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**A COMPUTER
PROGRAM FOR
EVALUATING
FORESTRY
OPPORTUNITIES
UNDER THREE
INVESTMENT
CRITERIA**

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INTRODUCTION

Researchers have provided forest managers and their consultants with several computer programs for analyzing investments in forestry (Hall 1962, Row 1963, Schweitzer et al. 1967, and Forster 1968). These computer programs have been modified in many cases to apply to situations not originally envisioned by the program developers (e.g., see Marty et al. 1966, Green and Alley 1967, Wikstrom and Alley 1968). These programs are particularly useful if the situation being analyzed fits one of the options available in the program and if the manager's investment criterion is handled by the program. However, most of the available computer programs are designed for specific problems and, therefore, are relatively complex to use.^{1/} In addition, only two investment criteria are available in the programs; namely, internal rate of return and present net worth.

This paper is meant to fulfill the following objectives. First, to announce the availability of the IVST computer program to prospective users. Second, to discuss the applicability of this program to managerial problems. Finally, to outline the operating characteristics of the program so analysts can use it.

PROBLEMS WHICH MAY BE ANALYZED WITH IVST

IVST, in common with all other investment analysis computer programs, is designed to help the decisionmaker decide whether or not to pursue certain productive activities or alternatives. There are many types of investment decisions, including: (1) whether a certain kind of productive activity should be pursued at all, (2) the intensity at which a productive enterprise should be operated, (3) timing of the productive activity in relation to other activities, (4) sequence of the productive activity in relation to other activities, (5) the location at which the productive activity takes place, and (6) the best way to accomplish the productive activity--i.e., technology. Depending upon the way the alternatives are formulated, any decision may be included in an IVST analysis.

The type of decision to be analyzed dictates the kinds of data which are required. Here it is presumed that data will be expressed in economic units, e.g., dollars. Data will consist, therefore, of costs and returns tagged with a time dimension--date of occurrence. Realistically, the costs and returns must be regarded as managerial expectations, since an investment analysis of historical occurrences provides few guidelines to the future.

However, data alone are not sufficient to guide managers in their decision-making function. Also required is a decision rule or criterion, which simply stated is the manager's systematic way of evaluating how well alternative strategies provide for fulfilling the firm's goals.

Now, whereas the type of investment is completely open when IVST is used, the choice of criterion is not. Three alternative investment criteria are available in IVST: internal rate of return, present net worth, and benefit-cost

^{1/} The rate-of-return computer programs devised by Hall (1962) and Forster (1968) are exceptions, since they are general and presume no particular problem context.

ratio.^{2/} It is the job of the manager to choose the criterion which will best provide for fulfillment of the firm's goals. If one of the three criteria available in IVST will fill this bill, then this computer program will be useful to the manager. On the other hand, if the manager selects an investment criterion that is not available in IVST, then the program will not be useful and, indeed, its use would be harmful, since misallocated resources would result.

IVST is a generalized computer program in that no particular problem context is presumed by its structure and output formats. The program is simple to use in that input requirements are minimal for the types of problems which may be analyzed. It is assumed that all preliminary data preparation is handled externally. Input data consist of a time-tagged stream of costs and returns and certain identifying information. A data preparation computer program will be required if data are in the form of quantities and prices. Large problems may be analyzed since data storage requirements are low per alternative analyzed. Finally, as pointed out above, IVST permits the analyst to select for examination one or more of three optional investment criteria: present net worth, internal rate of return, and the benefit-cost ratio. In addition, the structure of IVST is such as to permit other criteria subroutines to be added if desired by the analyst.

IVST was derived from two computer programs developed to analyze data for the Douglas-fir Supply Study, a cooperative study by the Pacific Northwest Region, Forest Service, and this Station. One of the computer programs was based on the internal rate-of-return criterion, the other on the present net worth and benefit-cost ratio criteria. These computer programs were modified to become options within IVST.

STRUCTURE OF IVST

IVST consists of a main program and two subroutines. The main program reads all data and provides for the printing of the first report, which consists of the input data. Subroutine BCA calculates the benefit-cost ratio and present net worth for the range of interest rates selected by the user. Subroutine IROR calculates the internal rate of return.^{3/} All results of the analyses are printed under control of the subroutines. Either BCA and/or IROR may be selected for any problem by the analyst.

Both BCA and IROR are closed or linked subroutines, i.e., a subroutine not stored in the path of the main routine, IVST. A closed subroutine is entered by a jump operation in the main routine and return to the main routine is provided at the end of the operation. Because of this configuration, it is possible to

^{2/} The reader interested in the theoretical aspects of these economic criteria should consult Eckstein (1958, pp. 70-79) on the benefit-cost ratio, and Hirshleifer (1958, pp. 329-352) on the internal rate of return and present net worth criteria. A comparison of management guides developed by application of these criteria to a forestry problem may be found in Webster (1965).

^{3/} Development of IROR began with a major modification of Row's rate-of-return program (Row 1963). The author wishes to acknowledge the programming assistance of Edgel E. Skinner of the Station's statistical and data processing services staff in this initial effort.

make use of the subroutines independently of the main routine. That is, the prospective user may design his own main routine and simply call either BCA and/or IROR when needed. It may be desirable to do this when input data are not in proper form for the present main routine. Prospective users are urged to consult a computer programmer if the coding of a new main routine appears necessary.

If the user wishes output for all three criteria options, then a total of four reports will be printed. As noted above, the first report consists of the input data. In the second report, the benefit-cost ratio and present net worth for every interest rate within the selected range will be listed for each alternative. The third report consists of certain messages generated within the IROR subroutine that will assist the analyst in interpreting results of the internal rate-of-return analysis. Finally, the fourth report lists present net worth for each interest rate within the selected range for each alternative until the internal rate of return is found. The internal rate of return is listed as the last interest rate for each alternative. After the last report is printed, control is switched back from the subroutines to the main routine and an end-of-problem card is read. At that time, the user can either terminate the program or solve another problem.

The Main Program IVST

Function

The function of the main program is to read a stream of periodic annual costs, a stream of periodic annual returns, and associated data; prepare a report of the input data; generate annual costs and annual returns if data are for a period other than 1 year; and call in the criteria subroutines desired by the user. IVST is designed to accept periodic annual data for whatever period length the user desires. However, the same length period must apply to each cost and return entered for that particular problem. Of course, if period length differs from one alternative to another, each alternative may be run as a separate problem. If period length varies within an alternative, however, it is mandatory that period length be set at 1 year and that annual data be read.

The advantages of having the capability of reading periodic annual costs and returns, as opposed to annual inputs, include savings of time, card costs, keypunching costs, the minimization of input error, and convenience.

IVST permits initial costs and returns to be read when a period length of 1 year is designated. Initial costs and returns are those costs and returns that occur in year zero of the investment series.

IVST Inputs

There are 17 specific types of inputs to the IVST program. Formats of input cards are shown in table 1 of the Appendix. The inputs are:

1. Alphanumeric study identification.
2. Beginning interest rate of the range to be examined, decimal.
3. Final or ending interest rate of the range to be examined, decimal.

4. Increment in interest rate, decimal.
5. Number of alternatives in problem.
6. Indicator of an initial cost or return (i.e., a cost or return occurring in year 0). If initial costs and returns are used, then period length must be 1 year (i.e., annual data must be read).
7. Alphanumeric identification of alternatives.
8. Problem number.
9. Series type indicator (either terminable or perpetual).
10. Investment criterion indicator (either internal rate of return or benefit-cost ratio and present net worth, or all three).
11. Length of period over which periodic costs and returns apply, years. Annual data may be read by setting period length equal to 1.
12. Maximum number of years in any alternative, i.e., length of longest investment series of any alternative in the problem.
13. Number of years in each alternative.
14. Alphanumeric problem identification.
15. Periodic annual costs for each alternative, dollars.
16. Periodic annual returns for each alternative, dollars.
17. End of problem indicator.

IVST Main Program Outputs

Input items 1, 7, 8, 9, 11, 14, 15, and 16 constitute the first report of IVST (see fig. 1). Data for five alternatives are printed on each page.

INVESTMENT ANALYSIS--				RESEARCH PAPER SAMPLE PROBLEM								
PROBLEM NO. 1		TEST DATA										
TERMINABLE SERIES											PERIOD=	5 YEARS
ONE			TWO		MANAGEMENT ALTERNATIVE THREE		FOUR		FIVE			
PERIOD	ANNUAL CCST	ANNUAL RETURN	ANNUAL COST	ANNUAL RETURN	ANNUAL CCST	ANNUAL RETURN	ANNUAL CCST	ANNUAL RETURN	ANNUAL CCST	ANNUAL RETURN		
1	15	12	2266425	104294	32	34	33	91	65	12		
2	23	65	2293800	29337	45	52	22	92	21	23		
3	65	42	1279570	-74550	89	12	44	93	45	52		
4	34	83	-2186855	1562249	78	65	55	94	23	45		
5	0	0	-2214230	1584476	52	89	66	95	57	78		
6	0	0	-2031064	1607694	14	35	88	96	84	65		
7	0	0	C	C	65	67	77	97	52	98		
8	0	0	C	C	23	85	22	98	11	63		
9	0	0	C	C	15	64	11	31	32	65		
10	0	0	C	C	24	13	22	32	11	32		
11	0	0	0	0	57	25	44	34	44	12		
12	0	0	C	C	62	35	66	35	55	45		
13	0	0	C	C	54	53	88	36	22	78		
14	0	0	C	C	13	92	99	37	33	96		
15	0	0	0	0	52	45	33	38	65	32		
16	0	0	C	C	C	0	55	39	47	58		
17	C	0	C	C	C	0	45	32	0	0		
18	C	0	C	C	C	0	23	45	0	0		
19	0	0	C	C	C	0	15	68	0	0		
20	0	0	C	C	C	0	72	28	0	0		

Figure 1.--First report of the IVST computer program showing input data.

Subroutine BCA

Function

The function of subroutine BCA is to calculate present net worth and benefit-cost ratio for each alternative for the range of interest rates selected by the analyst.

Criterion

Present net worth of a terminable series of costs and returns (dollars) is:

$$PNW_n = \sum_{t=0}^n \frac{R_t}{(1+i)^t} - \sum_{t=0}^n \frac{C_t}{(1+i)^t} \quad (1)$$

where

C_t = cost in year t , dollars^{4/}

R_t = return or benefit in year t , dollars^{4/}

i = discount rate, decimal

n = number of years in the investment series

Present net worth of a perpetual series of costs and returns is:

$$PNW_p = PNW_n \cdot \frac{(1+i)^n}{(1+i)^n - 1} \quad (2)$$

In contrast, the benefit-cost ratio is:

$$\frac{B}{C} = \frac{\sum_{t=0}^n R_t / (1+i)^t}{\sum_{t=0}^n C_t / (1+i)^t} \quad (3)$$

Equation 3 can be used for both terminable and perpetual series because the infinite series multiplier (the last term in equation 2) cancels out of equation 3.

Subroutine BCA does not assume that discounted returns (or benefits) or discounted costs are positive. It is likely that both negative returns and negative costs will occur if the analyst is working with marginal values (i.e., differences from some base).

^{4/} Any asset salvage values (revenues) or replacement costs should be included in the last term of the series.

Four conditions are possible:

<u>Condition</u>	<u>Return (or benefit)</u>	<u>Cost</u>
1	+	+
2	-	+
3	+	-
4	-	-

Since the benefit-cost ratio must always be positive, it was necessary to include rules for conditions 2, 3, and 4 within the BCA subroutine. In conditions 2 and 3, the B/C is set equal to zero. In condition 2, the reasoning is that a negative return is equivalent to a positive cost, but returns are equal to zero, hence $B/C = 0/+ = 0$. Likewise, in condition 3 a negative cost is equivalent to a positive return, hence cost is equal to zero. Therefore, $B/C = +/0$, which is undefined. These two conditions can be easily discerned since condition 2 will always be associated with a negative present net worth, whereas present net worth will always be positive in the case of condition 3.

In condition 4, negative returns are equivalent to positive costs and negative costs are equivalent to positive returns, hence the benefit-cost ratio is set equal to its inverse, the ratio of costs to benefits (C/B).

In addition, it is possible that either discounted costs or discounted returns are equal to zero. In such a case, the BCA subroutine will set B/C equal to zero.

BCA Outputs

Subroutine BCA provides for printing the present net worth and benefit-cost ratio for each alternative for the entire range in interest rates, together with identification (see fig. 2).^{5/} Results for five alternatives are printed on each page. After results are printed for all alternatives, control is returned to the main program.

Subroutine IROR

Function

The function of subroutine IROR is to calculate the internal rate of return for each alternative within a range of starting interest rates selected by the user, using the annual costs and annual returns generated by the IVST main program.

^{5/} The discounted costs and discounted returns may also be printed if the user so desires. The slight modification of the BCA subroutine which will provide this output is described in the Appendix, page 17.

PROBLEM NO. 1 TEST DATA

BENEFIT-COST RATIO (B/C) AT ALTERNATIVE RATES OF INTEREST
PRESENT NET WORTH (PNW) AT ALTERNATIVE RATES OF INTEREST

RATE	ONE		TWO		MANAGEMENT		ALTERNATIVE		FOUR		FIVE	
	PNW	B/C	*PNW	B/C*	*PNW	B/C*	*PNW	B/C*	*PNW	B/C*	*PNW	B/C*
0.	0.3250E 03	1.47	0.2703E 08	0.	0.4550E 03	1.13	0.1155E 04	1.24	0.9350E 03	1.28		
0.50	0.3032E 03	1.47	0.2202E 08	0.	0.3284E 03	1.12	0.1171E 04	1.31	0.7102E 03	1.26		
1.00	0.2832E 03	1.47	0.1765E 08	12.19	0.2322E 03	1.10	0.1156E 04	1.38	0.5356E 03	1.23		
1.50	0.2640E 03	1.46	0.1365E 08	5.11	0.1588E 03	1.08	0.1130E 04	1.45	0.3951E 03	1.20		
2.00	0.2470E 03	1.46	0.1054E 08	3.15	0.1026E 03	1.06	0.1090E 04	1.53	0.2915E 03	1.17		
2.50	0.2322E 03	1.46	0.7657E 07	2.23	0.5956E 02	1.04	0.1045E 04	1.61	0.2063E 03	1.14		
3.00	0.2178E 03	1.45	0.5150E 07	1.70	0.2650E 02	1.02	0.9984E 03	1.68	0.1383E 03	1.11		
3.50	0.2046E 03	1.45	0.2971E 07	1.36	0.1186E 01	1.00	0.9510E 03	1.75	0.8375E 02	1.07		
4.00	0.1923E 03	1.45	0.1078E 07	1.12	-0.1810E 02	0.98	0.9048E 03	1.81	0.3972E 02	1.04		
4.50	0.1809E 03	1.44	-0.5625E 06	0.94	-0.3268E 02	0.97	0.8605E 03	1.88	0.4019E 01	1.00		
5.00	0.1704E 03	1.44	-0.1963E 07	0.81	-0.4355E 02	0.95	0.8184E 03	1.93	-0.2506E 02	0.97		
5.50	0.1606E 03	1.44	-0.3211E 07	0.70	-0.5152E 02	0.94	0.7789E 03	1.99	-0.4884E 02	0.94		
6.00	0.1516E 03	1.44	-0.4270E 07	0.61	-0.5717E 02	0.93	0.7419E 03	2.04	-0.6835E 02	0.91		
6.50	0.1432E 03	1.43	-0.5181E 07	0.54	-0.6101E 02	0.92	0.7075E 03	2.09	-0.8439E 02	0.88		
7.00	0.1354E 03	1.43	-0.5962E 07	0.48	-0.6335E 02	0.91	0.6754E 03	2.14	-0.9761E 02	0.85		
7.50	0.1281E 03	1.43	-0.6629E 07	0.43	-0.6464E 02	0.90	0.6457E 03	2.18	-0.1085E 03	0.82		
8.00	0.1213E 03	1.42	-0.7156E 07	0.39	-0.6499E 02	0.89	0.6180E 03	2.22	-0.1175E 03	0.79		
8.50	0.1150E 03	1.42	-0.7675E 07	0.35	-0.6463E 02	0.89	0.5923E 03	2.26	-0.1249E 03	0.77		
9.00	0.1090E 03	1.42	-0.8078E 07	0.32	-0.6373E 02	0.88	0.5685E 03	2.29	-0.1310E 03	0.74		
9.50	0.1035E 03	1.42	-0.8413E 07	0.30	-0.6241E 02	0.88	0.5462E 03	2.33	-0.1360E 03	0.72		
10.00	0.9834E 02	1.42	-0.8665E 07	0.27	-0.6076E 02	0.88	0.5255E 03	2.36	-0.1401E 03	0.70		

Figure 2.--Second report of the IVST computer program showing results of use of the present net worth and benefit-cost ratio criteria.

Criterion

The internal rate of return (i) is defined as that interest rate which equates discounted returns to discounted costs, i.e., the rate that results in a present net worth of zero. If we use the same notation as above, then the internal rate of return is defined as i when the following condition is satisfied:

$$\sum_{t=0}^n \frac{R_t}{(1+i)^t} = \sum_{t=0}^n \frac{C_t}{(1+i)^t} \quad \text{for a terminable series} \quad (4)$$

or

$$\left[\sum_{t=0}^n \frac{R_t}{(1+i)^t} \right] \cdot \left[\frac{(1+i)^n}{(1+i)^n - 1} \right] = \left[\sum_{t=0}^n \frac{C_t}{(1+i)^t} \right] \cdot \left[\frac{(1+i)^n}{(1+i)^n - 1} \right] \quad (5)$$

for a perpetual series.

It should be noted that infinite series multiplier $\left[\frac{(1+i)^n}{(1+i)^n - 1} \right]$ cancels in equation 5, leaving it equivalent to equation 4. Therefore, the internal rate of return for a perpetual series is identical to the internal rate for a terminable series. However, discounted costs and returns will not be identical for both series.

At this point it may be helpful to indicate how the three investment criteria relate to one another. When the discount rate is equal to the internal rate and hence discounted costs are equal to discounted returns (present net worth is equal to zero), then the benefit-cost ratio is one (compare equations 1, 3, and 4).

Except for Forster's program (1968), all of the rate-of-return computer programs cited earlier use unmodified iteration to isolate the internal rate of return. In contrast, in IVST present net worth is iterated at interest rate intervals selected by the analyst until a change of sign is found. At that point,

the bisection method is applied until the internal rate of return is found within the interval at which the sign change occurs.^{6/} ^{7/}

The power of this technique can best be realized by selecting a wide range of interest rates and a large value for the rate increment. In this way, convergence to the internal rate of return occurs quickly as large bisection intervals are used.

However, if one desires to calculate present net worth and the benefit-cost ratio as well as internal rate of return, the advantage of selecting a wide range of interest rates and a large value for the rate increment may be lost. The analyst will generally wish to use the BCA subroutine with a small value for the rate increment. This in turn may necessitate investigating a narrow range of interest rates (see program limitation 8, page 14). Because interest rates to be used in both subroutines are determined in the main program, they must represent a compromise if the two subroutines are to be used together. Therefore, in cases such as this, the analyst may prefer to use the subroutines sequentially. This can be accomplished by setting up two problems for a single computer run, both with identical data except for interest rate range and increment. One of the problems would be run with the IROR subroutine with a wide range of interest rates and large increment, and the other problem would be run with the BCA subroutine with a narrow range of interest rates and a small increment.

An example which illustrates the bisection method utilized in IROR is shown in figure 3. In this example a range of interest rates of 0 to 10 percent at increments of 5 percent were specified. The program calculated the present net worth (PNW) at a rate of 0 percent and found it to be \$455. Next PNW was calculated at 5 percent and found to be -\$43. At this point, the change in sign initiates the bisection procedure. The program calculates PNW halfway between 0 percent and 5 percent, that is at 2.50 percent. Here PNW is positive (\$60), so the program tries the rate midway between 2.50 percent and 5 percent, or 3.75 percent. PNW at that rate is negative (-\$9), so it is apparent that the internal rate lies between 2.50 percent and 3.75 percent. This procedure is continued until the internal rate of return is found at 3.52 percent on the sixth bisection (see fig. 3).

IROR Outputs

Three types of messages may be generated prior to the printing of tables showing the internal rate of return (see fig. 4).

^{6/} For a discussion of the use of the bisection method for finding a real zero, see Hamming (1962, p. 352). The bisection method can result in both decreased computation time and increased accuracy. As Hamming points out, "Since each step halves the interval in which the zero lies, ten steps will reduce the interval by a factor of about 1,000; 20 steps, 1,000,000; etc. Thus the method, which assumes *only* continuity and the ability to evaluate the function at any point, is fairly effective."

^{7/} The recent rate-of-return computer program developed by Forster (1968) also utilizes the bisection method, which he terms "interval halving."

Figure 3.--An example of how the IROR subroutine converges to the internal rate of return.

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      DETERMINING RATE OF RETURN--      RESEARCH PAPER SAMPLE PROBLEM
PROBLEM NO. 1      TEST DATA

      MESSAGES

INTERNAL RATE OF RETURN DOES NOT FALL WITHIN SELECTED RANGE FOR ALTERNATIVE 1
BISECTION LIMIT EXCEEDED IN ALTERNATIVE 1 AND
CALCULATED PRESENT NET WORTH DOES NOT FALL BETWEEN PLUS AND MINUS 1.00 DOLLARS
PNW AS A FUNCTION OF INTEREST RATE IS NOT TENDING TOWARD ZERO WITHIN A PORTION OF ITS RANGE FOR ALTERNATIVE 4

```

Figure 4.--Third report of the IVST computer program indicating messages generated by the IROR subroutine.

If the internal rate of return is not found within the range of interest rates selected by the analyst, the message

```

INTERNAL RATE OF RETURN DOES NOT FALL WITHIN SELECTED RANGE FOR
ALTERNATIVE X

```

will be generated, with the alternative number filled in in place of X.

The second message that may be generated informs the user of the precision levels that apply to the internal rates of return. Precision level is indicated only when bisection is used. If the internal rate is found on iteration, a zero will appear in the PNW column and the precision level is to the nearest \$0.01.

Three precision levels are built into the bisection phase of the IROR subroutine, \$1, \$10, and \$100 (i.e., rate-of-return equation identity may be correct either to the nearest \$1, \$10, or \$100). Up to 100 bisections may occur within each of these precision levels. Whenever an internal rate fails to be determined at one of these precision levels, a message is generated and the next lower level of precision is tried. The message is of the form

```

BISECTION LIMIT EXCEEDED IN ALTERNATIVE X. CALCULATED PRESENT
NET WORTH DOES NOT FALL BETWEEN PLUS AND MINUS Y DOLLARS

```

with the alternative number filled in by IROR in place of X, and the precision level in place of Y.

A third message will be generated whenever present net worth as a function of interest rate does not converge toward zero. In this case, the form of the message is

```

PNW AS A FUNCTION OF INTEREST RATE IS NOT TENDING TOWARD ZERO
WITHIN A PORTION OF ITS RANGE FOR ALTERNATIVE X

```

Occurrence of this message does not necessarily mean that the internal rate of return does not fall within the range of interest rates selected by the user. However, IROR will discontinue searching for the internal rate whenever the above condition is encountered. When this condition occurs, the analyst is advised to use the BCA subroutine to generate sufficient points to indicate the form of the present net worth function. If the above condition is caused by portions of the function which are not monotonic, it is likely that the interest rate range can be modified so as to exclude such portions, thereby permitting IROR to converge to the internal rate of return.

The behavior of IROR in various situations is illustrated in figure 5, wherein 10 representative types of present net worth functions are depicted.^{8/} The types shown in figure 5 by no means exhaust the possibilities. In each graph, present net worth (dollars) is plotted over the range of interest rates selected for examination. IROR will treat each type of function as follows:

Type 1.--Present net worth is a monotonic decreasing function of interest rate. The internal rate of return falls within the range selected and will be determined by IROR.

Type 2.--Present net worth is a monotonic increasing function of interest rate. The internal rate of return falls within the range selected and will be determined by IROR.

Type 3.--Present net worth is a monotonic decreasing function of interest rate. However, the internal rate of return is located outside the range selected.

Type 4.--Present net worth is a monotonic increasing function of interest rate. However, the internal rate of return is located outside the range selected.

In the case of types 3 and 4, IROR will calculate present net worth for the full range of interest rates and then generate the message

INTERNAL RATE OF RETURN DOES NOT FALL WITHIN SELECTED RANGE FOR
ALTERNATIVE X

Type 5.--Present net worth is a monotonic decreasing function of interest rate. The internal rate of return is located outside the range selected, and present net worth is not converging toward zero as interest rate increases.

Type 6.--Present net worth is a monotonic increasing function of interest rate. The internal rate of return is located outside the range selected, and present net worth is not converging toward zero as interest rate increases.

In the case of types 5 and 6, IROR will calculate two iterated points along that segment and then print the message

PNW AS A FUNCTION OF INTEREST RATE IS NOT TENDING TOWARD ZERO
WITHIN A PORTION OF ITS RANGE FOR ALTERNATIVE X

Types 7 and 8.--Present net worth is not a monotonic function of interest rate. Although the internal rate of return lies within the range of rates selected, IROR will not determine it. Rather, these situations will be handled by IROR exactly as types 5 and 6. If these types of functions are suspected, the analyst should examine PNW over a wide range of interest rates by use of BCA subroutine. After examining BCA outputs, it is possible to reset the range in interest rates to avoid the program stop, thereby permitting the IROR subroutine to converge to the internal rate of return. Also, it should be pointed out that

^{8/} Samuelson (1937, p. 475) indicates that some investment opportunities may have no real internal rate of return (i.e., the present net worth equation has only imaginary roots). Also, he mentions the possibility of multiple internal rates, i.e., the present net worth function may equal zero at many interest rates.

Figure 5.--Representative types of present net worth functions.

if the analyst initially sets the interest rate increment large enough, the program stop may be avoided and convergence will occur.

Type 9.--Present net worth is zero at two interest rates. IROR will locate only point a.

Type 10.--Points will be iterated until point b is reached, at which time the following message is printed and the program proceeds to the next alternative.

PNW AS A FUNCTION OF INTEREST RATE IS NOT TENDING TOWARD ZERO
WITHIN A PORTION OF ITS RANGE FOR ALTERNATIVE X

The final output is a table listing interest rates and present net worths for each alternative until the internal rate of return is reached (see fig. 6). When the internal rate of return is found, the precision level applicable to that rate is indicated in the present net worth (PNW) column.

ONE		TWO		THREE		FOUR		FIVE	
* RATE	PNW *	* RATE	PNW *	* RATE	PNW *	* RATE	PNW *	* RATE	PNW *
0.	3.2500E 02	0.	2.7029E 07	0.	4.5500E 02	0.	1.1550E 03	0.	9.3507E 02
0.50	3.0320E 02	0.50	2.2019E 07	0.50	3.2838E 02	0.50	1.1709E 03	0.50	7.1018E 02
1.00	2.8318E 02	1.00	1.7654E 07	1.00	2.3221E 02	0.	0.	1.00	5.3560E 02
1.50	2.6477E 02	1.50	1.3851E 07	1.50	1.5883E 02	0.	0.	1.50	3.9906E 02
2.00	2.4784E 02	2.00	1.0539E 07	2.00	1.0265E 02	0.	0.	2.00	2.9154E 02
2.50	2.3223E 02	2.50	7.6571E 06	2.50	5.9556E 01	0.	0.	2.50	2.0631E 02
3.00	2.1784E 02	3.00	5.1499E 06	3.00	2.6496E 01	0.	0.	3.00	1.3831E 02
3.50	2.0456E 02	3.50	2.9706E 06	3.50	1.1855E 00	0.	0.	3.50	8.3747E 01
4.00	1.9228E 02	4.00	1.0784E 06	3.53	1.0000E 00	0.	0.	4.00	3.9720E 01
4.50	1.8092E 02	4.32	1.0000E 01	0.	0.	0.	0.	4.50	4.0187E 00
5.00	1.7040E 02	0.	0.	0.	0.	0.	0.	4.56	1.0000E 00
5.50	1.6065E 02	0.	0.	0.	0.	0.	0.	0.	0.
6.00	1.5159E 02	0.	0.	0.	0.	0.	0.	0.	0.
6.50	1.4318E 02	0.	0.	0.	0.	0.	0.	0.	0.
7.00	1.3536E 02	0.	0.	0.	0.	0.	0.	0.	0.
7.50	1.2808E 02	0.	0.	0.	0.	0.	0.	0.	0.
8.00	1.2129E 02	0.	0.	0.	0.	0.	0.	0.	0.
8.50	1.1496E 02	0.	0.	0.	0.	0.	0.	0.	0.
9.00	1.0904E 02	0.	0.	0.	0.	0.	0.	0.	0.
9.50	1.0351E 02	0.	0.	0.	0.	0.	0.	0.	0.
10.00	9.8338E 01	0.	0.	0.	0.	0.	0.	0.	0.

END OF RUN

Figure 6.--Fourth report of the IVST computer program showing results of use of the internal rate-of-return criterion.

LIMITATIONS OF IVST

There are several limitations which must be observed in the use of IVST:

1. The number of alternatives analyzed within a problem must be less than or equal to 20.
2. The type of series (either terminable or perpetual) must be the same for all alternatives within a problem.
3. The number of years in the investment series for any alternative must be equal to or less than 140.

4. The length of period to which periodic annual costs or returns apply must be identical for all alternatives within a given problem. However, the number of periods may vary from one alternative to another. The number of years in each alternative (i.e., the investment series length in years) is therefore equal to the product of number of periods and period length.
5. The range and increment in interest rate must be identical for all alternatives within a given problem.
6. The beginning interest rate must be greater than -100 percent.
7. The ending interest rate must be less than 85 percent if the investment series length for any alternative in the problem is 140 years. Higher interest rates may be analyzed if the maximum investment series length decreases. Users should consult with computing center personnel regarding the limits on the exponential function subroutine being used, as this is the factor that limits the range of interest rates which may be analyzed.
8. The interest rate range and increment selected by the user must not result in more than 200 interest rates being generated. However, more than 200 interest rates may be generated during the bisection procedure, which is not under the user's control but is automatically controlled by the IROR subroutine.
9. An attempt to analyze a zero interest rate for a perpetual series will result in the program skipping that rate and passing on to the next interest rate within the range selected by the user. No program stop or computational error will result.

OPERATION OF IVST

Input card formats, program flow charts, and a listing of the IVST source program are included in the Appendix. IVST is coded in FORTRAN IV and is operable on either the IBM 7040 or the IBM 360/50 (both time-sharing and nontime-sharing modes) computing systems. Slight modification may be necessary before IVST can be used with other systems. A total of 31,988 words of core storage are required on the IBM 7040 computer for this program. Use of IVST on computers with smaller memory capacities will require modification of the program. The sample problem shown in this paper required 1 minute and 4 seconds of execution time on the IBM 7040.

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APPENDIX

Preparation of IVST Input Cards

There are nine types of input cards required by the IVST program. The format of these input cards is indicated in table 1. Card columns for which no punch is indicated should be left blank. All data except alphanumeric must be right-justified (i.e., the units position must be at the extreme right of the field). It should be pointed out that input card types 1-6 and 9 contain identification and control data, whereas input card types 7 (periodic annual costs) and 8 (periodic annual returns) are sets of data applicable to independent alternatives. All costs are read for a given alternative. Then all returns are read for that same alternative. This sequence (i.e., all costs and then all returns for each alternative) is repeated until all alternatives have been read before the next input card type is read. The last card contains the end-of-problem indicator (MEND).

BCA Optional Output

The discounted returns and discounted costs at each interest rate may be printed if the user desires. The only modification required in the BCA subroutine to provide for this output is to reproduce BCA program cards BCA 0370 and BCA 0375 (see listing of the BCA subroutine) deleting the "C" in the first column.

Table 1.-- IVST Program Input Format

Input card type	Program code	Item	Form	Card columns
1	STD(I)	Alphanumeric study identification.	A.....A	1-72
2	BRATE	Beginning interest rate, decimal.	X.XX	7-10
2	FRATE	Final interest rate, decimal.	X.XX	17-20
2	DELTA	Interest rate increment, decimal.	X.XX	27-30
2	LX	Number of alternatives in problem.	XX	34-35
2	INIT	Indicator of an initial cost or return; = 0, if there is an initial cost or return, = 1, if not.	X	40
3	LI(I,L)	Alphanumeric identification of alternative L. A second card is needed to handle over 10 alternatives.	AAAAAAA	1-8, 9-16, ..., 73-80
4	NO	Problem number.	XXXX	1-4
4	NZ	Type of calculation; = 01, if series is perpetual, = 02, if series is terminable.	XX	7-8
4	IC	Investment criterion; = 01, internal rate of return, = 02, benefit/cost and present net worth, = 03, all three criteria.	XX	11-12
4	IP	Length of period, years.	XX	15-16
4	KCXX	Maximum number of years in the investment series of any alternative. If initial costs and returns are read, present year should be included in KCXX.	XXX	18-20
5	KCX(L)	Number of years in the investment series of each alternative L. If initial costs and returns are read, present year should be included in KCX(L).	XXX	1-3, 4-6, ..., 58-60
6	A(I)	Alphanumeric problem identification.	A.....A	1-72
7	COST(L,KC)	Periodic annual cost of alternative L, for period KC, dollars. A second card is needed to handle 9-16 alternatives. A third card is needed to handle 17-20 alternatives. ADDITIONAL CARDS ARE REQUIRED TO READ DATA FOR MORE THAN 8 PERIODS.	XXXXXXXXXX	1-10, 11-20, ..., 71-80
8	REV(L,KC)	Periodic annual return of alternative L for period KC, dollars. A second card is needed to handle 9-16 alternatives. A third card is needed to handle 17-20 alternatives. ADDITIONAL CARDS ARE REQUIRED TO READ DATA FOR MORE THAN 8 PERIODS.	XXXXXXXXXX	1-10, 11-20, ..., 71-80
9	MEND	Terminal card code; = 98, to do another problem. = 99, end-of-run.	XX	2-3

FLOW CHART FOR MAIN ROUTINE IVST

LEGEND FOR FLOW CHARTS

START OF DO LOOP i
INDEX j , LIMITS n,m .

SUBROUTINE
CALL OR RETURN

TERMINUS OF LOOP i

PROGRAM
BEGINNING AND END

COMPUTATION
OR PROCESSING

AN ENTRY FROM, OR EXIT
TO, ANOTHER PART OF
THE PROGRAM FLOWCHART

INPUT OR OUTPUT

DIRECTION OF FLOW

DECISION

FLOW CHART FOR SUBROUTINE BCA

FLOW CHART FOR SUBROUTINE IROR

IVST SOURCE PROGRAM


```

C
C      FOR PERIOD KC, DOLLARS.
C      STD(1)=ALPHANUMERIC STUDY IDENTIFICATION (1-72 CHARACTERS)
C      TYPE OF CALCULATION-
C      NZ=01, IF PERPETUAL SERIES.
C      NZ=02, IF TERMINABLE SERIES.
C      TYPE OF CALCULATION MUST BE THE SAME FOR ALL ALTERNATIVES
C      WITHIN A PROBLEM.
C      YR(L,LZ)=YEAR IN WHICH LTH COST AND RETURN OCCURS (1-140).
C
C      INTEGER COST(20,140), REV(20,140)
C      DIMENSION KCX(20), RTLOG(200), PECO(20,140), RETURN(20,140), LI(2,20),
C      1A(18), STD(18), YR(20,140), RATE(200)
C      2,BCR(20,200), VALIN(20,200)
C      COMMON KCX,RTLOG,PECO,RETURN,LI,A,STD,YR,NZ,RATE,NR,LX,BCR,VALIN,
C      1NO,FRATE
C
C      INPUT FORMATS
C
C      100 FORMAT (3F10.2,2I5)
C      105 FORMAT (10(2A4))
C      110 FORMAT (20I3)
C      115 FORMAT (5I4)
C      120 FORMAT (I3)
C      125 FORMAT (8I10)
C      130 FORMAT (18A4)
C
C      OUTPUT FORMATS
C
C      135 FORMAT (1H1,19X,21HINVESTMENT ANALYSIS--,18A4/1H0,11HPROBLEM NO.,
C      1I3,6X,18A4)
C      140 FORMAT (1H0, 17HTERMINABLE SERIES,85X,8HPERIOD= ,I3,6H YEARS)
C      145 FORMAT (1H ,52X,22HMANAGEMENT ALTERNATIVE)
C      150 FORMAT (1H0,16HPERPETUAL SERIES,84X,8HPERIOD= ,I4,6H YEARS)
C      155 FORMAT(1H0,60X,10HEND OF RUN)
C      160 FORMAT(1H0,3X,6HPERIOD,2X,5(6HANNUAL,5X,6HANNUAL,7X)/13X,4(4HCOST,
C      16X,6HRETURN,8X),4HCOST,6X,6HRETURN)
C      165 FORMAT (1H ,16X,2A4,4(16X,2A4))

```

```

IVST0180
IVST0185
IVST0190
IVST0195
IVST0200
IVST0205
IVST0210
IVST0215
IVST0220
IVST0225
IVST0230
IVST0235
IVST0240
IVST0245
IVST0250
IVST0255
IVST0260
IVST0265
IVST0270
IVST0275
IVST0280
IVST0285
IVST0290
IVST0295
IVST0300
IVST0305
IVST0310
IVST0315
IVST0320
IVST0325
IVST0330
IVST0335
IVST0340
IVST0345
IVST0350
IVST0355
IVST0360
IVST0365
IVST0370
IVST0375

```

```

170 FORMAT (1H ,3X,I3,5(1X,I10,1X,I10,2X))
C
C READ STUDY IDENTIFICATION CARD
C
C      READ (5,130) (STD(I),I=1,18)
C
C READ RATE CARD
C
C      175 READ (5,100) BRATE,FRATE,DELTA,LX,INIT
C
C READ PROBLEM NO. AND ALTERNATIVE TITLE CARDS
C
C      READ (5,105) ((LI(I,L),I=1,2),L=1,LX)
C      READ (5,115) NO,NZ,IC,IP,KCXX
C      READ (5,110) (KCX(L),L=1,LX)
C      KCT=KCXX/IP
C      DO 180 L=1,LX
C      DO 180 KC=1,KCT
C      COST(L,KC) = 0
C      REV(L,KC) = 0
C
180 CONTINUE
      IF (BRATE.NE.0.0.AND.FRATE.NE.0.0) GO TO 185
      IF (NZ.EQ.2) GO TO 185
      IF (BRATE.EQ.0.0) BRATE=BRATE+DELTA
      IF (FRATE.EQ.0.0) FRATE=FRATE-DELTA
C
C CALCULATE NUMBER RATES (NR), RATE(I),I=1,NR) AND
C      LOG(1.+RATE(I) WHICH IS RTLOG(I) IN PROGRAM
C
C      185 NR=((FRATE-BRATE)/DELTA)+1.05
C      RATE(1)=BRATE
C      RTLOG(1)=ALOG(1.0+RATE(1))
C      DO 195 I=2,NR
C      RATE(I)=RATE(I-1)+DELTA
C      IF (RATE(I).NE.0.0) GO TO 190
C      IF (NZ.EQ.2) GO TO 190
C      RATE(I)=RATE(I)+DELTA
C      RTLOG(I)=ALOG(1.0+RATE(I))
C      190 CONTINUE
C
C      195 CONTINUE
C

```

```

IVST0380
IVST0385
IVST0390
IVST0395
IVST0400
IVST0405
IVST0410
IVST0415
IVST0420
IVST0425
IVST0430
IVST0435
IVST0440
IVST0445
IVST0450
IVST0455
IVST0460
IVST0465
IVST0470
IVST0475
IVST0480
IVST0485
IVST0490
IVST0495
IVST0500
IVST0505
IVST0510
IVST0515
IVST0520
IVST0525
IVST0530
IVST0535
IVST0540
IVST0545
IVST0550
IVST0555
IVST0560
IVST0565
IVST0570
IVST0575

```

```

C READ PROBLEM IDENTIFICATION CARD
C
C READ(5,130)(A(I),I=1,18)
C
C READ PERIODIC ANNUAL COSTS AND RETURNS
C
C      DO 200 L=1,LX
C      KCS = KCX(L)/IP
C      READ (5,125) (COST(L,KC),KC=1,KCS)
C      READ (5,125) (REV(L,KC),KC=1,KCS)
C      200 CONTINUE
C
C WRITE PERIODIC ANNUAL COSTS AND RETURNS
C
C      L1=1
C      L2=2
C      L3=3
C      L4=4
C      L5=5
C
C      205 LINE=0
C      210 DO 245 K=1,KCT
C      215 IF(LINE.NE.0) GO TO 235
C      220 WRITE (6,135) (STD(I),I=1,18),NO,(A(I),I=1,18)
C      IF (NZ.EQ.1) GO TO 225
C      WRITE (6,140) IP
C      GO TO 230
C
C      225 WRITE (6,150) IP
C      230 WRITE (6,145)
C      WRITE (6,165) LI(1,L1),LI(2,L1),LI(1,L2),LI(2,L2),LI(1,L3),LI(2,L3)
C      1),LI(1,L4),LI(2,L4),LI(1,L5),LI(2,L5)
C      WRITE (6,160)
C
C      235 KC=K
C      KT=K
C      IF(IP.EQ.1.AND.INIT.EQ.0) KT=K-1
C      WRITE (6,170) KT,COST(L1,KC),REV(L1,KC),COST(L2,KC),REV(L2,KC),COSI
C      1T(L3,KC),REV(L3,KC),COST(L4,KC),REV(L4,KC),COST(L5,KC),REV(L5,KC)
C      240 LINE=LINE+1
C      IF (LINE.EQ.31) LINE=0
C      245 CONTINUE
C      IF (L5.EQ.20) GO TO 250

```

IVST0580
 IVST0585
 IVST0590
 IVST0595
 IVST0600
 IVST0605
 IVST0610
 IVST0615
 IVST0620
 IVST0625
 IVST0630
 IVST0635
 IVST0640
 IVST0645
 IVST0650
 IVST0655
 IVST0660
 IVST0665
 IVST0670
 IVST0675
 IVST0680
 IVST0685
 IVST0690
 IVST0695
 IVST0700
 IVST0705
 IVST0710
 IVST0715
 IVST0720
 IVST0725
 IVST0730
 IVST0731
 IVST0732
 IVST0733
 IVST0735
 IVST0740
 IVST0745
 IVST0750
 IVST0755
 IVST0760

```

L1=L1+5
L2=L2+5
L3=L3+5
L4=L4+5
L5=L5+5
IF (L1.GT.LX) GO TO 250
GO TO 205

C
C   GENERATE ANNUAL COSTS AND RETURNS
C
250 DO 265 L=1,LX
    LZ=0
    DO 260 KC=1,KCT
        LXX=0
        255 LZ=LZ+1
            PECO(L,LZ)=COST(L,KC)
            RETURN(L,LZ)=REV(L,KC)
            YR(L,LZ)=LZ
            IF(IP.EQ.1.AND.INIT.EQ.0) YR(L,LZ)=YR(L,LZ)-1.0
            LXX=LXX+1
            IF (LXX.LT.IP) GO TO 255
        260 CONTINUE
    265 CONTINUE

C
C   CALL INVESTMENT CRITERION
C   IF (IC.EQ.03.OR.IC.EQ.02) CALL BCA
C   IF (IC.EQ.03.OR.IC.EQ.01) CALL IROR

C
C   READ TERMINAL CARD
C
270 READ(5,120) MEND
    IF(MEND.EQ.99) GO TO 275
    GO TO 175
275 WRITE(6,155)
    STOP
    END

```

```

IVST0765
IVST0770
IVST0775
IVST0780
IVST0785
IVST0790
IVST0795
IVST0800
IVST0805
IVST0810
IVST0815
IVST0820
IVST0825
IVST0830
IVST0835
IVST0840
IVST0845
IVST0850
IVST0851
IVST0855
IVST0860
IVST0865
IVST0870
IVST0875
IVST0880
IVST0885
IVST0890
IVST0895
IVST0900
IVST0905
IVST0910
IVST0915
IVST0920
IVST0925
IVST0930
IVST0935
IVST0940

```



```

C BENEFIT/COST AND PRESENT NET WORTH ANALYSIS
C SUBROUTINE BCA
C BY D.E. CHAPPELLE
C PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
C
C CALLED BY PROGRAM IVST
  SUBROUTINE BCA
    DIMENSION KCX(20),YR(20,140),BCR(20,200),RATE(200),
    1RTLOG(200),PECO(20,140),RETURN(20,140),LI(2,20),
    2A(18), VALIN(20,200),STD(18)
    COMMON KCX,RTLOG,PECO,RETURN,LI,A,STD,YR,NZ,RATE,NR,LX,BCR,VALIN,
    1NO,FRATE
C
C OUTPUT FORMATS
  100 FORMAT (1H1)
  105 FORMAT (1H1,19X,23HBENEFIT-COST ANALYSIS--,18A4,/1H0,11HPROBLEM NOBCA
    1.,13,6X,18A4)
  110 FORMAT (1H0,52X,22HMANAGEMENT ALTERNATIVE)
  115 FORMAT (1H0,57HBENEFIT-COST RATIO (B/C) AT ALTERNATIVE RATES OF INBCA 0095
    1TEREST,/1H ,56HPRESENT NET WORTH (PNW) AT ALTERNATIVE RATES OF INBCA 0100
    2TEREST)
  120 FORMAT (1H ,21X,2A4,4(15X,2A4),/,1H0,2X,4H*PNW,8X,4HB/CBCA 0110
    1*,4(8X,4H*PNW,8X,4HB/C*),//)
  125 FORMAT (2PF7.2,4X,0PE13.4,F9.2,4(2X,E13.4,F9.2))
C
  WRITE (6,100)
C
C CLEAR ARRAY FOR PRESENT NET WORTH (VALIN(L,I)) AND BENEFIT-COST
C RATIO (BCR(L,I)) ARRAY
C
  DO 130 LLL=1,LX
  DO 130 III=1,NR
    VALIN(LLL,III) = 0.0
    BCR(LLL,III)=0.0
  130 CONTINUE
C
C BEGINNING OF L-LOOP (ALTERNATIVES)
C

```



```

DO 175 L=1,LX
KCXA=KCX(L)
XLY=FLOAT(KCX(L))
IF (KCXA.EQ.0) GO TO 175
C
C BEGINNING I-LOOP (RATES OF RETURN)
C
135 DO 175 I=1,NR
DKC=0.0
DK1=0.0
IF(RTLOG(I).EQ.0.0) GO TO 145
C
C CALCULATE DISCOUNTED COST AND RETURN
C
DO 140 KC=1,KCXA
DKC=DKC+PECO(L,KC)/EXP(RTLOG(I)*YR(L,KC))
DK1=DK1+RETURN(L,KC)/EXP(RTLOG(I)*YR(L,KC))
140 CONTINUE
GO TO 155
145 DO 150 KC=1,KCXA
DKC=DKC+PECO(L,KC)
DK1=DK1+RETURN(L,KC)
150 CONTINUE
C
C CALCULATE PRESENT NET WORTH (VALIN) AND BENEFIT-COST RATIO (B/C)
C
155 IF (NZ.EQ.2) GO TO 160
DISCO=EXP(RTLOG(I)*XLY)
DIS=(1.0+1.0/(DISCO-1.0))
DK1=DK1*DIS
DKC=DKC*DIS
160 VALIN(L,I) = DK1 - DKC
C
C IF USER DESIRES TO PRINT DISCOUNTED RETURNS AND COSTS, REMOVE THE C
C FROM COLUMN 1 OF THE NEXT 2 CARDS
C
WRITE(6,162) DK1,DKC
162 FORMAT (1H,E15.4,10X,E15.4)
IF (DK1.EQ.0.0.OR.DKC.EQ.0.0) GO TO 170
IF (DK1.GT.0.0) GO TO 165
IF (DKC.GT.0.0) GO TO 170

```

```

BCA 0195
BCA 0200
BCA 0205
BCA 0210
BCA 0215
BCA 0220
BCA 0225
BCA 0230
BCA 0235
BCA 0240
BCA 0245
BCA 0250
BCA 0255
BCA 0260
BCA 0265
BCA 0270
BCA 0275
BCA 0280
BCA 0285
BCA 0290
BCA 0295
BCA 0300
BCA 0305
BCA 0310
BCA 0315
BCA 0320
BCA 0325
BCA 0330
BCA 0335
BCA 0340
BCA 0345
BCA 0350
BCA 0355
BCA 0360
BCA 0365
BCA 0370
BCA 0375
BCA 0380
BCA 0385
BCA 0390

```

```

BCR(L,I) = DKC / DK1
GO TO 175
165 IF (DKC.LT.0.0) GO TO 170
BCR(L,I) = DK1 / DKC
GO TO 175
170 BCR(L,I) = 0.0
175 CONTINUE
C
C END OF I-LOOP
C END OF L-LOOP
C
C WRITE BENEFIT-COST RATIO
C
L1=1
L2=2
L3=3
L4=4
L5=5
180 LINE=0
DO 195 I=1,NR
IF (LINE.EQ.0) GO TO 185
IF (LINE.NE.31) GO TO 190
185 WRITE (6,105) (STD(IN), IN=1,18), ND, (A(IN), IN=1,18)
WRITE (6,115)
WRITE (6,110)
WRITE (6,120) LI(1,L1), LI(2,L1), LI(1,L2), LI(2,L2), LI(1,L3), LI(2,L3)BCA 0520
1), LI(1,L4), LI(2,L4), LI(1,L5), LI(2,L5)
190 WRITE (6,125) RATE(I), VALIN(L1,I), BCR(L1,I), VALIN(L2,I), BCR(L2,I), BCA 0530
1VALIN(L3,I), BCR(L3,I), VALIN(L4,I), BCR(L4,I), VALIN(L5,I), BCR(L5,I)
LINE=LINE+1
195 CONTINUE
IF (L5.EQ.20) RETURN
L1=L1+5
L2=L2+5
L3=L3+5
L4=L4+5
L5=L5+5
IF (L1.GT.LX) RETURN
GO TO 180
END
BCA 0395
BCA 0400
BCA 0405
BCA 0410
BCA 0415
BCA 0420
BCA 0425
BCA 0430
BCA 0435
BCA 0440
BCA 0445
BCA 0450
BCA 0455
BCA 0460
BCA 0465
BCA 0470
BCA 0475
BCA 0480
BCA 0485
BCA 0490
BCA 0495
BCA 0500
BCA 0505
BCA 0510
BCA 0515
BCA 0525
BCA 0530
BCA 0535
BCA 0540
BCA 0545
BCA 0550
BCA 0555
BCA 0560
BCA 0565
BCA 0570
BCA 0575
BCA 0580
BCA 0585
BCA 0590

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C DETERMINING RATE OF RETURN
C SUBROUTINE IROR
C BY D.E. CHAPPELLE
C PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
C
C CALLED BY PROGRAM IVST
C
C (BASED ON SOUTHERN FOREST EXPERIMENT STATION INVESTMENT ANALYSIS
C PROGRAM BY CLARK ROW)
C
C BISECTION METHOD IS USED TO DETERMINE RATE AT WHICH DISCOUNTED NET
C WORTH APPROACHES 0.0
C
C PRECISION LEVELS ARE VARIED WITHIN THE BISECTION ANALYSIS
C
C THE PRECISION APPLICABLE TO THE CALCULATED RATE OF RETURN IS SHOWN
C AS THE LAST ENTRY IN THE PRESENT NET WORTH COLUMN
C
C SUBROUTINE IROR
C DIMENSION KCX(20),YR(20,140),VALIN(20,200),X(100),Y(100),NRATE(20)
C 1,RATE(200),RTLOG(200),PECO(20,140),RETURN(20,140),LI(2,20),
C 2A(18),STD(18)
C COMMON KCX,RTLOG,PECO,RETURN,LI,A,STD,YR,NZ,RATE,NR,LX,XRATE(20,20)
C 10),VALIN,NO,FRATE
C
C OUTPUT FORMATS
C
C 100 FORMAT (1H0,10X,39HBISECTION LIMIT EXCEEDED IN ALTERNATIVE,2A4/1H
C 1,10X,66HCALCULATED PRESENT NET WORTH DOES NOT FALL BETWEEN PLUS ANI
C 20 MINUS ,F6.2,8H DOLLARS,/)
C 105 FORMAT (1H1,19X,28HDETERMINING RATE OF RETURN--,18A4/1H0,11HPROBLE
C 1M NO.,I3,6X,18A4)
C 110 FORMAT (1H0,50X,8HMESSAGES,/)
C 115 FORMAT (1H0,52X,22HMANAGEMENT ALTERNATIVE,/)
C 120 FORMAT(1H0,56HPRESENT NET WORTH (PNW) AT ALTERNATIVE RATES OF INTE
C 1REST)
C 125 FORMAT (1H ,5X,2A4,4(20X,2A4)/1H0,4(7H * RATE,7X,5HPNW *,8X),7H *
C 1RATE,7X,5HPNW *,//)
IROR0000
IROR0005
IROR0010
IROR0015
IROR0020
IROR0025
IROR0030
IROR0035
IROR0040
IROR0045
IROR0050
IROR0055
IROR0060
IROR0065
IROR0070
IROR0075
IROR0080
IROR0085
IROR0090
IROR0095
IROR0100
IROR0105
IROR0110
IROR0115
IROR0120
IROR0125
IROR0130
IROR0135
IROR0140
IROR0145
IROR0150
IROR0155
IROR0160
IROR0165
IROR0170
IROR0175
IROR0180
IROR0185

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MAY 1968


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C      160 TDVAL=DK1-DKC
      IF(NZ.EQ.2) GO TO 190
C
C      PRESENT NET WORTH (VALIN)
C
      DISCO=EXP(RTLOG(I)*XLY)
      VALIN(L,I)=TDVAL*(1.0+1.0/(DISCO-1.0))
      165 IF(VALIN(L,I).LE.0.01.AND.VALIN(L,I).GE.(-0.01)) GO TO 225
      IF(1.EQ.1) GO TO 210
      IF(VALIN(L,I-1))170,225,180
      170 IF(VALIN(L,I).GT.0.0) GO TO 235
      IF(VALIN(L,I).GE.VALIN(L,I-1)) GO TO 210
      IF (LINE.LT.37) GO TO 175
      WRITE (6,105) (STD(IN),IN=1,18),NO,(A(IN),IN=1,18)
      LINE=0
      175 LINE=LINE+1
      WRITE (6,140) L
      GO TO 225
      180 IF(VALIN(L,I).LT.0.0)GO TO 235
      IF(VALIN(L,I).LE.VALIN(L,I-1)) GO TO 210
      IF (LINE.LT.37) GO TO 185
      WRITE (6,105) (STD(IN),IN=1,18),NO,(A(IN),IN=1,18)
      LINE=0
      185 LINE=LINE+1
      WRITE (6,140) L
      GO TO 225
      190 VALIN(L,I)=TDVAL
      GO TO 165
      195 DO 200 KC=1,KCXA
      DKC=DKC+PECO(L,KC)
      DK1=DK1+RETURN(L,KC)
      200 CONTINUE
      205 VALIN(L,I)=DK1-DKC
      GO TO 165
      210 CONTINUE
C
C      END OF I-LOOP

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IROR0380
IROR0385
IROR0390
IROR0395
IROR0400
IROR0405
IROR0410
IROR0415
IROR0420
IROR0425
IROR0430
IROR0435
IROR0440
IROR0445
IROR0450
IROR0455
IROR0460
IROR0465
IROR0470
IROR0475
IROR0480
IROR0485
IROR0490
IROR0495
IROR0500
IROR0505
IROR0510
IROR0515
IROR0520
IROR0525
IROR0530
IROR0535
IROR0540
IROR0545
IROR0550
IROR0555
IROR0560
IROR0565

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```

C      215 IRT=NR
          NRATE(L)=IRT
          XRATE(L,IRT)=FRATE
          LR = 1
          IF (LINE.LT.37) GO TO 220
          WRITE (6,105) (STD(IN),IN=1,18),ND,(A(IN),IN=1,18)
          LINE=0
220      LINE=LINE+1
          WRITE (6,135) L
          GO TO 295
225      IRT=I
          NRATE(L)=IRT
          XRATE(L,IRT)=RATE(IRT)
          IF (VALIN(L,IRT).LE.0.01.AND.VALIN(L,IRT).GE.(-0.01)) GO TO 230
          GO TO 295
230      VALIN(L,IRT)=0.0
          IF (NRATE(L).EQ.1) GO TO 305
          GO TO 295

C      C BEGINNING BISECTION COMPUTATION
C
235      PH=1.00
          PL=-1.00
240      IRT=I
          Y(1)=VALIN(L,IRT)
          Y(2)=VALIN(L,IRT-1)
          X(1)=RATE(IRT)
          X(2)=RATE(IRT-1)
          DO 275 II=3,100
          IF (X(II-2).EQ.X(II-1)) GO TO 275
          X(II)=(X(II-2)+X(II-1))/2.0
          RLOG=ALOG(1.0+X(II))
          DISCO=EXP(RLOG*XLY)
          DKC=0.0
          DK1=0.0
          DO 245 KC=1,KCXA
          DKC=DKC+PECO(L,KC)/EXP(RLOG*YR(L,KC))
          DK1=DK1+RETURN(L,KC)/EXP(RLOG*YR(L,KC))
245      CONTINUE

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IROR0570
IROR0575
IROR0580
IROR0585
IROR0590
IROR0595
IROR0600
IROR0605
IROR0610
IROR0615
IROR0620
IROR0625
IROR0630
IROR0635
IROR0640
IROR0645
IROR0650
IROR0655
IROR0660
IROR0665
IROR0670
IROR0675
IROR0680
IROR0685
IROR0690
IROR0695
IROR0700
IROR0705
IROR0710
IROR0715
IROR0720
IROR0725
IROR0730
IROR0735
IROR0740
IROR0745
IROR0750
IROR0755
IROR0760
IROR0765

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```

TDVAL=DK1-DKC
IF (NZ.EQ.2) GO TO 250
Y(II)=TDVAL*(1.0+1.0/(DISCO-1.0))
GO TO 255
250 Y(II)=TDVAL
255 IF(Y(II).LE.PH.AND.Y(II).GE.PL) GO TO 285
IF(Y(II).) 260,285,270
260 IF(Y(II-1).GT.0.0) GO TO 275
265 Y(II-1)=Y(II-2)
X(II-1)=X(II-2)
GO TO 275
270 IF(Y(II-1).LT.0.0) GO TO 275
GO TO 265
275 CONTINUE
C
C END OF BISECTION
C
IF (LINE.LT.37) GO TO 280
WRITE (6,105) (STD(IN),IN=1,18),VO,(A(IN),IN=1,18)
LINE=0
280 LINE=LINE+2
WRITE (6,100) LI(1,L), LI(2,L), PH
VALIN(L,IRT)=Y(II)
PH=PH*10.0
PL=PL*10.0
IF(PH.GT.100.00) GO TO 290
GO TO 240
285 VALIN(L,IRT)=PH
290 NRATE(L)=IRT
XRATE(L,IRT)=X(II)
295 NRT=NRATE(L)-1
DO 300 JIM=1,NRT
KK=NRATE(L)-JIM
300 XRATE(L,KK)=RATE(KK)
305 CONTINUE
C
C END OF L-LOOP
C
IF(LX.EQ.1) GO TO 320
IF (LR.NE.1) GO TO 310

```

```

IROR0770
IROR0775
IROR0780
IROR0785
IROR0790
IROR0795
IROR0800
IROR0805
IROR0810
IROR0815
IROR0820
IROR0825
IROR0830
IROR0835
IROR0840
IROR0845
IROR0850
IROR0855
IROR0860
IROR0865
IROR0870
IROR0875
IROR0880
IROR0885
IROR0890
IROR0895
IROR0900
IROR0905
IROR0910
IROR0915
IROR0920
IROR0925
IROR0930
IROR0935
IROR0940
IROR0945
IROR0950
IROR0955
IROR0960
IROR0965

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```

NRR = NR
GO TO 325
C
C  SORT TO FIND LARGEST NRATE(L) WHICH DETERMINES LENGTH OF I-LOOP BELOW
C
310 KM=LX-1
DO 315 I1=1,KM
JJ=LX-I1
DO 315 J1=1,JJ
IF(NRATE(J1+1).LE.NRATE(J1))GO TO 315
ITEMP=NRATE(J1)
NRATE(J1)=NRATE(J1+1)
NRATE(J1+1)=ITEMP
315 CONTINUE
320 NRR=NRATE(1)
C
C  WRITE RATE OF RETURN
C
325 L1=1
L2=2
L3=3
L4=4
L5=5
330 LINE=0
DO 345 I=1,NRR
IF(LINE.EQ.0) GO TO 335
IF (LINE.NE.31) GO TO 340
335 WRITE (6,105) (STD(IN),IN=1,18), NO, (A(IN),IN=1,18)
WRITE (6,120)
WRITE (6,115)
WRITE (6,125) LI(1,L1),LI(2,L1),LI(1,L2),LI(2,L2),LI(1,L3),LI(2,L3)
1),LI(1,L4),LI(2,L4),LI(1,L5),LI(2,L5)
340 WRITE (6,130) XRATE(L1,I),XRATE(L2,I),XRATE(L3,I),XRATE(L4,I),XRATE(L5,I)
1E(L3,I),VALIN(L3,I),XRATE(L4,I),VALIN(L4,I),XRATE(L5,I),VALIN(L5,I)
2)
LINE=LINE+1
345 CONTINUE
IF (L5.EQ.20) RETURN
L1=L1+5
L2=L2+5

```

```

IROR0970
IROR0975
IROR0980
IROR0985
IROR0990
IROR0995
IROR1000
IROR1005
IROR1010
IROR1015
IROR1020
IROR1025
IROR1030
IROR1035
IROR1040
IROR1045
IROR1050
IROR1055
IROR1060
IROR1065
IROR1070
IROR1075
IROR1080
IROR1085
IROR1090
IROR1095
IROR1100
IROR1105
IROR1110
IROR1115
IROR1120
IROR1125
IROR1130
IROR1135
IROR1140
IROR1145
IROR1150
IROR1155
IROR1160
IROR1165

```

L3=L3+5
L4=L4+5
L5=L5+5
IF (L1.GT.LX) RETURN
GO TO 330
END

IROR1170
IROR1175
IROR1180
IROR1185
IROR1190
IROR1195

Chappelle, Daniel E.

1969. A computer program for evaluating forestry opportunities under three investment criteria. U.S.D.A. Forest Serv. Res. Pap. PNW-78, 64 pp., illus. Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.

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Headquarters for the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is in Portland, Oregon. The Station's mission is to provide the scientific knowledge, technology, and alternatives for management, use, and protection of forest, range, and related environments for present and future generations. The area of research encompasses Alaska, Washington, and Oregon, with some projects including California, Hawaii, the Western States, or the Nation. Project headquarters are at:

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