully whether they are not imitating the behavior of ostriches by not examining what their clients actually intend to do with the resulting preference ordering of alternatives.

In the light of this, one might ask why one has to rely on an EU axiomatization of the decomposition to level 1, without question. Such reliance becomes necessary only when one accepts that the axioms of decision theory should be treated on a par with the principles of logic (e.g., Marschak, 1968), that is, as principles that are accepted as not open to rejection following violation. Allais (1953), Ellsberg (1961), and Slovic and Tversky (1974) have raised strong objections to the sure thing assumption being granted such a status because it can lead to some intuitively unappealing prescriptions about choices and has been found to be occasionally but systematically violated in studies of subjective choice behavior (Tversky, 1969). If we accept objections such as these, then the solution prescribed by the failure of sure thing checks is to attempt a reaxiomatization of the decomposition to level 1, based on assumptions more persuasive on logical grounds than is Savage's Independence Principle.

Humphreys (1977, section 3.2.2) has reviewed several such attempts at reaxiomatization, which are generally represented as joint axiomatizations of EU (or EV) and risk. However, none of these attempts has yet met with sufficient success and acceptance to form the basis for technology to implement interactive decision aids.

Hence there is no easy way out of the sure thing problem. One suggestion (due to Ward Edwards) is that lack of risk preferences can be handled within the MAUD structure by eliciting an attribute dimension of the form

low risk ———— high risk

folding it about the ideal level of risk[7] and assigning it a value-wise importance (using standard MAUD methodology) relative to the other dimensions in the decision maker's preference structure. There are, of course, parallels to Coombs' portfolio theory of risk in this suggestion (Coombs & Bowen, 1971), but it should be remembered that here risk is treated as content input into the preference structure (as ratings on an attribute dimension), rather than forming any part of the axiomatization of the structure. Hence coherence tests for the adequacy of such a conceptualization of risk in any particular

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[7]See section 3.6 for a discussion of "folding."

situation are not available, and it is left to the decision analyst to ascertain that the decision maker's risk preference component of his or her worth structure for the alternatives under consideration has been adequately modeled in adopting this solution.

3.4.2 Value-wise Independence Assumption

Under conditions of risky choice, the WCUI and joint independence assumptions used in the axiomatization under riskless choice (section 3.3) must be strengthened to a Strong Conditional Utility Independence (SCUI) assumption (Raiffa, 1969). Keeney (1969, 1971) and Keeney and Raiffa (1976) have called this assumption simply utility independence. In formal terms, SCUI requires that preferences among multiattributed alternatives, in which a subset of attributes has constant values across all outcomes, should not depend on the particular level at which the constant values are held fixed. It would be extremely difficult to carry out efficient and exhaustive SCUI tests in the applications to which MAUD is likely to be directed.

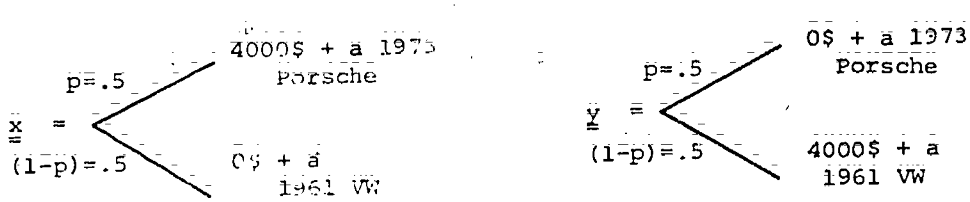
However, there is an easier way out of the SCUI problem than searching for appropriate test procedures. It follows from the result that when an n-WCUI is satisfied, but SCUI is not, a riskless decomposition procedure may be used provided (a) that the riskless conjoint measurement composition rule utility functions f_i (section 3.3.4) are replaced by utility functions u_i, adequate for use under risky choice, and (b) that a marginality assumption is met (Raiffa, 1969; Fishburn, 1970).

MAUD adopts this approach, using a utility function assessment procedure that yields u_i. This procedure is described in the section that follows. However, in doing this, MAUD assumes that the marginality assumption discussed next is met.

3.4.3 Marginality Assumption

In formal terms, marginality, also known as value independence (Fishburn & Keeney, 1974), is judged solely on the basis of the marginal probability distribution over the single attribute values. Von Winterfeldt & Fischer (1975) discuss details of this formulation and give the following counter example:

Marginality would require you to be indifferent between the gambles $\underline{x}$ and $\underline{y}$, shown below, because the marginal distributions are the same.



However, most people are likely to prefer **y** or **x**. This can be attributed to variance preferences[8] (Coombs & Pruitt, 1960), because **y** has a much smaller variance than **x**.

Failure of Marginality Checks in Applications of MAUT. In applications of MAUT under risky choice, each choice alternative is a gamble with a probability distribution over the outcomes in the decomposition. Marginality checks are most likely to fail in cases in which the variance of the various probability distributions is distinctly unequal. In such cases, there are three principal solutions to decomposition; these are discussed below.

Reordering solution. This solution (called the buck-passing solution in Humphreys, 1977) is analogous to the ostrich solution described in section 3.4.1 but may be more successful. The basic idea is to reorder the structure of the decomposition to level 1 so that the relationship between choice alternatives and terminal acts (outcomes) is described in terms of probability distributions with less unequal variances. This amounts to passing the buck to the decomposition to level 1, because there is no guarantee that the reordered decomposition will pass the sure thing checks just because the original one did. The reordering will certainly involve pruning the decision tree, in some cases so severely that the result may amount to cutting it off at the roots (Brown, 1975).

Decision analysts unwilling to undertake such radical surgery may well find it impossible to arrange things in such a way that the decomposition to level 1 passes sure thing checks at the same time that the decomposition to level 2 passes marginality checks. In this case, the reordering buck-passing solution degenerates into an ostrich solution.

Quasi-additive solution (multiplicative rule). Von Winterfeldt and Fischer (1975) describe a multiplicative composition rule that is appropriate for use in assessing utilities of risky alternatives where SCUI checks are satisfied but marginality is not. In theory, this rule may be expressed in terms of transformations of the functions $f_i(x_{ij})$ in the riskless composition rule described in section 3.3.4. Keeney and Raiffa (1976) discuss this rule (section 6.3), and the assessments involved in its construction and use (section 6.6.5). The present version of MAUD is equipped only with the technology required to implement an additive composition rule, but later versions will involve the optional use of a multiplicative rule instead. However, the multiplicative rule brings with it axiom-checking and assessment problems of its own, and a reordering solution, if possible, is usually preferred.[9]

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[8] The variance (V) of a two-outcome gamble is defined as $V = p(1-p)(U_1-U_2)^2$, where U_1-U_2 is the difference in utilities of the two outcomes of the gambles.

[9] Fischer (1972b, experiment 2), investigating decomposition under risky choice, found an additive composition rule to be an efficient prediction of subjects' holistic choices among alternatives at level 1, even in situations in which one would expect the marginality assumption to be violated on intuitive grounds. Hence distortions introduced through the use of decompositions to level 2 with violations of marginality, together with an additive composition rule of the type employed by MAUD, are unlikely to be serious when n-WCUI checks are satisfied.

3.4.4 Additive Composition Rule from Level 2 and Level 1 Under Risky Choice

Given that the appropriate value-wise independence assumptions have been met, we may use the following model as the composition rule from level 2 to level 1 under both riskless and risky choice:

$$X_j \geq X_k \text{ iff } U(X_j) = \sum_{i=1}^{n} u_i(x_{ij}) \geq \sum_{i=1}^{n} u_i(x_{ik}) = U(X_k)$$

Note that for any x_{ij}, $u_i(x_{ij})$ is monotonically related to $f_i(x_{ij})$ (Raiffa, 1969; Fischer, 1972a).

This composition rule is useful in applications of MAUT under both risky and riskless choice, provided it is used in conjunction with value-wise importance assessment techniques based on a device known as the Basic Reference Lottery Ticket, or BRLT (Raiffa, 1969, p. 35-6; von Winterfeldt & Fischer, 1973; Humphreys & Humphreys, 1975; Keeney & Sicherman, 1975, p. 10-12). It is the standard composition rule used in the current version of MAUD.

Given a scaling procedure that yields attribute values $g_i(x_{ij})$, monotonically related to $f_i(x_{ij})$ (section 3.3.4), and hence to $u_i(x_{ij})$, a BRLT-based procedure may be used to construct the $u_i(x_{ij})$ directly. The relation is of the form

$$u_i(x_{ij}) = \lambda_i \, [g_i(x_{ij})], \quad \text{where} \quad \sum \lambda = 1.$$

The λ_i assessed by BRLT-based procedures are in fact products of

[value-wise importance weight] x [relative scaling factor]
w_i q_i
x [f_i to u_i correction]
h_i

Hence, in separated form:

$$u_i(x_{ij}) = w_i q_i h_i \, [g_i(x_{ij})].$$

From a conjoint measurement point of view, the separation of λ_i into $w_i q_i h_i$ is both unnecessary and vacuous, since w_i, q_i, and h_i cannot be assessed separately from one another. Hence the procedure used by MAUD for the assessment of λ_i[10] does not attempt any such separation.

3.5 Mapping Between Level 2a and Level 2

In applications of MAUT, data are usually collected in the form of rating of attributes of outcomes on arbitrarily scaled rating scales. (The current version of MAUD uses an arbitrary seven-point scale on all attribute dimensions.) Before such data can be used in MAUT composition rules, they must be subjected to two mapping transformations, folding and relative scaling, which are described in sections 3.5.1 and 3.5.2.

Since both the raw rating scale data and the transformed data are represented at level 2 in the decomposition scheme, the two forms of data are distinguished here by describing the raw data as represented at level 2a and the transformed data at level 2.

3.5.1 Folding J-Scales

As an example demonstrating the need for folding transformations of rating scale data, consider the case of a decision maker who is trying to decide which of several potential companions to take to a dance. One of the attribute dimensions used in the decomposition of outcomes (companions) might be

degree of boldness

SHY .... BOLD
↑
ideal point

This attribute dimension, as represented here, is scaled monotonically between the two poles SHY and BOLD, but the most preferred point on this attribute dimension for most decision makers in this situation would be somewhere in the middle. Clearly, no monotone transformation of scale values on a SHY-BOLD rating scale can yield $g_i(x_{ij})$ appropriate for use in MAUT additive composition rules.

Coombs (1964) has called such scales, and all physically represented scales, J-scales, where J stands for joint--shared across individuals. In order to transform any J-scaled data from any individual decision maker into a form suitable for use as $g_i(x_{ij})$, one must first fold each J-scale about that individual's ideal point on the J-scale (Coombs, 1964; Dawes,

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[10] Described in section 3.6.

1972, section VI.2). This yields the decision maker's individual preference scaling of the attribute dimensions and hence I-scaled data.[11]

The following example shows MAUD folding a J-scale in interaction with a decision maker.

```
GIRLS under consideration :

(1) NANCY
(2) CHARLOTTE
(3) MARY
(4) HELEN
```

```
Can you specify a way in which one of these

( 1 ) NANCY
( 2 ) MARY
( 3 ) CHARLOTTE

is different from the other two (in a way that matters
to you now)?        Please answer YES or NO          YES
What is the number next to the GIRL
that differs ? 2
```

```
You have said that MARY
is different from :
   NANCY                      and        CHARLOTTE

In not more than three words each time, please describe
how the three differ from each other.
First describe MARY
MARY                          is :
SHY
On the other hand,
NANCY                       and CHARLOTTE                  are:
BOLD
Are you reasonably happy with this description ?  YES
```

[11] Note that the use of an additive composition rule from level 2a (J-scaled attributes) to level 1 (outcomes) will violate the MAUT monotonicity assumption (section 3.3.1) unless the ideal points of all decision makers under consideration are located at one or other pole of all the J-scales on which the attributes are represented.

7

It should be possible to give each GIRL
a rating from 1 to 9 according to its position
on the scale

SHY
1
2
3
4
5 to
6
7
8
9
BOLD

Your rating of NANCY is : 9
Your rating of CHARLOTTE is : 8
Your rating of MARY is : 1
Your rating of HELEN is : 5
Are these ratings OK ? YES

Thinking only about the scale below, what position
on the scale would you like most of all for
an IDEAL GIRL

SHY
1
2
3
4
5 to
6
7
8
9
BOLD

Your best possible value is : 5

Is this alright? YES

Can you specify a way in which one of these

(1) CHARLOTTE
(2) NANCY
(3) HELEN

is different from the other two (in a way that matters
to you now)? Please answer YES or NO) YES
What is the number next to the GIRL
that differs ? 3

```
You have said that HELEN
is different from :
    CHARLOTTE                    and        NANCY

In not more than three words each time, please describe
how the three differ from each other.
First describe HELEN
HELEN                            is :
NOT SEXY
On the other hand,
CHARLOTTE                        and NANCY             are:
SEXY
Are you reasonably happy with this description ?  YES
```

The following extract from the log resulting from the session shows how MAUD used this information in folding the J-scale ratings to produce I-scaled values.

```
ATTRIBUTE DIMENSIONS USED

(1)   SHY (1)......TO.......... BOLD (9)
    IDEAL VALUE = 5

(2)   NOT SEXY (1)......TO.......... SEXY (9)
    IDEAL VALUE = 9
```

RATINGS OF GIRLS ON ATTRIBUTE DIMENSIONS

GIRL ATTRIBUTE DIMENSION		1	2	3	4
(1)		9.00	8.00	1.00	5.00
	VALUE	.00	.25	.00	1.00
(2)		9.00	7.00	2.00	1.00
	VALUE	1.00	.75	.13	[illegible]

3.5.2 Relative Scaling

Construction of I-scales on all attribute dimensions insures that the numbers assigned to attributes on each dimension will be monotonic with worth on that dimension, but it does not insure that the scaling metrics will be comparable across dimensions. Making scaling metrics comparable across dimensions involves operations called relative scaling (Raiffa, 1969).

The use of assessment techniques based upon BRLTs, such as that used in MAUD, effectively carries out relative scaling simultaneously with the assessment of value-wise importance of each dimension. In this case, one does not need to consider separate techniques for relative scaling. The λ_i values assessed in BRLT-based procedures are suitable for direct combination with I-scaled attribute values, providing that the λ_i values were assessed on the same I-scales as the attributes themselves. However, some direct methods for assessing value-wise importances of dimensions do assume that the values of the attributes on the dimensions are fully relatively scaled. Procedures attempting to accomplish such relative scaling are discussed in Humphreys (1977, section 4.2) but are rather complex and not currently available in MAUD.

3.6 Evaluation of Algorithms for Composition Rules from Level 2a to Level 1

In applications of MAUT, a single algorithm is usually employed to implement the mapping rule between level 2a and level 2 and to implement the composition rules between level 2 and level 1. Huber (1974a,b) classified these algorithms into two principal groups: algorithms making use of client-explicated parameter values, in which the decision analyst has to ask the decision maker directly or indirectly for all parameter values, and algorithms making use of observer-derived parameters, usually with the help of multivariate statistical analyses. MAUD uses exclusively client-explicated parameter values, and only algorithms making use of such parameters are examined here.[12] The input to each algorithm is assumed to be scaled attribute values $g_i(x_{ij})$, and the output to be the utilities of the outcomes u_i. The notation is that presented in section 3.4.

3.6.1 Additive Rule: BRLT-Based Assessment Methods

This algorithm uses the additive composition rule under risky choice described in section 3.6 and is the algorithm used by MAUD. The attribute values $g_i(x_{ij})$ input to the procedures must be scaled on I-scales (section 3.5.1). Value-wise importance weights, relative scaling factors, and the f_i to u_i corrections are determined simultaneously in compound form by the BRLT-based procedure. Early examples of applications using this algorithm are the following: evaluation of hypothetical compact cars (Fischer, 1972b), evaluation of apartments by students (von Winterfeldt & Edwards, 1973a), and the evaluation of cinema films (Humphreys & Humphreys, 1975). In each of these applications, algorithms using the BRLT-based procedure were found to be at least as good or better than algorithms in predicting holistic evaluation of outcomes.

This algorithm forms the basis for the assessment of value-wise importance weights within MAUD. On theoretical grounds, this technique is preferable to simpler ranking and direct rating techniques, such as those discussed in section 3.6.3 and Edwards' (1977) SMART technique because the

[12] See Huber, 1974a,b, and Humphreys, 1977 (section 5.2) for calculations of algorithms making use of observer-derived parameter values.

latter do not compensate properly for relative scaling factors and thus are vulnerable to distortion of assessed weights due to use in inappropriate anchors and scales by the decision maker. Despite this, Raiffa's (1969) original BRLT-based method is little used because it requires a large number of complex tradeoffs to be made between both abstract quantities (Knepp-reth et al., 1978). The procedure used within MAUD is computationally much more sophisticated than Raiffa's but provides a much simpler and shorter presentation to the user and requires much fewer and simpler assessments. In fact, within a preference structure comprising N attribute dimensions, the decision maker has to make only N-1 simple indifference judgments, fewer ratings than with any other technique, direct or indirect.

MAUD uses its computational to construct a streamlined set of BRLTs, each comparing tradeoffs on only two dimensions but organized within a hierarchical-free structure formed through a cluster analysis of attribute dimensions. A minimum information transfer algorithm is applied within the I-scaled decomposed preference matrix to construct a cluster fusion tree with two branches at each node. The tree underlying the BRLTs presented in the demonstration session reproduced in section 2 possesses the structure shown in Figure 2.

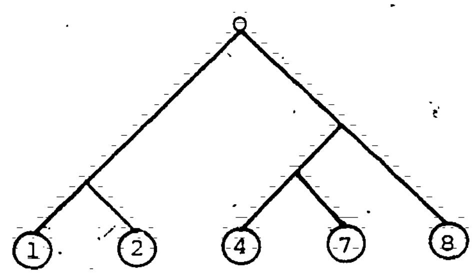

Figure 2. Hierarchical fusion tree for attributes represented in the decomposed preference structure illustrated in section 2.

Note. The (nondeleted) attribute dimensions fused in this structure were:

1. Pick up situation ... to ... Established couples.
2. With better jokes ... to ... With boring jokes.
4. Uninterrupted slogan ... to ... Interrupted slogan.
7. Involving ... to ... Not involving.
8. Appealing to boys ... to ... Appealing to boys and girls.

The BRLT technique is used at each of the N-1 nodes in the N-attribute fusion tree to compare the subsets of dimensions connected at that node. Computation of λ values for each dimension on the basis of the lottery results is then analogous to the computation of probabilities of terminal events in a decision tree. Many possible trees can be formed to link a set of attribute dimensions. In theoretical terms, all are equally suitable, but it is desirable to construct a tree in such a way that it minimizes the effect of any violations of value-wise independence

The clustering procedure used by MAUD clusters first those dimensions, or sets of dimensions, that are most highly associated. This clustering procedure possesses two merits. First, in any node, the set of dimensions being compared are more highly associated than any possible combinations of dimensions that have not yet been considered. This helps to generate stereotype items that seem realistic to people. Second, the requirement of weak conditional utility independence is optimized. It is important to insure value-wise independence between branches connected at the top of the tree, because incorrect estimates of λ here will affect the λ calculations for many more dimensions than will incorrect λ estimates for branches connected lower down. Note that as one moves up the cluster hierarchy, the degree of association between the sets of dimensions clustered at each node decreases; thus, hopefully, the lotteries estimating λ weights involving larger numbers of dimensions have the greater chance of meeting the value-wise independence assumption. The structure of the tree is not visible to the user but is used to direct the sequence of the BRLTs presented by MAUD to the user and the conversion of the probabilities thus elicited from him or her into the relative importance (λ) values and the preference (holistic utility) values of items under consideration. The following example describes the construction of the sequence of BRLTs illustrated in the session with MAUD described in section 2.

Consider the first BRLT constructed. This example contrasted attribute dimensions 1 and 2 by constructing three stereotype alternatives defined in terms of their extreme positions on the two-attribute dimension.

Alternative I	Alternative II	Alternative III
A cola ad. which scores as high as the best alternative (Fish and Chip Shop) on attribute dimension 1 (with better jokes)	A cola ad. which scores as high as the best alternative (Fish and Chip Shop) on attribute dimension 1 (with better jokes)	A cola ad. which scores as low as the worst alternative (Bermuda) on attribute dimension 2 (with boring jokes)
AND	BUT	AND
which scores as high as the best alternative (Fish and Chip Shop) on attribute dimension 2 (pickup situation).	which scores as low as the worst alternative (Bermuda) on attribute dimension 2 (established couples).	which scores as low as the worst alternative (Bermuda) on attribute dimension 2 (established couples).

Alternative I is a best cola ad stereotype, anchored at the point at which the best alternative within the set under consideration scores on each of the two dimensions.

Alternative III is a worst cola ad stereotype, anchored at the point at which the worst alternative within the set under consideration scores on each of the two dimensions. Note that in this example Fish and Chip Shop happened to be best on each of dimensions 1 and 2, and Bermuda happened to be worst on each of dimensions 1 and 2. If this had not occurred (if, e.g., Party had scored best on dimension 2, and Hair worst), then these other alternatives would have been used as anchors on dimension 2 instead.

Alternative II is a compromise alternative, anchored at the best point on dimension 1 but at the worst point on dimension 2.

Now suppose you had to choose between two options. One, option A, guarantees your compromise alternative II for sure, and the other, option B, gives you a chance of getting best alternative I, with probability p, or worst alternative III, with probability (1-p), as shown in Figure 3.

Option A (sure thing)	Option B (gamble)
Alternative II for sure	p → Alternative I; 1-p → Alternative III

Figure 3. BRLT for attribute dimensions 1 and 2.

It follows from expected utility theory that if a value p is found for which you are indifferent between the options A and B, then the ratio of p to (1-p) is the same as the ratio λ_1 to λ_2, the value-wise importances of the two dimensions. (This result is due to Fishburn; for its derivation, see Raiffa, 1969, pp. 35-6.)

MAUD uses descending and ascending methods of limits (starting with a descending series) to find this indifference point for the BRLT, as illustrated in section 2.10. In the example, this occurred where p = .75 and (1-p) = .25, hence λ_1 = .75 and λ_2 = .25, subject to the constraint $\lambda_1 + \lambda_2 = 1$. Similarly, MAUD next constructed a BRLT for dimensions 4 and 7, yielding λ_4 = .15 and λ_7 = .85, subject to the constraint $\lambda_4 + \lambda_7 = 1$. The third BRLT was located at the node in the fusion tree connected to dimensions 4, 7, and 8. In order to avoid a complex stereotype alternative involving a composite of dimensions 4 and 7, the dimension that received the highest λ weight within this pair, i.e., dimension 7, is chosen as a <u>delegate</u> for this cluster in the BRLT, yielding λ_7 = .55, λ_8 = .45, subject to the constraint $\lambda_7 + \lambda_8 = 1$.

However, this constraint is not appropriate here; the constraint that should apply is $\lambda_4 + \lambda_7 + \lambda_8 = 1$, and the λ weights applied to the branches have to be renormalized to take into account that attribute dimension 7, used in the BRLT, only accounts for 0.7 of the value-wise importance to be assigned to the branch consisting of a fusion of attributes 4 and 7, for which it is the delegate.

MAUD therefore makes the appropriate corrections before proceeding to the next BRLT, where the results are similarly corrected, and so on, until all N-1 BRLTs have been assessed and all N λ values determined, under the constraint $\Sigma_1^N \lambda = 1$.

The final version of the tree, with (uncorrected) assessments and intermediate delegates filled in, appears, for this example, in Figure 4.

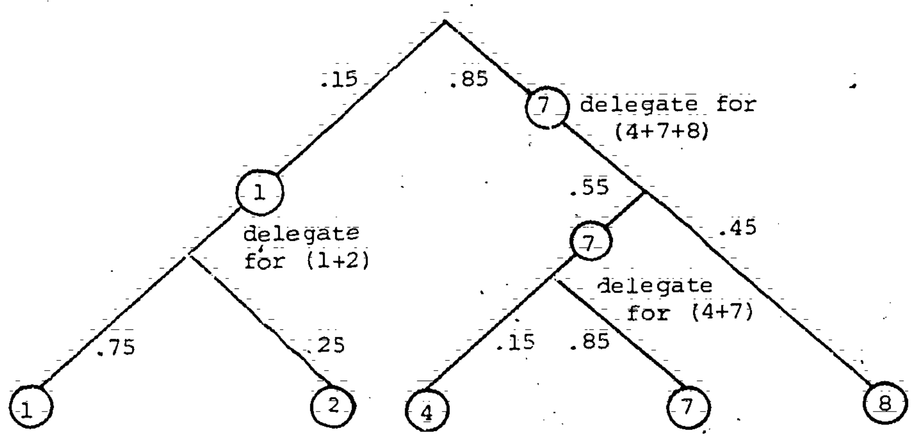

Figure 4. Final version of tree.

After the appropriate normalizations and corrections, the assessed λ weights constructed from the data represented in this tree are as follows:

$$\lambda_1 = .026$$
$$\lambda_2 = .079$$
$$\lambda_4 = .079$$
$$\lambda_7 = .448$$
$$\lambda_8 = .367$$

These λ weights are shown in the summary of the MAUD session, reproduced in section 2.10, together with the holistic utility values of alternatives computed through their use in an additive MAUT composition rule.

Multiplicative Rule: BRLT-Based Assessment Procedure. This rule and its use is described in Keeney and Raiffa (1976, chapter 6). The multiplicative rule is used in cases in which the λ_i assessed by a BRLT-based procedure do not sum to 1 over all n attribute dimensions (i = 1 to n). From a conjoint measurement standpoint, this use of a multiplicative rule is a procedural device to simplify computation. Logarithmic transformation of both sides of the equation are used for the multiplicative forms of the composition rule according to which is most convenient to use, given the nature of the data and the decision-making situation. In situations in which the result of obtaining a worst value on a particular attribute dimension is so severe that this worst value is not compensated by best values and on all other attribute dimensions, then one's best strategy is either (a) to use a multiplicative form of the composition rule, which will delete all outcomes that possess such a value through multiplying them by zero, or (b) to delete all such outcomes as nonstarters before using an additive form of the rule in the evaluation of the remaining outcomes. Strategy b is the strategy recommended for use with MAUD, although a multiplicative procedure will be implemented in future versions of MAUD to deal with residual problems where marginality is still not satisfied (see section 3.4.3).

3.6.3 Non-BRLT-Based Assessment Methods

BRLT-based methods, while theoretically optimal, have the disadvantage that, with the exception of the methods currently used in MAUD, they require some extremely complex assessments from the user. In order to compute a set of λ weights, either a large number of simple lotteries or a smaller number of increasingly complex ones are usually employed, requiring the user to hold in his or her mind descriptions of quite complex stereotype items and make accurate comparisons between them. If n is greater than 5 or 6, the procedure becomes unwieldy, and the user usually begins to complain of information overload when required to make comparisons. In view of this problem, some alternative procedures considered by decision analysts are discussed below. They are theoretically suboptimal, usually adopted for their ease of use. They are not employed in MAUD, however, where we took the alternative route of improving the optimal procedure.

Compensation Method. This algorithm uses the composition rule under riskless choice described in section 3.3. It has been used by von Winterfeldt and Edwards (1973a) and Aschenbrenner (1975), in both cases in the evaluation of apartments by students under riskless choice. Von Winterfeldt and Edwards described the method as a "direct rating procedure with importance weights derived from the unstandardized utility functions as described by Sayeki (1972) in the framework of additive conjoint measurement."

In this procedure, each λ'_i ($=w_i q_i$) is determined by observing how much the decision maker's holistic U_j ratings change when values of their (hypothetical) attributes on dimensions i are changed from worst to best. Consider the effect of switching from worst (0) to best (1) on dimension 1.

According to the conjoint measurement model described in section 2.6,

$$\Delta F_j = \left[\sum_{i=2}^{n} \lambda'_i g(x_{ij}) + \lambda'_1 (1) \right] - \left[\sum_{i=2}^{n} \lambda'_i g(x_{ij}) + \lambda'_1 (0) \right] = \lambda'_1$$

where ΔF_j is the change in the holistic rating of outcome j. All other attribute dimensions are similar.

Aschenbrenner's version of the procedure starts with attributes on all dimensions at their worst value, and the decision maker is asked, if he or she had the opportunity to change only one attribute for its best level, which one would he or she choose? He assumed that the attribute chosen will be that which maximizes ΔF_j. The question is repeated until all attributes have been changed to their best levels and all dimensions ranked in terms of their value-wise importances. The λ'_i are then found through direct rating of the importance ratios of the attributes.

As with BRLT-based assessment methods, the $g_i(x_{ij})$ input to the model must be scaled on I-scales, and value-wise independence is assumed. However, unlike algorithms employing BRLT-based assessment techniques, this algorithm is not appropriate for use under risky choice, because f_i to u_i corrections (h_i) are not determined. Von Winterfeldt and Edwards (1973a) found the compensation method to be inferior to a BRLT-based assessment method but superior to a direct rating method.

Direct Rating Method. In typical applications using the direct rating method, the value-wise importance weights (w_i) are assessed by asking the decision maker for direct ratings. Formally, algorithms making use of this procedure require also the use of a relative scaling procedure to estimate values of q_i (section 3.4.4), because under the riskless choice $f_i(x_{ij}) = w_i q_i[g(x_{ij})]$. However, in most applications of MAUT in which direct rating techniques have been used, the q_i have not been assessed. Such applications have included college admissions (Khlar, 1969), evaluation of medical care research proposals (Gustafson et al., 1971), evaluation of military tactics (Turban & Metersky, 1971), and others reviewed by Huber (1974a). Technically, the additive models used in these applications are incoherent, because values of $f_i(x_{ij})$ or $u_i(x_{ij})$ cannot be assessed in the absence of values of q_i. However, they can be made coherent by adding the constant scaling assumption $q_i = 1$ ($i = 1$ to n) and then applying an additive composition rule.

The constant scaling assumption seems to be reasonable in many applications of MAUT, because direct rating models incorporating this assumption have often performed quite well in practice (Dawes & Corrigan, 1974; Huber, 1974a). As would be expected, though, their predictions are inferior to BRLT-based models (Fischer, 1972b; von Winterfeldt & Edwards, 1973a). The apparent efficiency of these models is due in part to the fact that they have been used in applications in which the constant scaling assumption is reasonable a priori. As a counter example, consider the evaluation of proprietary brands of sweets (outcomes) on the following attribute dimensions:

	value-wise importance	relative scaling factor
1. Not tasty ... to ... tasty	w_1	q_1
2. Poisonous ... to ... not poisonous	w_2	q_2

Direct rating of value-wise importance would, for most people, yield $w_1 < w_2$ because preservation of life is more important than having a nice taste in your mouth. However, $q_1 > q_2$, because attributes of proprietary brands of sweets range right along dimension 1 but are all squeezed together at the preferred pole of dimension 2. When we consider the products $w_i q_i = f_i$, we can see that attribute values on dimension 1 will dominate the analysis only if $w_1/w_2 > q_2/q_1$.

Equal Weights Method. This method is like the direct rating method except that an additional equal weights assumption $w_1 = w_2 \ldots w_i \ldots = w_n$ is made. Hence value-wise importance weights need not be assessed. The resulting model is that underlying the Likert scale technique used in a vast number of attitude and personality scaling applications (Edwards, 1957; Dawes, 1972). Despite the strong and arbitrary character of the equal weights assumption, such models have been found quite efficient in MAUT applications (Dawes & Corrigan, 1974), although inferior to a model using a BRLT-based assessment method (Humphreys & Humphreys, 1975). Einhorn and Hogarth (1975) delineate the situations in which equal weights methods can always be improved by combining them with appropriate prior information. Using BRLTs is one way of gaining such prior information. One reason for the apparent efficiency of the equal-weights model may be the demonstrated insensitivity of additive model compositions to variations in the w_i values (von Winterfeldt & Edwards, 1973b).

MAUD can provide an equal weight option that allows a user to examine his or her preference structure and the computed holistic utility values of alternative items within this structure before (and without) having to make any assessments within a λ-weight estimating procedure. This option is convenient but can lead to misleading results when assumptions relative to scaling and equal weights are infringed. It should therefore be used with caution.

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APPENDIX A

PROGRAM DOCUMENTATION

MAUD is written in BASIC for the IBM 5110 system, using the display screen for input and output.

Screen Manipulation on the IBM 5110

The screen is treated as a record I/O file. It is opened using the device number '002';

```
e.g., 0075 OPENFILE FL5, '002',ALL
```

where ALL specifies both read and write operations.

The system allows manipulation of the top 14 lines of the screen, with a maximum of 64 characters per line. Data can be written on the screen using WRITEFILE or REWRITEFILE statements and read using the READ statement. When addressing the screen, the first character position and the length of the I/O string both have to be specified. When necessary, the final position of the pointer can also be specified;

```
e.g., 0225 WRITEFILE USING 130,FL5,'Title for this session'
      0130 FORM POS129,C25,POS154
      0140 READFILE USING 150,FL5,T$
      0150 FORM POS154,C60.
```

The Internal Layout of MAUD

MAUD comprises three programs:

MAUD--is the main program. It elicits choice alternatives and attribute dimensions. In addition, it also checks ratings of alternatives on dimensions and elicits ideal points on each dimension.

BRLT--computes lotteries for assessing value-wise importance of dimensions, computes preference values for choice alternatives, and computes cluster correlation.

LOG--produces a hard copy of the summary.

Data Files

MAUD has four data files:

F1--stores titles and control values.

F2--stores a matrix containing the names of choice alternatives and two other matrixes containing the names of poles of attribute dimensions.

F3--stores control values.

F4--stores data. The file is three records long.

F1, F2, and F3 are sequential files. They can be accessed by using an OPEN statement;

e.g., OPEN FL1,'E80',4,'F1',IN,IOERR 6990.

FR is a record-oriented file. It is accessed by using the OPENFILE statement;

e.g., OPENFILE FL4,'E80',7,'F4',IN,IOERR 6990.

Details of File Storage

F1 contains seven variables.

T$: title of the session (maximum 60 characters long)

S$: generic name for all items under consideration in singular form (maximum 30 characters long)

P$: generic name for all items in plural form (maximum 30 characters long)

J: number of attribute dimensions (J_{max} = 20)

N1: number of choice alternatives ($N1_{max}$ = 8)

N2: number of successful mappings of attribute dimensions ($N2_{max}$ = 8)

K2: error flag

F2 contains three matrixes.

A$: contains names of choice alternatives (maximum 30 characters each)

B$ and C$: contain poles of attribute dimensions (maximum 30 characters each)

F3 holds seven matrixes.

H: status codes for attribute dimensions (negative if the dimension has been deleted)

S: standard deviations of ratings on attribute dimensions

B: positions of ideal points on attribute dimensions

W: weights of attribute dimensions

U: utility values for items (range between 0 and 1, negative if not yet computed)

L: lists of branches of nodes in utility hierarchy

Y: sums of ratings on attribute dimensions

F4 holds three records consisting of a single matrix each.

Z (record 1): stores the ratings of choice alternatives on each attribute dimension (values are between 1 and 9)

X (record 2): stores the value of each choice alternative on each attribute dimension

R (record 3): stores the correlation coefficient between attribute dimensions

Details on MAUD

MODULE 1:

Lines 195-795: Parameter used → N1 (which counts the number of choice alternatives under consideration, $N1_{max} = 8$).
This module deals with input of title (T$), generic name: in singular form (S$) and plural (P$), and choice alternatives (A$(I)--where I is an index between 1 and N1).
Line 520 checks that N1 is <= to 8.
Finally, the module displays all the choice alternatives entered by the user.
* End of module.

MODULE 2:

Lines 800-1165: Parameter used → N1.
This module deals with changes (if any) in choice alternatives.
Lines 880-990 change the name of a choice alternative.
Lines 995-1095 delete a choice alternative.
Lines 1100-1165 add a choice alternative to the list.
* End of module.

MODULE 3:

Lines 1170-1820: Parameter used → J (which counts the number of attribute dimensions, $J_{max} = 20$).
This module deals with elicitation of attribute dimensions poles (stored in E$(J) and C$(J)--where J is the index of each attribute dimension).

MODULE 3 (continued):

At line 1270, the module calls a subroutine: RANDOM TRIAD GENERATOR (lines 5375-5420), which randomly picks out triads of choice alternatives and stores their indexes in a G array (G(I), I=1 to 3).
Lines 1285-1320 present those three alternatives and stores them in an X$ array (X$(I), I=1 to 3).
Lines 1580-1820 elicit the attribute dimension. Each dimension consists of two poles, i.e., B$(J) and C$(J).
* End of module.

MODULE 4:

Lines 1830-2200: Parameters used → N1 and J.
This module elicits values of Z(I,J)--between 1 and 9, where I is the index of each choice alternative (I=1 to N1) and J is the index of the current attribute dimension being assessed.
* End of module.

MODULE 5:

Lines 2220-2525: Parameters used → J and H(J).
This module allows the user to make alterations by either changing the ratings or canceling the scale altogether.
Changes are dealt with by a subroutine: CHANGE RATINGS (lines 8270-8410).
Changing the scale will take the user back to the previous module.
Canceling the scale will take the user back to MODULE 3; the status, H(J) is assigned the value -299.
If there is no alteration to be made, H(J) remains 0 and the program carries on to the next module.
* End of module.

MODULE 6:

Lines 2530-2895: Parameter used → J.
This module elicits ideal points for each attribute dimension J with poles B$(J) and C$(J). The value of the ideal point is stored in B(J)--where the range of the scale is between 1 and 9.
* End of module.

MODULE 7:

Lines 2920-2933: Parameters used → J and H(J).
This module allows the user to change the ratings of the ideal point (B(J)) or cancel the entire scale.
Changes are dealt with by the subroutine: CHANGE RATINGS (lines 8270-8410).
Changing the rating will take the user back to the previous module.

MODULE 7 (continued):

Canceling the scale will take the user back to MODULE 3; the status, H(J) is assigned the value -299.
* End of module.

MODULE 8:

Lines 3080-3190: Parameters used → N1 and J.
Values of X(I,J) are computed, i.e., values of each choice alternative (I=1 to N1) on the current attribute dimension being assessed.
Lines 3140-3185 adjust the scale such that the worst value=0 and the best value=1.
If there is very little variation (i.e., ≤ .5) between all values of X(I,J), the program will pass on to the next module; otherwise it will proceed to MODULE 10.
* End of module.

MODULE 9:

Lines 3200-3390: Parameters used → J and H(J).
This module becomes active when there is ≤ .5 difference between all values of X(I,J). It allows the user to do one of the following three operations:

- change the values of Z(I,J). This will take the user back to MODULE 4.
- change the value of B(J). This will take the user back to MODULE 6.
- change nothing. The status, H(J) is set to -99 and the program proceeds to MODULE 11.

* End of module.

MODULE 10:

Lines 3395-4040: Parameters used → N1,J,H(J),N2, and K1.
The variance, S(J) is computed and the current status, ,H(J), is set to 1.
If N2 is <2, the program will bypass the rest of the module and pass on to the next module.
Line 3515 computes the value of R(M,J), where M is an index between 1 and J-1, and J is the index of the current attribute dimension, which at this stage must be ≥ 2.
If the current R(M,J) is <.866, the next value R(M+1,J) is computed. When all values of R(M,J) have been successfully computed, the program passes on to the next module.
For each R(M,J) which has a value ≥ .866, the following process is activated:

Lines 3530-3745 check with the user whether or not a change is required. If the response is negative, the program will increment M by 1 and compute the next value of R(M,J).
If the response is affirmative (i.e., the two attribute dimensions being analyzed have similar meaning), the following submodule is activated:
Lines 3755-4040 conduct a constructivist solution. K1 is incremented by 1 (K1 is a count for the number of attribute dimensions. $K1_{max} = 20$).
The current status, H(J) is set to -M, H(M) is set to -J, and N2 is decreased by 2.
A new attribute dimension is created, and the poles are stored in B$(J) and C$(J).
The program goes back to MODULE 4.
* End of module.

MODULE 11:

Lines 4045-4160: Parameter used → N2.
If N2 is <2, the program will bypass the rest of the module and go back to MODULE 3.
This module gives the user the option of viewing a summary of progress to date by chaining to LOG.
If no summary is required, the program passes on to the next module.
* End of module.

MODULE 12:

Lines 4165-4495: Parameter used → J.
This module allows the user to add another dimension to the list. J is incremented by 1 ($J_{max} = 20$), and the program goes back to MODULE 4.
If the user does not wish to carry out this process, the program passes on to the next module.
* End of module.

MODULE 13:

Lines 4500-4630: Parameter used → N2.
If N2 is <2, the program bypasses the rest of the module and goes back to MODULE 3.
The module allows the user to elicit another dimension; this process is carried out by going back to MODULE 3.
If the response is negative, the program will pass on to the next module.
* End of module.

MODULE 14:

Lines 4640-4740: This module allows the user to investigate preferences between alternatives, i.e., U values.
The program will chain to BRLT.

MODULE 14 (continued):

If this process is not required, the user will have the option of saving the data for future use. This uses the subroutine: FILE DATA (lines 5426-5500).

* End of module.

END OF MAUD

Subroutines in MAUD

RANDOM TRIAD GENERATOR (lines 5375-5420)

This subroutine generates three different numbers between 1 and N1 and stores those numbers in a G array.

FILE DATA (lines 5426-5500)

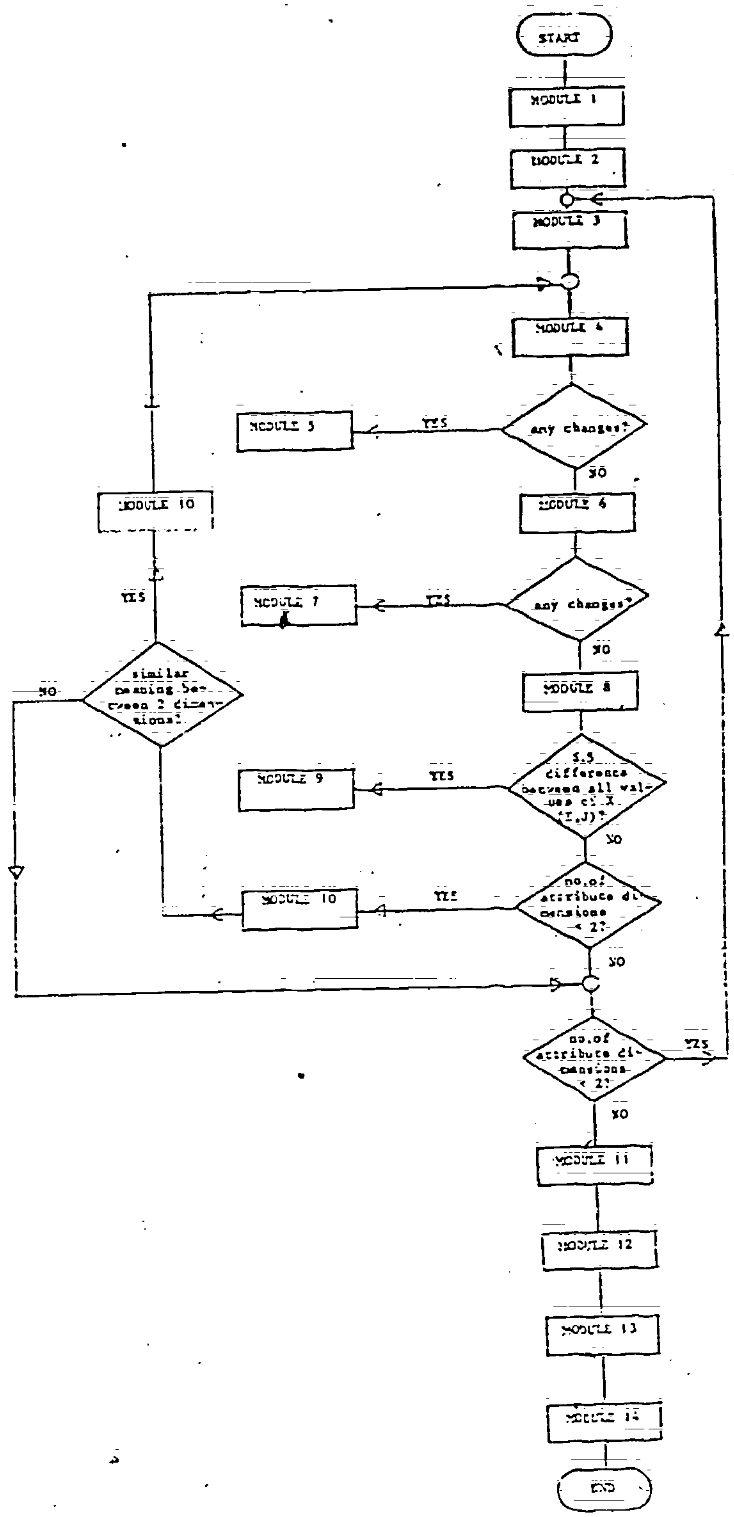
This subroutine files data in FL1, FL2, FL3, and FL4. (For more information on file storage, see "Details of file storage," p. 52.

DISPLAY ALTERNATIVES (lines 7680-7715)

This subroutine displays choice alternatives between 1 and N1.

CHECK NUMERIC INPUT (lines 7900-7970)

This subroutine checks that numeric input is within range.



MODULAR REPRESENTATION OF MAUD

APPENDIX B

PROGRAM LISTING OF MAUD

```
0010 REM
0015 REM *******MAUD **************
0020 REM
0024 REM
0025 USE T$60,S$30,P$30
0030 USE C,J,N1,N2,K2,S1
0035 USE A$60(20),B$60(20),C$60(20)
0040 USE Z(20,20),X(20,20),R(20,20)
0045 USE H(20),S(20),B(20),W(20),U(20),L(20),Y(20),V(20)
0050 DIM Z$64,Y$64,X$64,Q$64,E$64
0051 FORM POS1,C
0052 FORM POS65,C
0053 FORM POS129,C
0054 FORM POS193,C
0055 FORM POS257,C
0056 FORM POS321,C
0057 FORM POS385,C
0058 FORM POS449,C
0059 FORM POS513,C
0060 FORM POS577,C
0061 FORM POS641,C
0062 FORM POS705,C
0063 FORM POS769,C
0064 FORM POS833,C
0068 FORM POSP,C
0069 FORM POS895,C1
0075 OPEN FILE FL5,'002',ALL
0076 S1=20
0077 REM ***********S1 IS MAX NUMBER OF ATTRIBUTES *************
0078 S8=4
0079 S9=8
0080 REM S8 AND S9 ARE MIN AND MAX NUMBER OF ALTERNATIVES ******
0081 P9=1
0082 REM ******PRINTER ON CODE******
0084 Z$='Please type  YES  or  NO'
0085 Y$='
0087 E$='            Press EXECUTE to proceed'
0090 IF C=1 GOTO 4995
0091 IF C=2 GOTO 5300
0092 IF C=3 GOTO 5215
0093 GOSUB 8000
0094 PRINT '*****************<MAUD>*************************'
0095 PRINT '-----------------------------------------------'
0101 REM ******************************************************
0102 PRINT 'Do you want to use material already on file';
0103 INPUT Q$
0104 IF Q$='YES' GOTO 6000
0105 IF Q$='NO' GOTO 109
0106 PRINT Z$
0107 PRINT
0108 GOTO 102
0109 PRINT
0113 REM ### INITIALISE ###
0114 GOSUB 8000
0115 N1=0
0120 N2=0
0125 MAT Z=(0)
0130 MAT X=(0)
0135 MAT R=(0)
```

```
0400 Q$='can be whatever you like; so long as YOU know what you'
0401 REWRITEFILE USING 54,FL5,Q$
0402 REWRITEFILE USING 55,FL5,'mean. You should put in'
0403 REWRITEFILE USING 404,FL5,P$,'which are available now,'
0404 FORM POS281,C16,X,C
0405 Q$='as well as others that you want to think about.'
0406 REWRITEFILE USING 56,FL5,Q$
0407 REWRITEFILE USING 58,FL5,'Keep the description of each'
0408 REWRITEFILE USING 409,FL5,S$
0409 FORM POS478,C
0410 REWRITEFILE USING 59,FL5,'short; type just one or two words.'
0411 REWRITEFILE USING 61,FL5,E$
0412 READFILE USING 69,FL5,Q$
0413 GOSUB 8000
0419 REWRITEFILE USING 420,FL5,'Please type in the name of a',S$
0420 FORM POS129,C29,X,C30
0425 REWRITEFILE USING 430,FL5,'you want to consider'
0430 FORM POS193,C30
0435 N1=N1+1
0440 REWRITEFILE USING 445,FL5,'Its name is '
0445 FORM POS321,C11,POS333
0450 READFILE USING 455,FL5,A$(N1)
0455 FORM POS333,C30
0460 GOSUB 8000
0465 IF N1=S8 GOTO 505
0475 REWRITEFILE USING 480,FL5,'Now the next',S$
0480 FORM POS129,C15,X,C30
0485 REWRITEFILE USING 490,FL5,'you want to consider'
0490 FORM POS193,C20
0500 GOTO 435
0505 GOSUB 8000
0520 IF N1<S9 GOTO 550
0525 REWRITEFILE USING 530,FL5,'You have considered the'
0530 FORM POS65,C25,POS90
0535 REWRITEFILE USING 540,FL5,'maximum number of',P$
0540 FORM POS90,C17,X,C30
0545 GOTO 675
0550 REWRITEFILE USING 555,FL5,'Is there another ',S$
0555 FORM POS129,C17,C30
0560 REWRITEFILE USING 565,FL5 'you want to consider?'
0565 FORM POS1[illegible],C20,POS[illegible]
0570 READFILE USING 5[illegible],FL5,Q$
0585 FORM POS[illegible],C30
0590 IF Q$='YES' GOTO 625
0595 N1=N1+1
0600 REWRITEFILE USING 445,FL5,'Its name is '
0610 READFILE USING 455,FL5,A$(N1)
0620 GOTO 505
0625 IF Q$='NO' GOTO 660
0630 REWRITEFILE USING 365,FL5,Z$
0635 READFILE USING 375,FL5,Q$
0640 GOSUB 8000
0655 GOTO 590
0660 GOSUB 8000
0675 REWRITEFILE USING 680,FL5,P$,'under consideration'
0680 FORM POS129,X10,C18,X,C30
0685 P=129
0690 GOSUB 7680
0745 P=P+128
```

```
0750 P1=P+34
0755 REWRITEFILE USING 760,FL5,'Do you want to change anything ?'
0760 FORM POSP,C33,POSP1
0765 READFILE USING 770,FL5,Q$
0770 FORM POSP1,C30
0773 GOSUB 8000
0775 IF Q$='YES' GOTO 800
0780 IF Q$='NO' GOTO 1170
0785 REWRITEFILE USING 365,FL5,Z$
0790 READFILE USING 375,FL5,Q$
0795 GOTO 775
0800 REM #### USER WANTS TO CHANGE SOMETHING ###
0805 REWRITEFILE USING 54,FL5,"Do you want to'
0815 REWRITEFILE USING 820,FL5,'(1) Change the name of a ',S$
0820 FORM POS321,X5,C22,X,C30
0825 REWRITEFILE USING 830,FL5,'(2) Remove a',S$
0830 FORM POS385,X5,C13,X,C30
0835 REWRITEFILE USING 840,FL5,'(3) Add a',S$
08[illegible] FORM POS449,X5,C10,X,C30
0842 Q$='Please type in 1, 2, or 3 :'
0845 REWRITEFILE USING 850,FL5,Q$
0850 FORM POS577,C27,POS605
0852 P=1
0855 READFILE USING 860,FL5,Q$
0860 FORM POS605,C1
0865 GOSUB 8000
0880 REM ### CHANGE A NAME ###
0885 IF Q$≠'1' GOTO 975
0886 GOSUB 7680
0887 P=P+128
0890 REWRITEFILE USING 895,FL5,'What is the number of the ',S$
0895 FORM POSP,C25,C30
0897 P=P+64
0898 P1=P+20
0900 REWRITEFILE USING 905,FL5,'you want to change?'
0905 FORM POSP,C19,POSP1
[illegible] GOSUB 7[illegible]
[illegible] P=P+64
[illegible] P1=P+12
[illegible] REWRITEFILE USING 975,FL5,'New name :'
[illegible] FORM POSP,C12,POSP1
[illegible] READFILE USING 985,FL5,A$(I)
[illegible] FORM POSP1,C
[illegible] GOTO [illegible]
[illegible] REM ### DELETE AN ITEM ###
[illegible] IF Q$≠'2' GOTO 1100
[illegible] GOSUB 7[illegible]
[illegible] P=P+128
[illegible] REWRITEFILE USING 895,FL5,'What is the number of the ',S$
1010 P=P+64
1012 P1=P+19
1015 REWRITEFILE USING 1020,FL5,'you want to remove?'
1020 FORM POSP,C19,POSP1
1025 GOSUB 7[illegible]
1070 IF I=N1 GOTO 1090
1075 FOR J=1 TO N1-1
10[illegible] A1(J)=A1(J+1)
1085 NEXT J
1090 N1=N1-1
```

```
1095 GOTO 660
1100 REM ####### ADD AN ITEM #######
1105 IF Q$<>'3' GOTO 755
1106 IF N1=S9 GOTO 525
1107 GOSUB 7680
1108 P=P+128
1110 N1=N1+1
1115 IF N1>S9 GOTO 525
1120 REWRITEFILE USING 1125,FL5,'Please type the name of the ',S$
1125 FORM POSP,C28,C30
1127 P=P+64
1130 REWRITEFILE USING 1135,FL5,'job you want to add
1135 FORM POSP,C
1140 N$=CHR(N1)
1142 P=P+64
1143 P1=P+10
1145 REWRITEFILE USING 1150,FL5,'(',N$,')'
1150 FORM POSP,C1,X,C1,X,C1,POSP1
1155 READFILE USING 1160,FL5,A$(N1)
1160 FORM POSP1,C30
1165 GOTO 660
1170 REM ****INTRODUCE METHOD OF DIFFERENCES*******
1171 J=0
1172 GOSUB 8000
1173 PRINT 'You are now going to be asked about differences'
1174 PRINT 'between ';P$;'. Try to think about differences'
1175 PRINT 'which are important to you in making your decision.'
1176 PRINT 'For instance, some people feel that certain ';P$
1177 PRINT 'are INTERESTING while other ';P$;' are BORING,'
1178 PRINT 'and some ';P$;' are in between.'
1179 PRINT 'This is just one example and may not be relevant to'
1180 PRINT 'you.  There are no right or wrong answers. Even if'
1181 PRINT 'you are not sure that you are correct about an aspect'
1182 PRINT 'of a ';S$;', just work with what you imagine it'
1183 PRINT 'to be like.'
1184 PRINT
1185 PRINT
1186 REWRITEFILE USING 64,FL5,E$
1187 READFILE USING 69,FL5,Q$
1188 J=J+1
1197 GOSUB 8000
1205 IF J<11 GOTO 1250
1210 REWRITEFILE USING 1215,FL5,'Attribute dimension storage
1215 FORM POS127,C28,POS157
1220 REWRITEFILE USING 1225,FL5,'space full.'
1225 FORM POS157,C30
1230 GOSUB 8000
1245 GOTO 4635
1250 Q$='Can you specify a way in which one of these'
1255 REWRITEFILE USING 53,FL5,Q$
1270 GOSUB 5375
1275 REM_----------------------
1280 P=193
1285 FOR I=1 TO 3
1290 N$=CHR(I)
1295 P=P+64
1300 E=G(I)
1305 REWRITEFILE USING 1310,FL5,'(',N$,')',A$(E)
1310 FORM POSP,C1,X,C2,X,C1,X,C30
```

```
1315 X$(1)=A$(E)
1320 NEXT I
1325 Q$='is different from the other two (in a way that matters'
1330 REWRITEFILE USING 59,FL5,Q$
1335 Q$='to you now)?          Please answer YES or NO '
1337 REWRITEFILE USING 1340,FL5,Q$
1340 FORM POS577,C55,POS633
1345 READFILE USING 1350,FL5,Q$
1350 FORM POS633,C
1355 REWRITEFILE USING 64,FL5,Y$
1360 IF Q$≠'NO' GOTO 1385
1365 FOR I=1 TO 16
1370 PRINT
1375 NEXT I
1380 GOTO 1250
1385 IF Q$='YES' GOTO 1410
1390 REWRITEFILE USING 365,FL5,Z$
1395 REWRITEFILE USING 1400,FL5,Y$
1400 FORM POS513,C63
1405 GOTO 1325
1410 REWRITEFILE USING 1415,FL5,'What is the number next to the'
1415 FORM POS641,C32,POS673
1420 REWRITEFILE USING 1425,FL5,S$
1425 FORM POS673,C
1430 REWRITEFILE USING 1435,FL5,S$,'that differs ?'
1435 FORM POS705,C16,POS721
1440 READFILE USING 1445,FL5,C$
1445 FORM POS721,C
1450 Q$=STR(C$,1,1)
1452 IF Q$<'1' GOTO 1465
1455 IF Q$>'3' GOTO 1465
1457 D=NUM(Q$)
1460 GOTO 1490
1465 REWRITEFILE USING 1470,FL5,'Please type  1  ,  2  or  3'
1470 FORM POS[illegible]9,C28,POS777
1475 READFILE USING 1480,FL5,C$
1480 FORM POS777,C
1485 GOTO 1450
1490 GOSUB 8900
1500 Q$='You have said that'
1505 REWRITEFILE USING 1510,FL5,Q$,X$(D)
1510 FORM POS[illegible],C18,X,C
1515 REWRITEFILE USING 1520,FL5,'is different from :'
1520 FORM POS[illegible],C20
1525 C=0
1530 FOR I=1 TO 3
1535 IF I=D GOTO 1575
1540 IF C=1 GOTO 1565
1545 REWRITEFILE USING 1550,FL5,X$(I),'and'
1550 FORM POS197,C30,C4,POS237
1555 C=1
1560 GOTO 1575
1565 REWRITEFILE USING 1570,FL5,X$(I)
1570 FORM POS237,C30
1575 NEXT I
1580 Q$='In not more than three words each time, please describe'
1585 REWRITEFILE USING 56,FL5,Q$
1590 Q$='how the three differ from each other.'
1595 REWRITEFILE USING 57,FL5,Q$
```

```
1600 REWRITEFILE USING 1605,FL5,'First describe ',X$(D)
1605 FORM POS449,C15,C30
1610 REWRITEFILE USING 1615,FL5,X$(D),'is :'
1615 FORM POS513,C30,X,C5,POS577
1620 READFILE USING 60,FL5,B$(J)
1630 REWRITEFILE USING 61,FL5,'On the other hand,'
1640 C=0
1645 FOR I=1 TO 3
1650 IF I=D GOTO 1690
1655 IF C=1 GOTO 1680
1660 REWRITEFILE USING 1665,FL5,X$(I),'and'
1665 FORM POS705,C30,C4,POS739
1670 C=1
1675 GOTO 1690
1680 REWRITEFILE USING 1685,FL5,X$(I),'are :'
1685 FORM POS739,C25,C5
1690 NEXT I
1695 READFILE USING 63,FL5,C$(J)
1700 REWRITEFILE USING 1710,FL5,'Are you reasonably happy with'
1710 FORM POS833,C30,POS863
1715 REWRITEFILE USING 1720,FL5,'this description ?'
1720 FORM POS863,C20,POS883
1725 READFILE USING 1730,FL5,Q$
1730 FORM POS883,C10
1735 IF Q$='NO' GOTO 1760
1740 IF Q$='YES' GOTO 1825
1745 REWRITEFILE USING 365,FL5,Z$
1750 READFILE USING 375,FL5,Q$
1755 GOTO 1735
1760 GOSUB 8000
1775 REWRITEFILE USING 1780,FL5,'Do you want to describe again'
1780 FORM POS193,C30,POS223
1785 REWRITEFILE USING 1790,FL5,'how',X$(D)
1790 FORM POS223,C3,X,C
1795 REWRITEFILE USING 1800,FL5,'differs from the other two ?'
1800 FORM POS257,C30,POS287
1805 READFILE USING 1810,FL5,Q$
1810 FORM POS287,C
1815 IF Q$='YES' GOTO 1490
1820 IF Q$='NO' GOTO 1197
1825 REM #### HAPPY WITH DESCRIPTION ####
1830 REM #### ELICIT J-SCALED SCORES OF ITEMS ON CURRENT DIM ##
1835 GOSUB 8000
1840 Q$='O.K. You now have a scale going from'
1845 REWRITEFILE USING 51,FL5,Q$
1850 P=65
1855 GOSUB 8500
1955 REWRITEFILE USING 1957,FL5,'Is this scale O.K?'
1957 FORM POS769,C17,POS787
1958 READFILE USING 1959,FL5,Q$
1959 FORM POS787,C10
1960 IF Q$='YES' GOTO 1970
1961 IF Q$='NO' GOTO 1760
1963 REWRITEFILE USING 1964,FL5,Z$
1964 FORM POS833,C25,POS859
1965 READFILE USING 1966,FL5,Q$
1966 FORM POS859,C10
1967 GOTO 1960
1970 GOSUB 8000
```

```
1972 Q$='It should be possible to give each '
1974 REWRITEFILE USING 1975,FL5,Q$,S$
1975 FORM POS1,C35,C29
1980 Q$='a rating from 1 to 9 according to its position'
1985 REWRITEFILE USING 52,FL5,Q$
1990 Q$='on the scale'
1995 REWRITEFILE USING 53,FL5,Q$
2000 P=193
2005 GOSUB 8860
2065 P=211
2080 FOR I=1 TO N1
2085 P=P+64
2090 P1=P+44
2100 REWRITEFILE USING 2105,FL5,Y$
2105 FORM POSP,C46
2130 REWRITEFILE USING 2135,FL5,'Your rating of',A$(I),'is :'
2135 FORM POSP,C14,X,C24,C5,POSP1
2140 READFILE USING 2145,FL5,I$
2145 FORM POSP1,C2
2150 Q$=STR(I$,1,1)
2152 IF Q$<'1' GOTO 2165
2155 IF Q$>'9' GOTO 2165
2157 Z(I,J)=NUM(Q$)
2160 GOTO 2200
2165 P2=P+64
2172 Q$='Please type a number between 1 and 9'
2175 REWRITEFILE USING 2180,FL5,Q$
2180 FORM POSP2,C36
2195 GOTO 2100
2200 NEXT I
2210 P=P+64
2215 P1=P+23
2220 REWRITEFILE USING 2225,FL5,'Are these ratings OK ?'
2225 FORM POSP,C23,POSP1
2230 READFILE USING 2235,FL5,Q$
2235 FORM POSP1,C10
2240 IF Q$='YES' GOTO 2530
2245 IF Q$='NO' GOTO 2265
2250 REWRITEFILE USING 2252,FL5,Z$
2252 FORM POS865,C26,POS890
2255 READFILE USING 2257,FL5,Q$
2257 FORM POS890,C3
2259 GOTO 2240
2265 REM *** RATINGS NOT OK ****
2270 GOSUB 8100
2272 P1=0
2275 GOTO 8270
2520 H(J)=-199
2525 GOTO 1185
2530 REM **** ELICIT IDEAL POINT ****
2535 GOSUB 8000
2540 Q$='Thinking only about the scale below, what position'
2545 REWRITEFILE USING 51,FL5,Q$
2550 Q$='on the scale would you like most of all for'
2555 REWRITEFILE USING 52,FL5,Q$
2560 REWRITEFILE USING 2565,FL5,'an IDEAL ',S$
2565 FORM POS129,C9,C40
2575 P=193
2590 GOSUB 8860
```


73

```
2585 REWRITEFILE USING 2590,FL5,'Your best possible value is :'
2590 FORM POS403,C29,POS433
2765 READFILE USING 2770,FL5,I$
2770 FORM POS433,C5
2775 Q$=STR(I$,1,1)
2795 IF Q$<'1' GOTO 2860
2800 IF Q$>'9' GOTO 2860
2802 B(J)=NUM(Q$)
2805 REWRITEFILE USING 2810,FL5,'Is this alright? '
2810 FORM POS595 C17,POS612
2815 READFILE USING 2820,FL5,Q$
2820 FORM POS612,C10
2825 GOSUB 8000
2830 IF Q$='YES' GOTO 3080
2835 IF Q$='NO' GOTO 2920
2840 REWRITEFILE USING 2252,FL5,Z$
2845 REWRITEFILE USING 2850,FL5,Y$
2850 FORM POS595,C46
2855 GOTO 2805
2860 REM ****************************************
2865 REWRITEFILE USING 2870,FL5,Y$
2870 FORM POS403,C46
2875 Q$='Please type a number between 1 and 9'
2885 REWRITEFILE USING 2890,FL5,Q$
2890 FORM POS531,C36
2895 GOTO 2585
2920 REM ****RATINGS NOT O.K.*****************
2925 GOSUB 8000
2930 P1=1
2933 GOTO 8270
3075 REM ****************************************
3080 REM --------- J TO I  SCALE MAPPING --------
3085 GOSUB 8000
3100 D1=9-B(J)
3105 IF B(J)<5.01 GOTO 3115
3110 D1=B(J)
3115 FOR I=1 TO N1
3120 D2=Z(I,J)-B(J)
3125 X(I,J)=D1-ABS(D2)
3130 NEXT I
3135 REM ****************************************
3140 REM -- ADJUST SCALE SO THAT (WORST)=0 AND (BEST)=I ---
3145 X1=10
3150 X2=0
3155 FOR I=1 TO N1
3160 IF X(I,J)>X1 GOTO 3170
3165 X1=X(I,J)
3170 IF X(I,J)<X2 GOTO 3180
3175 X2=X(I,J)
3180 NEXT I
3185 X2=X2-X1
3190 IF X2>.5 GOTO 3395
3195 REM ****************************************
3200 REM ------ ALMOST NO RANGE ON I SCALE -------
3205 REWRITEFILE USING 3210,FL5,'There seems to be very little'
3210 FORM POS65,C30,POS95
3215 REWRITEFILE USING 3220,FL5,'variation in your preference'
3220 FORM POS95,C30
3225 REWRITEFILE USING 3230,FL5,'ordering of',P$
```

```
3230 FORM POS129,C12,X,C30,POS172
3235 REWRITEFILE USING 3240,FL5,'on this scale'
3240 FORM POS172,C15
3245 REWRITEFILE USING 3250,FL5,'You have the choice of :'
3250 FORM POS257,C30
3255 REWRITEFILE USING 3260,FL5,'1)  Changing your ratings on'
3260 FORM POS389,C29,POS418
3265 REWRITEFILE USING 3270,FL5,'this scale'
3270 FORM POS418,C30
3275 REWRITEFILE USING 3280,FL5,'2)  Changing the ideal value'
3280 FORM POS453,C30
3285 REWRITEFILE USING 3290,FL5,'3)  Changing nothing'
3290 FORM POS517,C30
3295 REWRITEFILE USING 3300,FL5,'Please type your choice.'
3300 FORM POS641,C27,POS668
3305 REWRITEFILE USING 3310,FL5,'1  ,2  or  3  :'
3310 FORM POS668,C17,POS685
3315 READFILE USING 3320,FL5,I$
3317 GOSUB 8000
3320 FORM POS685,C5
3325 IF I$='1' GOTO 1972
3330 IF I$='2' GOTO 2540
3335 IF I$='3' GOTO 3355
3340 REWRITEFILE USING 3345,FL5,Y$
3345 FORM POS641,C63
3350 GOTO 3295
3355 REM ***********************************************
3360 REWRITEFILE USING 3365,FL5,'OK'
3365 FORM POS705,C2
3370 REWRITEFILE USING 64,FL5,'Press EXECUTE to proceed'
3375 READFILE USING 3060,FL5,O$
3385 H(J)=-99
3390 GOTO 4045
3395 REM ***COMPUTE VARIANCE IN PREFERENCE ORDERINGS***
3400 V(J)=0
3405 FOR I=1 TO N1
3410 X(I,J)=(X(I,J)-X1)/X2
3415 Y(J)=Y(J)+X(I,J)
3420 V(J)=V(J)+X(I,J)↑2
3425 NEXT I
3430 S(J)=(N1*V(J)-Y(J)↑2)/N1
3435 N2=N[illegible]1
3440 H(J)=[illegible]
3445 IF N2<1 GOTO 4045
3450 REM ***********************************************
3455 REM ---------------  WCUI CHECKING  ---------------
3460 FOR M=1 TO J-1
3465 GOSUB 8000
3480 R(M,J)=-9
3485 IF H(M)<.5 GOTO 3740
3490 R1=0
3495 FOR I=1 TO N1
3500 R1=R1+X(I,J)*X(I,M)
3505 NEXT I
3510 R1=(N1*R1-Y(J)*Y(M))/N1
3515 R(M,J)=R1/SQR(S(J)*S(M))
3520 IF R(M,J)<.66 GOTO 3740
3525 REM ----------------------
3530 REM **** CHECK WITH USER ABOUT RATINGS ****
```

```
3535 REWRITEFILE USING 3540,FL5,'Your preferences for the
3540 FORM POS65,C30,POS95
3545 REWRITEFILE USING 3550,FL5,P$
3550 FORM POS95,C30
3555 REWRITEFILE USING 3560,FL5,'under consideration in terms'
3560 FORM POS129,C29,POS158
3565 REWRITEFILE USING 3570,FL5,'of their ratings on the scale'
3570 FORM POS158,C30
3575 REWRITEFILE USING 3580,FL5,'ranging from',B$(M)
3580 FORM POS193,C14,C30,POS237
3585 REWRITEFILE USING 3590,FL5,'to',C$(M)
3590 FORM POS237,C3,C30
3595 REWRITEFILE USING 3600,FL5,'seem very much the same as'
3600 FORM POS257,C28,POS285
3605 REWRITEFILE USING 3610,FL5,'your preferences for the'
3610 FORM POS285,C31
3615 REWRITEFILE USING 3620,FL5,P$,'in terms of their ratings'
3620 FORM POS321,C30,C30
3625 REWRITEFILE USING 3630,FL5,'on the scale ranging from'
3630 FORM POS385,C28,POS413
3635 REWRITEFILE USING 3640,FL5,B$(J)
3640 FORM POS413,C30
3645 REWRITEFILE USING 3650,FL5,'to',C$(J)
3650 FORM POS449,C4,C30
3655 REWRITEFILE USING 3660,FL5,'Does this mean that these two'
3660 FORM POS513,C30,POS543
3665 REWRTIEFILE USING 3670,FL5,'scales mean similar things'
3670 FORM POS543,C30
3675 REWRITEFILE USING 3680,FL5,'to you ?'
3680 FORM POS577,C8,POS586
3685 READFILE USING 3690,FL5,Q$
3690 FORM POS586,C10
3700 IF Q$='YES' GOTO 3755
3705 IF Q$='NO' GOTO 3730
3710 REWRITEFILE USING 365,FL5,Z$
3715 REWRITEFILE USING 3720,FL5,Y$
3720 FORM POS577,C63
3725 GOTO 3675
3730 REWRITEFILE USING 3735,FL5,'OK'
3731 REWRITEFILE USING 64,FL5,'PRESS EXECUTE TO PROCEED'
3732 READFILE USING 69,FL5,Q$
3733 GOSUB 8000
3735 FORM POS705,C2
3740 NEXT M
3745 GOTO 4045
3750 REM ------******************************
3755 REM ****** CONSTPUCTIVIST SOLUTION ****
3757 GOSUB 8900
3760 H(J)=-M
3765 N2=N2-1
3770 K1=J+1
3775 IF K1>S1 GOTO 3800
3795 GOTO 1210
3800 H(M)=-J
3805 N2=N2-1
3810 M1=0
3815 J1=0
3820 S2=0
3825 FOR I=1 TO N1
```

```
3830 M1=M1+Z(I,M)
3835 J1=J1+Z(I,J)
3840 S2=S2+Z(I,J)*Z(I,M)
3845 NEXT I
3850 R1-N1*S2-J1*M1
3855 Q$='O.K. Please type in a word (or phrase of not more than'
3860 REWRITEFILE USING 51,FL5,Q$
3865 Q$='three words) which has the same meaning as both'
3870 REWRITEFILE USING 52,FL5,Q$
3900 REWRITEFILE USING 3905,FL5,B$(M),'and'
3905 FORM POS129,C30,C4
3910 IF R1<0 GOTO 3930
3915 REWRITEFILE USING 3920,FL5,B$(J)
3920 FORM POS163,C30
3922 GOTO 3935
3930 REWRITEFILE USING 3920,FL5,C$(J)
3935 REWRITEFILE USING 3940,FL5,'Your new words(s) :'
3940 FORM POS257,C20,POS321
3945 READFILE USING 3950,FL5,I$
3950 FORM POS321,C60
3955 Q$='Now please type in a word (or phrase of not more than'
3960 REWRITEFILE USING 59,FL5,Q$
3965 Q$='three words) which has the same meaning as both'
3970 REWRITEFILE USING 60,FL5,Q$
3975 REWRITEFILE USING 3980,FL5,C$(M)
3980 FORM POS641,C30
3985 IF R1<0 GOTO 4005
3990 REWRITEFILE USING 3995,FL5,'and',C$(J)
3995 FORM POS672,C3,C30
4000 GOTO 4010
4005 REWRITEFILE USING 3995,FL5,'and',B$(J)
4010 REWRITEFILE USING 4015,FL5,'Your new word(s) :'
4015 FORM POS705,C20,POS769
4020 J=K1
4025 READFILE USING 4030,FL5,C$(J)
4030 FORM POS769,C60
4035 B$(J)=I$
4040 GOTO 1230
4045 REM ************************************
4050 REM ------ NO SIMILAR MEANING BETWEEN ---------
4055 REM ------ 2 SCALES OF SIMILAR RATINGS --------
4057 REM -----SEE IF PERSON WANTS A SUMMARY*********
4060 IF [illegible] GOTO 1195
4062 IF [illegible] GOTO 4065
4065 [illegible]
4070 Q$='Would you like to be reminded of the information you'
4075 REWRITEFILE USING 52,FL5,Q$
4080 Q$='have put in so far?'
4085 REWRITEFILE USING 4090,FL5,Q$
4090 FORM POS129,C19,POS150
4110 READFILE USING 4115,FL5,Q$
4115 FORM POS150,C10
4125 IF Q$≠'YES' GOTO 4140
4127 GOSUB 8000
4135 GOTO 4990
4140 IF Q$≠'NO' GOTO 4145
4141 GOSUB 8000
4142 GOTO 4165
4165 REWRITEFILE USING 365,FL5,Z$
```

```
4150 REWRITEFILE USING 4155,FL5,Y$
4155 FORM POS129,C63
4160 GOTO 4080
4165 REM *****DIRECT ENTRY OF DIMENSION POLES***********
4170 Q$='Can you think of any other way that the'
4175 REWRITEFILE USING 4180,FL5,Q$,P$
4180 FORM POS1,C39,X,C25
4185 REWRITEFILE USING 4190,FL5,'differ from each other ?'
4190 FORM POS65,C24,POS90
4230 READFILE USING 4235,FL5,Q$
4235 FORM POS90,C10
4240 REWRITEFILE USING 64,FL5,Y$
4245 IF Q$='YES' GOTO 4275
4250 IF Q$='NO' GOTO 4500
4255 REWRITEFILE USING 365,FL5,Z$
4260 REWRITEFILE USING 52,FL5,Y$
4270 GOTO 4185
4275 J=J+1
4320 IF J>S1 GOTO 1210
4325 Q$='In not more than three words each time, please describe
4330 REWRITEFILE USING 54,FL5,Q$
4335 Q$='how some of them differ from the others:'
4340 REWRITEFILE USING 55,FL5,Q$
4355 REWRITEFILE USING 4360,FL5,'Some are :'
4360 FORM POS385,C10,POS397
4365 READFILE USING 4370,FL5,B$(J)
4370 FORM POS397,C52
4395 REWRITEFILE USING 4400,FL5,'Wheras others are :'
4400 FORM POS449,C19,POS469
4405 READFILE USING 4410,FL5,C$(J)
4410 FORM POS469,C44
4415 REWRITEFILE USING 4420,FL5,'Are you reasonably happy with'
4420 FORM POS577,C30,POS607
4425 REWRITESEILE USING 4430,FL5,'this description ?'
4430 FORM POS607,C20,POS627
4435 READFILE USING 4440,FL5,Q$
4440 FORM POS627,C
4450 IF Q$='YES' GOTO 4455
4451 GOSUB 2000
4452 GOTO 1225
4455 IF Q$='NO' GOTO 4480
4460 GOSUB 5000
4475 GOTO 41[illegible]
4480 REWRITEFILE USING 365,FL5,Z$
4485 REWRITEFILE USING 59,FL5,Y$
4495 GOTO 4415
4500 REM ****************************************
4505 REM ** NO ADDITIONAL WAY OF RATING SIM. AND DIFF. **
4515 GOSUB 5[illegible]00
4520 IF N2<3 GOTO 1195
4530 REWRITEFILE USING 4535,FL5,'Do you think you have now'
4535 FORM POS65,C26,POS91
4540 REWRITEFICE USING 4545,FL5,'worked through enough of the'
4545 FORM POS91,C30
4550 REWRITEFILE USING 4555,FL5,'main ways of describing'
4555 FORM POS129,C24,POS153
4560 REWRITEFILE USING 4565,FL5,'similarities and differences'
4565 FORM POS153,C30
4570 REWRITEFILE USING 4575,FL5,'between the',P$,'which you'
```

```
4575 FORM POS193,C12,C30,C
4580 REWRITEFILE USING 4585,FL5,'think are important ?'
4585 FORM POS257,C23,POS280
4590 READFILE USING 4595,FL5,Q$
4595 FORM POS280,C
4605 IF Q$='YES' GOTO 4635
4610 IF Q$≠'NO' GOTO 4615
4611 GOSUB 8000
4612 GOTO 1195
4615 REWRITEFILE USING 365,FL5,Z$
4620 REWRITEFILE USING 4625,FL5,Y$
4625 FORM POS257,C63
4630 GOTO 4580
4635 REM ************************************************
4640 REWRITEFILE USING 4645,FL5,'Do you want to investigate'
4645 FORM POS385,C27,POS412
4650 REWRITEFILE USING 4655,FL5,'your preferences among the'
4655 FORM POS412,C30
4660 REWRITEFILE USING 4665,FL5,P$,'on the basis of the'
4665 FORM POS449,C30,C20,POS499
4670 REWRITEFILE USING 4675,FL5,'similarities'
4675 FORM POS499,C
4680 REWRITEFILE USING 4685,FL5,'and differences you have'
4685 FORM POS513,C28,POS541
4690 REWRITEFILE USING 4695,FL5,'described so far ?'
4695 FORM POS541,C20,POS561
4700 READFILE USING 4705,FL5,Q$
4705 FORM POS561,C
4715 IF Q$='YES' GOTO 4855
4720 IF Q$='NO' GOTO 4745
4725 REWRITEFILE USING 365,FL5,Z$
4730 REWRITEFILE USING 4735,FL5,Y$
4735 FORM POS513,C63
4740 GOTO 4680
4745 REM ************************************************
4746 REWRITEFILE USING 61,FL5,'O.K. that is all for now.'
4747 PAUSE
4748 GOSUB 8000
4750 REWRITEFILE USING 4755,FL5 'Do you want to save all this'
4755 FORM POS641,C30,POS671
4760 REWRITEFILE USING 4765,FL5,'information ?'
4765 FORM POS671,C15,POS686
4770 READFILE USING 4775,FL5,Q$
4775 FORM POS686,C
4785 IF [illegible] GOTO 4800
4787 [illegible]
4790 GOSUB [illegible]
4795 GOTO [illegible]
4800 IF Q$='NO' GOTO 4830
4805 REWRITEFILE USING 365,FL5,Z$
4810 REWRITEFILE USING 4815,FL5,Y$
4815 FORM POS641,C63
4820 GOTO 4750
4825 PRINT 'DATA NOW FILED IN FILE NUMBER';32
4830 PRINT 'MAUD HAS NOW FINISHED.'
4845 STOP
4850 REM ************************************************
4855 WRITEFILE USING 64,FL5,E$
4860 READFILE USING 69,FL5,O$
```

```
4865 GOSUB 8000
4880 IF K2=0 GOTO 4970
4885 REWRITEFILE USING 4890,FL5,'Do you want to complete your'
4890 FORM POS65,C30,POS95
4895 REWRITEFILE USING 4900,FL5,'previous (incomplete)'
4900 FORM POS129,C22,POS151
4905 REWRITEFILE USING 4910,FL5,'investigations of preferences'
4910 FORM POS151,C30
4915 REWRITEFILE USING 4920,FL5,'(rather than start again) ?'
4920 FORM POS193,C29,POS222
4925 READFILE USING 4930,FL5,Q$
4930 FORM POS222,C30
4940 IF Q$='YES' GOTO 4980
4945 IF Q$='NO' GOTO 4970
4950 REWRITEFILE USING 365,FL5,Z$
4955 REWRITEFILE USING 54,FL5,Y$
4965 GOTO 4915
4970 REM ******************************************
4975 K2=0
4985 CHAIN 'E90',3
4990 CHAIN 'E80',2
4995 REM ******************************************
5000 WRITEFILE USING 5005,FL5,'Press  EXECUTE  to proceed'
5005 FORM POS449,C30,POS479
5010 READFILE USING 5015,FL5,Q$
5015 FORM POS479,C
5020 FOR I=1 TO 16
5025 PRINT
5030 NEXT I
5115 IF H(J)=0 GOTO 5125
5120 GOTO 4165
5125 J$=CHR(J)
5150 REWRITEFILE USING 5155,FL5,'Do you want to rerate',P$
5155 FORM POS65,C21,X,C30
5160 REWRITEFILE USING 5165,FL5,'on dimension  (',J$,')'
5165 FORM POS129,C15,C2,C1,POS150
5170 READFILE USING 5175,FL5,Q$
5175 FO[illegible] C30
5180 RE[illegible] USING 2360,FL5,Y$
5185 IF [illegible] GOTO 4165
5190 IF [illegible] GOTO 1835
5195 REWRITEFILE USING 365,FL5,Z$
5200 REWRITEFILE USING 5205,FL5,Y$
5205 FORM POS129,C63
[illegible]
5215 REM ---------******* CHAINING FROM FTLOG ***************
5220 WRITEFILE USING 5225,FL5,'None'
5225 FO[illegible],C5
5230 D$=E$
5295 GOTO 12[illegible]
5300 REM ************ CHAINING FROM FTLOG **************
5305 WRITEFILE USING 5225,FL5,'None'
5370 GOTO 220
5375 REM *********************************
5380 REM ********** SUBROUTINE ***********
5385 REM ##### RANDOM TRIAD GENERATOR #####
5390 G(1)=INT(N1*RND+1)
5395 G(2)=INT(N1*RND+1)
5400 IF G(1)=G(2) GOTO 5395
```

```
5405 G(3)=INT(N1*RND+1)
5410 IF G(1)=G(3) GOTO 5405
5415 IF G(2)=G(3) GOTO 5405
5420 RETURN
5425 REM ***** SUBROUTINE ************
5426 REM **** FILE  DATA ***********
5427 GOSUB 8000
5429 PRINT 'FILE NUMBER FOR DATA?';
5430 INPUT S2
5431 S3=S2+1
5432 S4=S3+1
5433 S5=S4+1
5435 WRITEFILE FLS,'F'
5437 OPEN FL1,'E80',S2,'F1',OUT,IOERR 5990
5440 PUT FL1,T$,S$,P$,J,N1,N2,K2
5445 CLOSE FL1
5450 OPEN FL2,'E80',S3,'F2',OUT,IOERR 5990
5455 MAT PUT FL2,A$,B$,C$
5460 CLOSE FL2
5465 OPEN FL3,'E80',S4,'F3',OUT,IOERR 5990
5470 MAT PUT FL3,H,S,P,W,U,L,Y
5475 CLOSE FL3
5480 OPEN FILE FL4,'E80',S5,'F4',OUT,RECL=3200,SEQ,IOERR 5990
5481 WRITEFILE FL4,MATZ
5482 WRITEFILE FL4,MATX
5483 WRITEFILE FL4,MATR
5490 CLOSE FILE FL4
5500 RETURN
5505 REM ********************************
5990 PRINT 'BAD FILE'
5995 PRINT 'REMAKE FILESPACE AND TYPE "GO 4790"'
5999 STOP
6000 REM ********* READ DATA FROM FILE**********
6002 PRINT 'FILE NUMBER FOR DATA?';
6003 INPUT S2
6004 S3=S2+1
6005 S4=S3+1
6006 S5=S4+1
6007 GOSUB [illegible]
6010 OPEN FL1,'E80',S2,'F1',IN,IOERR 6990
6015 GET FL1,T$,S$,P$,J,N1,N2,K2
6020 CLOSE FL1
6025 OPEN FL2,'E80',S3,'F2',IN,IOERR 6990
6030 MAT GET FL2,A$,B$,C$
6035 CLOSE FL2
6040 OPEN FL3,'E80',S4,'F3',IN,IOERR 6990
6045 MAT GET FL3,H,S,P,W,U,L,Y
6050 CLOSE FL3
6055 OPEN FILE FL4,'E80',S5,'F4',IN,IOERR 6990
6056 READFILE FL4,MATZ
6057 READFILE FL4,MATX
6058 READFILE FL4,MATR
6060 CLOSE FILE FL4
6070 PRINT 'DO YOU WANT A SUMMARY OF THE MATERIAL ON FILE?';
6080 INPUT Q$
6090 IF Q$='YES' GOTO 6150
6100 IF Q$='NO' GOTO [illegible]
6120 PRINT Z$
6130 PRINT
```

```
6140 GOTO 6070
6150 CHAIN 'E80',2
6990 PRINT 'BAD FILE; : , ABANDONED'
6995 STOP
7680 REM *****SUBROUTINE*****DISPLAY ALTERNATIVES
7690 FOR I=1 TO N1
7692 I$=CHR(I)
7695 P=P+64
7700 REWRITEFILE USING 7705,FL5,'( ',I$,' ) ',A$(I)
7705 FORM POSP,C2,C1,C3,C30
7710 NEXT I
7715 RETURN
7900 REM ******SUBROUTINE*****CHECK NUMERIC INPUT IS IN RANGE
7910 READFILE USING 7915,FL5,C$
7915 FORM POSP1,C
7920 I=NUM(C$)
7925 IF I>N1 GOTO 7935
7930 IF I>0 GOTO 7970
7935 P=P+64
7937 I$=CHR(N1)
7940 Q$='Please type a number between 1 and '
7945 REWRITEFILE USING 7950,FL5,Q$,I$
7950 FORM POSP,C36,C1,POSP1
7955 READFILE USING 7960,FL5,C$
7960 FORM POSP1,C
7965 GOTO 7920
7970 RETURN
8000 REM *****SUBROUTINE******CLEAR SCREEN******
8005 FOR I=1 TO 16
8010 PRINT
8020 NEXT I
8025 RETURN
8270 REM ******SUBROUTINE*****CHANGE RATINGS***********
8275 REWRITEFILE USING 51,FL5,'You can'
8280 Q$='     ( 1 ) Cancel this scale (and all ratings on it)'
8285 REWRITEFILE USING 53,FL5,Q$
[illegible] Q$='     ( 2 ) Change your ratings on this scale'
[illegible] REWRITEFILE USING 54,FL5,Q$
[illegible] IF [illegible] GOTO 8310
[illegible] Q$='     ( 3 ) Change the position of the ideal value'
[illegible] REWRITEFILE USING 55,FL5,Q$
[illegible] Q$='[illegible] would you like to do?'
[illegible] REWRITEFILE USING 57,FL5,Q$
[illegible] IF [illegible] GOTO 8330
[illegible] Q$='Please type in 1, 2, or 3 :'
[illegible] GOTO [illegible]
[illegible] Q$='     Please type in 1, or 2 :'
8335 REWRITEFILE USING 8340,FL5,Q$
8340 FORM POS513,C30,POS544
8345 READFILE USING 8350,FL5,Q$
8350 FORM POS544,C10
8355 IF Q$='1' GOTO 8390
8360 IF Q$>'3' GOTO 8390
8365 IF Q$='2'&P1=0 GOTO 8390
8367 GOSUB 8000
8370 IF Q$<>'1' GOTO 8380
8375 H(J)=-299
8377 GOTO 1195
8380 IF Q$='2' GOTO 1972
```

```
8385 GOTO 2540
8390 REWRITEFILE USING 59,FL5,Y$
8392 IF P1 0 GOTO 8400
8395 Q$='      u must choose one of 1, 2, or 3'
8397 GOTO 84
8400 Q$='      You must choose either 1 or 2 '
8405 REWRITE  LE USING 61,FL5,Q$
8410 GOTO 8320
8860 REM ******SUBROUTINE******DISPLAY J-SCALE*******
8885 REWRITEFILE USING 68,FL5,B$(J)
8900 FOR I=1 TO 9
8905 P=P+64
8910 I$=CHR(I)
8915 IF I>5 GOTO 8930
8920 REWRITEFILE USING 8935,FL5, 5 to '
8925 GOTO 8940
8930 REWRITEFILE USING 8935,FL5,I$
8935 FORM POSP,C30
8940 NEXT I
8945 P=P+64
8950 REWRITEFILE USING 8935,FL5,C$(J)
8955 RETURN
9999 STOP
```

```
0010 REM
0020 REM ### EOG ### CHAINING WITH COMMON USE AREA
0030 REM
0050 USE T$60,S$30,P$30
0060 USE C,J,N1,N2,K2,S1
0070 USE A$60(20),B$60(20),C$60(20)
0080 USE Z(20,20),X(20,20),R(20,20)
0090 USE H(20),S(20),B(20),W(20),U(20),L(20),Y(20)
0100 DIM Q$60,X$60(3),Y$60,Z$60
0110 DIM F(20),G(20)
0140 REM ###
0150 REM-----------------
0160 Y$=''
0170 Z$='Please type   YES  or  no'
0180 X$='  '
0190 REM ####
0210 PRINT FLP
0220 PRINT FLP,'*****  SUMMARY FOR  ';T$;'  *****'
0230 PRINT FLP
0240 PRINT FLP,X$;P$;' UNDER CONSIDERATION : '
0260 IF N1<1 GOTO 2120
0280 FOR I=1 TO N1
0300 I$=CHR(I)
0310 PRINT FLP,X$;'(';I$;')  ';A$(I)
0320 IF U(I)<-.5 GOTO
0330 PRINT FLP,'PREFER[illegible]    VALUE =';
0340 PRINT USING 350,F    (I)
0350 :##.###
0360 PRINT FLP
0370 PRINT FLP
0380 NEXT I
0390 PRINT FLP
0400 PRINT FLP,X$;'ATTRIBUTE DIMEN[illegible]ONS U[illegible]D'
0410 PRINT FLP
0420 IF [illegible] GOTO 2100
0430 FOR [illegible]=1 TO J
0450 [illegible](M)
0460 PRINT FLP,X$;'(';M$;')    ';B$(M);' (1)......TO..........'
0470 PRINT FLP,;C$(M);' (9)'
0480 IF [illegible] -100 GOTO 620
0490 [illegible] FLP,X$;'    IDEAL VALUE =';B(M)
[illegible] GOTO 650
[illegible] =2 GOTO 570
[illegible] =90 GOTO 590
[illegible]
0550 [illegible] FLP,'(DIMENSION CANCELLED BECAUSE OF SIMILARITY';
0560 [illegible] FLP;'WITH DIMENSION',H1;')'
0560 [illegible]
0570 PRINT [illegible] '(RATINGS INCOMPLETE: DIMENSION CANCELLED)'
0580 GOTO [illegible]
0590 PRINT FLP,'(NO VARIANCE IN PREFERENCE ORDERING ON THIS'
0600 PRINT FLP,'DIMENSION)'
0610 GOTO 650
0620 PRINT FLP,'(RATINGS CA[illegible]LLED ON THIS SCALE)'
0630 IF H(M)=-200 GOTO 650
0640 PRINT FLP;'(AFTER TRYING TO ELICIT IDEAL PO[illegible]T)'
0650 IF H(M) 1.5 GOTO 730
0660 IF H(M) 2.5 GOTO 710
0670 PRINT FLP,X$;'    RELATIVE IMPORTANCE =';
```

```
0680 PRINT USING 350,FLP,U(M)
0690 PRINT FLP
0700 GOTO 730
0710 PRINT FLP,'(INVESTIGATION OF RELATIVE IMPORTANCE';
0720 PRINT FLP,'INCOMPLETE)'
0730 PRINT FLP
0740 NEXT M
0750 PRINT FLP
0760 PRINT FLP
0770 PRINT FLP;'RATINGS OF ';P$;  ON ATTRIBUTE DIMENSIONS'
0780 PRINT FLP
0810 PRINT FLP;STR(S$;1,9);TAB(10);
0820 FOR I=1 TO N1
0830 :,####
0840 PRINT USING 830,FLP;I;
0850 NEXT I
0860 PRINT FLP
0870 PRINT FLP;'ATTRIBUTE'
0880 PRINT FLP;'DIMENSION'
0890 FOR M=1 TO 3
0900 M$=CHR(M)
0910 PRINT FLP,'(';M$;')
0920 FOR I=1 TO N1
0930 :##.##
0940 PRINT USING 930,FLP;Z(I;M);
0950 NEXT I
0960 PRINT FLP
0970 IF H(M)=-90 GOTO 1110
0980 IF H(M)=0 GOTO 1090
0990 PRINT FLP,'      VALUE';
1000 FOR I=1 TO N1
1010 PRINT USING 930,FLP;X(I;M);
1020 NEXT I
1030 PRINT FLP
1040 IF [illegible] 0 GOTO 1150
1050 M$=[illegible]
1060 PRINT FLP;'(RATINGS CANCELLED BECAUSE OF SIMILARITY TO';
1070 PRINT FLP;M$;')'
[illegible]
[illegible] PRINT [illegible] (RATINGS INCOMPLETE: CANCELLED)'
[illegible]
[illegible] IF [illegible] -100 GOTO 1140
[illegible] '(NO VARIANCE IN PREFERENCE ORDERING'
[illegible]
[illegible] FLP,'(RATINGS CANCELLED)'
[illegible]
[illegible]
1170 PRINT FLP
1180 [illegible]
1200 PRINT FLP
1210 PRINT FLP
1220 REM [illegible] SORT ITEMS IN ORDER OF PREFERENCE
1230 [illegible]
1240 FOR I=1 TO [illegible]
1250 IF [illegible] GOTO 1290
1260 [illegible]
1270 [illegible]
1280 [illegible]
1290 [illegible]
```

```
1300 IF I1<2 GOTO 1590
1310 PRINT FLP
1320 PRINT FLP,'CURRENT PREFERENCE ORDERING (FROM BEST TO
1330 PRINT FLP,'WORST;PREFERENCE VALUES ARE GIVEN IN BRACKETS)'
1340 I2=I1-1
1350 FOR I3=1 TO I2
1360 I4=I1-I3
1370 FOR I5=1 TO I4
1380 I6=I5+1
1390 IF F(I5)>F(I6) GOTO 1460
1400 L3=F(I6)
1410 L4=G(I6)
1420 F(I6)=F(I5)
1430 G(I6)=G(I5)
1440 F(I5)=L3
1450 G(I5)=L4
1460 NEXT I5
1470 NEXT I3
1480 PRINT FLP
1490 PRINT FLP,'BEST'
1500 FOR I3=1 TO I1
1510 L3=G(I3)
1520 PRINT FLP,A$(L3);
1540 :( #.## )
1550 PRINT USING 1540,FLP,F(I3)
1560 NEXT I3
1570 PRINT FLP,'WORST'
1580 PRINT FLP
1590 OPEN FILE FLS,'002',ALL
1600 WRITEFILE USING 1610,FLS,'Press EXECUTE to proceed'
1610 FORM POS449,C30,POS479
1620 READFILE USING 1630,FLS,Q$
1630 FORM POS479,C
1640 FOR I=1 TO 18
1650 [illegible]
1660 NEXT I
[illegible]TEFILE USING 1[illegible],FLS,'Do you want to see the'
[illegible]F[illegible],C23,POS[illegible]
[illegible]ITEFILE USING 1700,FLS,'correlation between your'
[illegible],C5
[illegible]TEFILE USING 1720,FLS,'preference ordering and'
[illegible]129,C23,POS152
[illegible]ILE USING 1740,FLS,'individual attribute prefer[illegible]ion
[illegible]153,C35,POS188
[illegible] USING 1760,FLS,Q$
[illegible]188,C16
[illegible]='Y' GOTO 18[illegible]
1780 IF Q$='N' GOTO 20[illegible]
[illegible]TEFILE USING 1[illegible],FLS,Y$
1800 FORM POS[illegible]23,C6
1810 REWRITEFILE USING 1[illegible],FLS,Y$
1820 FORM POS129,C63
1830 GOTO 1710
1840 PRINT FLP
1850 PRINT FLP,'ATTRIB[illegible]'
1860 PRINT FLP,'PREF[illegible] [illegible]ENT[illegible]'
1870 FOR M 2 T[illegible] J
1880 IF M[illegible] GOTO 1[illegible]
1890 M$ [illegible]
```


90

```
1900 PRINT FLP,'(';M$;')';
1910 FOR I=1 TO M-1
1920 IF H(I)<.5 GOTO 1940
1930 PRINT USING 930,FLP,R(I,M);
1940 NEXT I
1950 PRINT FLP
1960 NEXT M
1970 PRINT FLP,'    ';
1980 FOR I=1 TO J-1
1990 IF H(I)<.5 GOTO 2020
2000 :  (##)
2010 PRINT USING 2000,FLP,I;
2020 NEXT I
2030 PRINT FLP
2040 PRINT FLP
2050 PRINT FLP,' ###  END OF SUMMARY   ###'
2060 PRINT FLP
2100 C=1
2110 CHAIN 'E80',1
2120 C=2
2130 CHAIN 'E80',1
2140 C=3
2150 CHAIN 'E80',1
2160 STOP
```

```
0010 REM
0020 REM ### PREF ### CHAINING WITH COMMON USE AREA
0030 REM
0040 USE T$30,S$30,P$30
0050 USE C,J,N1,N2,L2,S1
0060 USE A$60(20),B$60(20),C$60(20)
0070 USE Z(20,20),X(20,20),R(20,20)
0080 USE H(20),S(20),D(20),W(20),U(20),L(20),Y(20)
0090 DIM Q$60,X$60,Y$60,Z$60,M$192,N$192,V$192,R$192,U$95
0100 DIM N(20,20),T(20),V(20),D(20),Q(20,20)
0110 OPEN FILE FL5,'002',ALL
0150 REM *** ------------------------------ ***
0290 Y$='
0300 Z$='Please type  YES  or  NO'
0310 WRITEFILE USING 320,FL5,'Press  EXECUTE to proceed'
0320 FORM POS449,C30,POS479
0330 READFILE USING 360,FL5,D$
0340 REWRITEFILE USING 350,FL5,Y$
0350 FORM POS449,C63
0360 FORM POS479,C39
0370 REWRITEFILE USING 38[illegible],FL5,'Would you like to assume that'
0380 FORM POS65,C30,POS9[illegible]
0390 REWRITEFILE USING 400,FL5,'the various ways you have used'
0400 FORM POS95,C30
0410 REWRITEFILE USING 420,FL5,'to describe the',P$
0420 FORM POS129,C15,X,C32
0430 REWRITEFILE USING 440,FL5,'are equally important in'
0440 FORM POS193,C25,POS218
0450 REWRITEFILE USING 460,FL5,'determining your preference ?'
0460 FORM POS218,C32,POS250
0470 READFILE USING 480,FL5,Q$
0480 FORM POS250,C6
0490 REWRITEFILE USING 500,FL5,Y$
0500 FORM POS2[illegible],C63
0510 [illegible]
0520 [illegible]
0530 [illegible] 540,FL5,Z$
0540 [illegible]
0550 [illegible]ITEFILE USING 560,FL5,Y$
0560 [illegible]193,C63
[illegible]
[illegible] ------------------------------ ***
[illegible]
[illegible] TO J
[illegible] GOTO 23[illegible]
0620 [illegible]
0630 [illegible]
0640 [illegible]
0650 [illegible] ------------------------------ ***
0660 [illegible]
0670 FOR I=1 TO S1
0680 U(I)=[illegible]
0690 L(I)=1
0700 N(1,I)=I
0710 IF [illegible] GOTO 750
0720 [illegible](I)=I
07[illegible] [illegible]
0[illegible] [illegible]
0[illegible] [illegible]
```

```
0737 NEXT I
0740 IF K2>.5 GOTO 780
0750 FOR I=1 TO S1
0760 W(I)=1
0770 NEXT I
0780 FOR M=1 TO S1
0790 FOR I=1 TO N1
0800 IF X(I,M)>.99 GOTO 820
0810 NEXT I
0820 T(M)=1
0830 T1=Z(I,M)
0840 FOR I [illegible] TO N1
0850 IF X(I,M)<.01 GOTO 370
0860 NEXT I
0870 V(M)-I
0880 D(M)=Z(I,M)-T1
0890 NEXT M
0900 REM *** ------------------------------ ***
0910 REM *** FIND NEXT BRCT ***
0920 IF N2<2 GOTO 2070
0930 REM ************************************
0940 K=K+1
0950 R2=-2
0960 FOR M=2 TO J
0970 IF H(M)<1.5 GOTO 1080
0980 IF H(M)>2.5 GOTO 1080
0990 FOR I=1 TO M-1
1000 IF H(I)<.5 GOTO 1070
1010 IF H(I)>2.5 GOTO 1070
1020 R1=Q(I,M)
1030 IF R1<R2 GOTO 1070
1040 M1=M
1050 M2=I
1060 R2=R1
1070 NEXT I
1080 NEXT M
1090 H(M[illegible]
1100 L1=L[illegible]
1110 L2=L[illegible]
1120 IF [illegible] 2080
[illegible] P2=[illegible]
[illegible] P3=[illegible]
[illegible] P4=[illegible]
[illegible]
[illegible] TO S1
[illegible]
[illegible] GOTO 1165
1147 [illegible]
[illegible] W1=[illegible]
1155 E1=[illegible]
1160 G1=[illegible]
1165 NEXT I
1170 W[illegible]
1175 FOR I=1 TO L2
[illegible]
[illegible] GOTO [illegible]
[illegible]
[illegible]
1195 [illegible]
```

```
1200 G2=V(F2)
120[illegible] NEXT I
1[illegible] REM PRINT OPTIONS ********************************
1211 M$=Y$
1212 N$=Y$
1213 V$=Y$
1214 R$=Y$
1215 U$=Y$
1220 STR(M$,1,33)='Imagine you had to choose between'
1235 STR(M$,44,8)='OPTION B'
1237 STR(M$,65,3)='and'
1245 STR(M$,95,3)='! A'
1250 STR(M$,99,2)=CHR(P2)
1255 STR(M$,101,19)='o/o chance to get a'
1265 STR(M$,139,8)='OPTION A'
1275 STR(M$,159,1)='!'
1280 STR(M$,161,26)=STR(S$,1,26)
1285 STR(M$,188,7)='that is'
1290 STR(N$,31,5)='! as '
1295 IF D(F1)<0 GOTO 1315
1300 STR(N$,36,29)=STR(B$(F1),1,29)
1310 GOTO 1320
1315 STR(N$,36,29)=STR(C$(F1),1,29)
1320 STR(N$,65,24)='A 100o/o chance to get a'
1330 STR(N$,95,5)='! as '
1335 STR(N$,1[illegible],29)=STR(A$(E1),1,29)
1340 STR(N$,129,[illegible] STR(S$,1,23)
1341 P5=LEN(S$)
1342 IF P5<22 GOTO 1344
1343 P5=22
1344 P5=P5+130
1345 STR(N$,P5,7)='that is'
1350 STR(N$,159,8)='! and as'
13[illegible] IF [illegible]<0 GOTO 1380
13[illegible] ST[illegible]168,25)=STR(B$(F2),1,2[illegible])
1375 [illegible] 1382
1380 ST[illegible]168,25)=STR(C$(F2),1,25)
1382 ST[illegible],1,3)='as '
1385 I[illegible]0 GOTO 1405
1390 ST[illegible]27)=STR(B$(F1),1,27)
14[illegible]
14[illegible] ST[illegible]27)=STR(C$(F1),1,27)
14[illegible] 31,5)='! as '
14[illegible] 36,29)=STR(A$(E2),1,29)
1[illegible] 65,3)='as '
1[illegible] 68,27)=STR(A$(E1),1,27)
14[illegible] P5,6)='!AND a'
1435 [illegible],102,2)=CHR(P3)
1440 S[illegible],104,25)='o/o chance to get [illegible]ead'
1450 STR(V$,129,16)='but that is also'
1460 STR(V$,159,3)='! a'
1465 STR(V$,163,23)=STR(S$,1,23)
1466 P5=LEN(S$)
1467 IF P5 2[illegible] GOTO 1469
1468 P5=2[illegible]
1469 P5=P5+160
1470 STR(V$,P5,7)='that is'
1475 STR(R$,1,3)='as '
1480 IF D(F2)<0 GOTO 1500
```

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1480 STR(R$,4,27)=STR(C$(F2),1,27)
1495 GOTO 1502
1500 STR(R$,4,27)=STR(B$(F2),1,27)
1502 STR(R$,31,5)='I as '
1505 IF D(F1)<0 GOTO 1525
1510 STR(R$,36,29)=STR(C$(F1),1,29)
1520 GOTO 1530
1525 STR(R$,36,29)=STR(B$(F1),1,29)
1530 STR(R$,65,3)='as '
1535 STR(R$,68,27)=STR(A$(G2),1,27)
1540 STR(R$,95,5)='I as '
1545 STR(R$,100,29)=STR(A$(G1),1,29)
1550 STR(R$,140,13)='....for sure'
1555 STR(R$,159,9)='I and as '
1560 IF D(F2)<1 GOTO 1580
1565 STR(R$,168,25)=STR(C$(F2),1,25)
1575 GOTO 1582
1580 STR(R$,168,25)=STR(B$(F2),1,25)
1582 STR(U$,31,5)='I as '
1585 STR(U$,36,29)=STR(A$(G2),1,29)
1595 STR(U$,65,31)='WHICH WOULD YOU PREFER: A OR B?'
1600 WRITEFILE USING 1601,FL5,M$,N$,V$,R$,U$
1601 FORM POS1,C,POS193,C,POS385,C,POS577,C,POS769,C,POS8[illegible]
1605 READFILE USING 1610,FL5,Q$
1610 FORM POS894,C1
1615 IF Q$='A' GOTO 1650
1620 IF Q$='B' GOTO 1770
1625 REWRITEFILE USING 1630,FL5,'PLEASE TYPE 'A' OR 'B''
1630 FORM POS871,C22,POS894
1635 READFILE USING 1640,FL5,Q$
1640 FORM POS894,C1
1645 GOTO 1615
1650 REM [illegible] PROBABILITY MIXTURE FOR OPTION ***************
1660 REWRITEFILE USING 1670,FL5,'ARE YOU SURE?'
1670 FORM POS871,C13,POS885
1680 READFILE USING 1690,FL5,[illegible]
1690 FORM POS885,C3
1700 IF [illegible]='YES' GOTO 2340
1710 IF [illegible] GOTO 1600
172[illegible] REWRITEFILE USING 1730,FL5,'TYPE YES IF SURE, NO IF NOT:'
1730 FORM [illegible],C28,POS899
1740 READFILE USING 1750,FL5,O$
[illegible] [illegible]894,C3
[illegible]
[illegible]
1775 [illegible]
178[illegible] [illegible]
179[illegible] IF [illegible] GOTO 1890
1800 STR([illegible],99,2)=CHR(E2)
1810 STR([illegible],102,2)=CHR(E3)
1820 WRITEFILE USING 1601,FL5,M$,N$,V$,R$,U$
1830 READFILE USING 1610,FL5,Q$
1840 IF Q$='B' GOTO 1770
1850 IF Q$='A' GOTO 18[illegible]
1860 REWRITEFILE USING 1630,FL5,'PLEASE TYPE 'A' OR [illegible]'
1870 READFILE USING 1640,FL5,Q$
1880 GOTO [illegible]
189[illegible] REWRITEFILE USING [illegible],FL5,'ARE YOU SURE'
1[illegible] READFILE USING 17[illegible],FL5,[illegible]
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```
1910 IF Q$='YES' GOTO 2340
1920 IF Q$='NO' GOTO 1960
1930 REWRITEFILE USING 1730;FL5;'TYPE YES IF SURE,"NO"IF NOT:'
1940 READFILE USING 1750;FL5;Q$
1950 GOTO 1910
1960 P2=P2+10
1965 P4=P3
1970 P3=P3-10
1975 IF P3<5 GOTO 2340
1980 STR(M$,99,2)=CHR(P2)
1990 STR(V$,102,2)=CHR(P3)
2000 WRITEFILE USING 1601;FL5,M$ [illegible] V$,R$,U$
2010 READFILE USING 1610;FL5 [illegible]
2020 IF Q$='B' GOTO 1770
2030 IF Q$='A' GOTO 1960
2040 REWRITEFILE USING 1630;F [illegible] SE TYPE "A" OR "B"'
2050 READFILE USING 1540,FL5,[illegible]
2060 GOTO 2020
2340 REM ****CORRECT P FOR RELATIVE WEIGHTS OF DELEGATE
2341 REM ****ITEMS WITHIN CLUSTERS COMPARED IN GAMBLE.
2342 P=(P3+P4)/200
2345 P=(P/W2)/(P/W2+(1-P)/W1)
2350 REM ****** UPDATE VALUEWISE IMPORTANCE WEIGHTS *****
2360 FOR I=1 TO L2
2370 I1=N(I,M2)
2380 W(I1)=W(I1)*P
2390 NEXT I
2400 P=1-P
2410 FOR I=1 TO L1
2420 I1=N(I,M1)
2430 W(I1)=W(I1)*P
2440 NEXT I
2480 REM ********** UPDATE CLUSTERS **********
2490 IF [illegible]-1 GOTO 2870
2500 F[illegible] I=1 TO L2
2510 I1=[illegible]
[illegible] N(I,[illegible])=N(I,M2)
2530 NE[illegible] I
[illegible]
[illegible] IF [illegible] 2650
[illegible] FOR [illegible] TO M1
[illegible] 5 GOTO 2680
[illegible] 2.5 GOTO 2700
[illegible] +1)
[illegible] +2)
[illegible] 0
[illegible] RETURN [illegible]
2630 [illegible] =F1
2640 [illegible]
2650 FOR [illegible]+1 TO [illegible]
2660 IF H([illegible]) 5 GOTO 2770
2670 IF H(M) 2.5 GOTO 2700
2680 S1 Q(M1,M)
2690 [illegible] Q(M2,M)
2700 [illegible] 2770
2710 [illegible] =R1
[illegible]
2750 GO[illegible] 930
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