

A COMPUTER PACKAGE FOR DECISION
MAKING IN ENGINEERING ENVIRONMENTS

by

BERTAN YILMAZ BADUR

B.S. in Ch.E., Boğaziçi University, 1986

Submitted to the Institute for Graduate Studies in
Science and Engineering in partial fulfillment of
the requirements for the degree of
Master of Science
in
Industrial Engineering

Bogazici University Library



39001100310401

14

Boğaziçi University

1989

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Yard.Doç. Dr. Gül ay Barba-
rosođlu for introducing me this topic and for her invaluable guidance as the
supervisor of the thesis. I wish to thank Doç.Dr. İlhan Or and Prof.Dr. Öner Hor-
taçsu for both their constructive suggestions and serving on my thesis com-
mittee. I also would like to thank to Fulya Gülmüş for typing my thesis and to
Metin Bağcı for his invaluable helps in preparing the final outputs.

ABSTRACT

In this thesis a user oriented package program has been developed for personal computers to solve practical problems about engineering economy and decision theory and to be useful in educational studies. The program developed enables to perform calculations about the alternative uses of capital in business and engineering projects.

The package consists of five subprograms; Basic Calculation Subprogram, Decision Matrices Subprogram, Decision Matrices Imbedded to Basic Calculations Subprogram, Decision Trees Subprogram and Risk Analysis Subprogram. The program is written with Turbo Pascal Version 4.0.

ÖZET

Bu tez çalışmasında, kullanıcıya yönelik, mühendislik ekonomisi ve karar teorisi ile ilgili pratik problemlerin çözümünde ve eğitim çalışmalarında kullanılmak üzere kişisel bir bilgisayarlar için bir paket program geliştirilmiştir. Geliştirilen program, mühendislik ve işletme projelerinde kaynakların alternatif kullanılış olanakları ile ilgili hesapların yapılmasında kullanılabilir.

Geliştirilen paket program, beş programdan oluşmuştur; bunlar Temel Hesaplamalar Alt Programı, Karar Matrisleri Alt Programı, Karar Matrislerinin Temel Hesaplarla Birlikte Kullanıldığı Alt Program, Karar Ağaçları Alt Programı ve Risk Analizi Alt Programlarıdır. Program Turbo Paskal Version 4.0 ile yazılmıştır.

TABLE OF CONTENTS

| | Page |
|--|------|
| ACKNOWLEDGEMENTS | iii |
| ABSTRACT | iv |
| ÖZET | v |
| TABLE OF CONTENTS | vi |
| LIST OF FIGURES | x |
| LIST OF TABLES | xi |
| LIST OF SYMBOLS | xii |
| I. INTRODUCTION | 1 |
| 1.1. Introduction | 1 |
| 1.2. Importance | 2 |
| II. BASIC METHODS OF ENGINEERING ECONOMY | 3 |
| 2.1. Introduction | 3 |
| 2.2. Interest and Money-Time Relationships | 3 |
| 2.2.1. Simple Interest | 3 |
| 2.2.1. Compound Interest | 4 |
| 2.2.3. Equivalence | 5 |
| 2.2.4. Interest Formulas for Discrete Compounding and Discrete Cash Flows | 5 |
| 2.2.5. Interest Formulas for Continuous Compounding and Discrete Cash Flows | 8 |
| 2.3. Basic Methods of Economic Analysis | 8 |
| 2.3.1. The Present Worth Method | 8 |
| 2.3.2. The Annual Worth Method | 9 |
| 2.3.3. The Future Worth Method | 10 |
| 2.3.4. The Internal Rate of Return Method | 10 |

| | |
|---|----|
| 2.3.5. The External Rate of Return Method | 12 |
| 2.3.6. The Payback Period Method | 13 |
| 2.3.7. The Discounted Payback Period Method | 13 |
| 2.4. Depreciation | 14 |
| 2.4.1. Introduction | 14 |
| 2.4.2. The Straight Line Method | 14 |
| 2.4.3. The Declining Balance Method | 15 |
| 2.4.4. The Sum-of-the-years'-Digits Method | 16 |
| 2.4.5. The Sinking Fund Method | 17 |
| 2.5. Consideration of Taxes | 18 |
| 2.6. Consideration of Inflation | 20 |
| 2.7. Capital Budgeting | 21 |
| III. DECISION MATRICES | 24 |
| 3.1. Introduction | 24 |
| 3.2. Decisions Under Risk | 24 |
| 3.2.1. Dominance | 25 |
| 3.2.2. Expectation-Variance Principle | 26 |
| 3.2.3. Most Probable Future Principle | 27 |
| 3.4.4. Aspiration-Level Principle | 27 |
| 3.3. Decisions Under Uncertainty | 27 |
| 3.3.1. The Laplace Principle | 27 |
| 3.3.2. Maximin and Minimax Principles | 28 |
| 3.3.3. Maximax and Minimin Principles | 28 |
| 3.3.4. Hurwicz Principle | 29 |
| 3.3.5. Savage Principle | 30 |
| IV. DECISION TREES | 31 |
| 4.1. Introduction | 31 |
| 4.2. Evaluation of a Decision Tree | 32 |

| | |
|---|----|
| 4.3. Calculation of Probabilities | 33 |
| V. RISK ANALYSIS | 35 |
| 5.1. Introduction | 35 |
| 5.2. Risk Aggregation | 36 |
| VI. DESCRIPTION OF THE PROGRAM | 37 |
| 6.1. Introduction | 37 |
| 6.2. Literature Survey | 39 |
| 6.3. Basic Calculations Subprogram | 40 |
| 6.3.1. Introduction | 40 |
| 6.3.2. Inputs | 41 |
| 6.3.3. Outputs | 47 |
| 6.4. Decision Matrices Subprogram | 47 |
| 6.4.1. Introduction | 47 |
| 6.4.2. Inputs | 48 |
| 6.4.3. Outputs | 50 |
| 6.5. Decision Matrices Imbedded to Basic Calculations Subprogram | 50 |
| 6.5.1. Introduction | 50 |
| 6.5.2. Inputs | 50 |
| 6.5.3. Outputs | 51 |
| 6.6. The Decision Tree Subprogram | 54 |
| 6.6.1. Introduction | 54 |
| 6.6.2. The Decision Tree Subprogram | 54 |
| 6.6.3. The Probability Calculation Subprogram | 57 |
| 6.7. The Risk Analysis Subprogram | 61 |
| 6.7.1. Introduction | 61 |
| 6.7.2. Inputs | 62 |

| | |
|--------------------------------|----|
| 6.7.3. Outputs | 64 |
| 6.8. Conclusion and Extensions | 65 |
| APPENDIX A Examples | 66 |
| REFERENCES | 98 |

LIST OF FIGURES

| | <u>Page</u> |
|---|-------------|
| FIGURE 4.1. A Decision Tree | 34 |
| FIGURE 6.1. Flowchart of the Basic Calculations Subprogram | 43 |
| FIGURE 6.2. Flowchart of the Capital Budgeting Unit | 46 |
| FIGURE 6.3. Flowchart of the Decision Matrices Subprogram | 49 |
| FIGURE 6.4. Flowchart of the Decision Matrices Imbedded to Basic Calculations Subprogram | 52 |
| FIGURE 6.5. Flowchart of the Probability Calculation Unit | 58 |
| FIGURE 6.6. Flowchart of the Utility Calculation Unit | 59 |
| FIGURE 6.7. Flowchart of the Decision Tree Subprogram | 60 |
| FIGURE 6.8. Flowchart of the Risk Analysis Subprogram | 65 |

LIST OF TABLES

| | <u>Page</u> |
|---|-------------|
| TABLE 2.1. Discrete Compounding Interest Factors and Symbols | 6 |
| TABLE 2.2. Continuous Compounding Interest Factors and Symbols | 7 |
| TABLE 6.1. Distributions Used in the Simulation | 63 |

LIST OF SYMBOLS

M.A.R.R. : Minimum attractive rate of return

P.W. : Present worth

A.W. : Annual worth

F.W. : Future worth

I.R.R. : Internal rate of return

E.R.R. : External rate of return

I. INTRODUCTION

I.1. Introduction

This thesis is aimed at developing a user-oriented interactive package program to perform economic analysis in business and engineering environments. The program developed enables to perform calculations about evaluations of alternative uses of capital in financial and engineering projects.

An outstanding phenomenon of present-day industrial civilizations is the extent to which engineers and business managers through the use of capital are able to multiply the effectiveness of efforts and to harness resources to satisfy the needs and wants of people. Consequently, capital, in the form of money for people, machines, and materials is an economic necessity in virtually all engineering and business projects.

Engineering economy is a body of knowledge devoted to the systematic evaluation of the net worth of benefits resulting from proposed engineering and business ventures, in relation to the expenditures associated with those undertakings. Accordingly, economic analyses that primarily involve engineering and technical projects commonly are called engineering economy studies.

The first chapter is the introduction. It explains the importance of developing such a program and gives a literature survey on similar package programs. Chapters II to V explain the theoretical concepts used in the subprograms. Chapter II discusses basic engineering economy concepts, interest, measure of merits, depreciation, taxes, inflation and capital budgeting. Chapter III is on the theory of decision matrices. Decision trees are explained in Chapter

IV and finally Chapter V discusses briefly risk analysis. The package program developed is explained in the last Chapter. For each subprogram after a short explanation the inputs that should be entered by the user and the outputs generated by the programs are given. The flowcharts of the subprograms are also included in this Chapter. Eight example problems are presented in Appendix A showing the input menus and computer outputs.

1.2. Importance

Today's investors are faced with many alternative ways of evaluating their capital, under highly risky environments and changing conditions. This situation increases the importance of applying scientific quantitative methods of engineering economy and decision theory through the use of facilities provided by the fast growing computer hardware and software.

Interactive and easy to use programs, as developed in this study are useful in assisting the analyst to the solution of as many practical problems as possible, by using different methods of engineering economy. Such programs are also excellent educational tools, providing the student a quick and easy mean, to apply the theoretical concepts and to study as many hypothetical situations as possible.

II. BASIC METHODS OF ENGINEERING ECONOMY

2.1. Introduction

The majority of economy studies involve commitment of capital for a period of time such that the effect of time on the money must be considered. Consequently, money has a "time value".

In privately financed sectors of a capitalistic economy, suppliers of capital expect to receive "rent" from the use of their money. This rent is called interest and is referred to by economists as the return to capital. There are several reasons why interest is essential and must be considered in engineering economy studies and economic decision making. First, interest pays the supplier for forgoing the use of his or her money, during the time the user has it. Second, the interest is the payment for the risk the supplier takes in permitting another person, or an organization, to use his or her capital. Third, the fact that the supplier can earn interest by making capital available acts as an incentive to accumulate capital and to make it available.

2.2. Interest and Money-Time Relationships

2.2.1. Simple Interest

When the total interest earned or charged is directly proportional to the amount of the loan (principal), the interest rate, and the number of interest periods for which the principal is committed, the interest and interest rate are said to be simple.

When simple interest is applicable, the total interest I , earned or paid may be computed by

$$I = P \times N \times i \quad (2.2.1.)$$

where P : principal amount lent or borrowed

N : number of interest periods

i : interest rate per interest period

2.2.2. Compound Interest

Whenever the interest charge for any interest period is based on the remaining principal amount plus any accumulated interest charges up to the beginning of the period, the interest is said to be compound.

When compound interest is used the total interest at any period n , I_n is given by

$$I_n = i \times P_{n-1} \quad (2.2.2.)$$

$$P_n = P_{n-1} \times (1+i) \quad (2.2.3.)$$

where P_n is the deposit accumulated at period n .

Compound interest is much more common in practice than is simple interest.

2.2.3. Equivalence

An item of money has an infinite set of equivalent and potential values over time (although it can have actual existence only in one point in time). Thus, to have precise meaning an item of money must be identified, in terms of timing as well as amount. Two amounts of money or series of monies at different points in time are said to be equivalent, if they are equal to each other, at some point in time at a given interest rate.

2.2.4. Interest Formulas for Discrete Compounding and Discrete Cash Flows

Discrete compounding means that the interest is compounded at the end of each finite-length period such as a month or a year. Furthermore, the formulas assume discrete (lump-sum) cash flows spaced at equal time intervals on a cash flow diagram. Table 2.1 provides a summary of the six most common discrete compound interest factors. In Table 2.1. and Table 2.2. the factor is multiplied with the entry in column two to find the entry in column one.

TABLE 2.1. Discrete Compounding Interest Factors and Symbols

| To Find | Given: | Factor by Which to Multiply "Given" | Factor Name | Factor Functional Symbol |
|---------------------------------|--------|-------------------------------------|--------------------------------|--------------------------|
| For single cash flows: | | | | |
| F | P | $(1+i)^N$ | Single payment compound amount | $(F/P, i\%, N)$ |
| P | F | $\frac{1}{(1+i)^N}$ | Single payment present worth | $(P/F, i\%, N)$ |
| For uniform series (annuities): | | | | |
| F | A | $\frac{(1+i)^N - 1}{i}$ | Uniform series compound amount | $(F/A, i\%, N)$ |
| P | A | $\frac{(1+i)^N - 1}{i(1+i)^N}$ | Uniform series present worth | $(P/A, i\%, N)$ |
| A | F | $\frac{i}{(1+i)^N - 1}$ | Sinking fund | $(A/F, i\%, N)$ |
| A | P | $\frac{i(1+i)^N}{(1+i)^N - 1}$ | Capital recovery | $(A/P, i\%, N)$ |

"i", effective interest rate per interest period; N, number of interest periods; A, uniform series amount (occurs at the end of each interest period); F, future worth; P, present worth.

Table 2.2. Continuous Compounding and Discrete Cash Flows Interest Factors and Symbols

| To Find: | Given: | Factor by Which to Multiply "Given" | Factor Name | Factor Functional Symbol |
|---------------------------------|--------|--------------------------------------|--|--------------------------|
| For single cash flows: | | | | |
| F | P | e^{rN} | Continuous compounding compound amount (single cash flow) | $(F/P, r\%, N)$ |
| P | F | e^{-rN} | Continuous compounding present worth (single cash flow) | $(P/F, r\%, N)$ |
| For uniform series (annuities): | | | | |
| F | A | $\frac{e^{rN} - 1}{e^r - 1}$ | Continuous compounding compounding amount (uniform series) | $(F/A, r\%, N)$ |
| P | A | $\frac{e^{rN} - 1}{e^{rN}(e^r - 1)}$ | Continuous compounding present worth (uniform series) | $(P/A, r\%, N)$ |
| A | F | $\frac{e^r - 1}{e^{rN} - 1}$ | Continuous compounding sinking fund | $(A/F, r\%, N)$ |
| A | P | $\frac{e^{rN}(e^r - 1)}{e^{rN} - 1}$ | Continuous compounding capital recovery | $(A/P, r\%, N)$ |

r , nominal annual interest rate, compounded continuously; N , number of periods (years); A , uniform series amount (occurs at the end of each year); F , future worth; P , present worth.

2.2.5. Interest Formulas for Continuous Compounding and Discrete Cash Flows

In the concept of continuous compounding it is assumed that cash payments occur once per period, but that compounding is continuous throughout the period. Table 2.2 gives six important continuous compounding interest factors.

2.3. Basic Methods of Economic Analysis

2.3.1. The Present Worth Method

The present worth method is based on the concept of equivalent worth of all cash flows relative to some base or beginning point in time called the present. That is, all cash inflows or outflows are discounted to the base point at an interest rate usually the M.A.R.R..

To find the present worth of a series of cash receipts and/or disbursements, it is necessary to discount future amounts to the present by using an interest rate usually the M.A.R.R. of the firm for the number of periods

$$P.W. = F_0 + F_1(1+i)^{-1} + \dots + F_N(1+i)^{-N} \quad (2.3.1)$$

where i = effective interest rate per compounding period

k = index for each compounding period

F_k = cash flow at the end of period k

N = number of compounding periods

The criterion for this method is that as long as the net present worth, is greater than, or equal to zero, the project is economically justified; otherwise not justified (rejected).

2.3.2. The Annual Worth Method

The term annual worth (A.W.) means a uniform series of money amounts for a certain period of time that is equivalent to a particular schedule of cash inflows (receipts or savings) and/or cash outflows (disbursements) under consideration. The net annual worth of a project is its annual equivalent receipts (R), minus annual equivalent expenses (E), less its annual equivalent capital recovery (C.R.) amount. In equation form the net annual worth is

$$A.W. = R - E - CR \quad (2.3.2)$$

The criterion for this method is that as long as the net annual worth, is greater than or equal to zero, the project is economically justified otherwise, not justified.

The capital recovery cost (C.R.) for a project is the equivalent uniform annual cost, of capital invested. It is an annual amount which covers the following two items;

- i. Depreciation (loss in value of the asset)
- ii. Interest on invested capital

There are several convenient formulas by which capital recovery cost may be calculated to obtain the same result (1). The easiest formula is to find the annual equivalent of the investment and then subtract the annual equivalent of the salvage value. Thus

$$\text{C.R.} = P \frac{i(1+i)^N}{(1+i)^N - 1} - S \frac{i}{(1+i)^N - 1} \quad (2.3.3)$$

where P = investment at the beginning of life

S = salvage value at the end of life

N = life of project

i = interest rate

2.3.3. The Future Worth Method

With this method, the future worth of an alternative can be calculated in view of M.A.R.R. and compared with the do-nothing option. If future worth is greater than zero the alternative is recommended. The future worth method for economy studies is exactly comparable to the present worth method, except that all cash inflows and outflows are compounded forward to a reference point in time called the future.

2.3.4. The Internal Rate of Return Method

The internal rate of return method (I.R.R.) is the most general and widely used rate of return method for making economy studies.

This method solves for the interest rate that equates the present worth of an alternative's cash inflows to the present worth of cash outflows. The resultant interest rate is termed the "internal rate of return". For a single alternative the I.R.R. is not defined unless both receipts and disbursements are present in the cash flow pattern.

The I.R.R. is percent i at which

$$\sum_{k=0}^N R_k \frac{1}{(1+i)^k} = \sum_{k=0}^N E_k \frac{1}{(1+i)^k} \quad (2.3.4)$$

where R_k = net receipts of savings for the k th year

E_k = net expenditure for the k th year

The interest calculated by equation (2.3.4) is compared with the M.A.R.R. to assess whether the alternative is acceptable. If (i) is greater than M.A.R.R. the project is acceptable, otherwise it is not.

The A.W., P.W., F.W. methods implicitly make the assumption that net receipts less disbursements are reinvested by the firm at the M.A.R.R.. However, the I.R.R. method is based on the assumption that funds are reinvested at (i) rather than M.A.R.R.. This assumption may not reflect real situations in some applications. Other disadvantages of the I.R.R. method are computational intractability and the occurrence of multiple internal rates of return in some problems (1), (11).

2.3.5. The External Rate of Return Method

The investment assumption of the I.R.R. method coupled with the computational difficulty and possible multiple interest rates has led to the development of other rate of return methods that can remedy some of these difficulties.

The external rate of return method (E.R.R) directly takes into account the external interest rate at which net cash flows generated by a project over its life can be reinvested outside the firm. If this external reinvestment rate equals the project's I.R.R., then the results of E.R.R. and I.R.R. methods for that project become identical.

In general all cash outflows are discounted to period zero at (e) percent per compounding period, while all cash inflows are compounded to period N at (e) percent. The external rate of return is then the interest rate that establishes equivalence between the two quantities. In equation form

$$\sum_{k=0}^N E_k \frac{(1+i)^N}{(1+e)^k} = \sum_{k=0}^N R_k (1+e)^{N-k} \quad (2.3.5)$$

where R_k = excess of receipts over disbursements in period k

E_k = excess of expenditures over receipts in period k

N = project life or number of period for the study

e = external reinvestment rate per period

i = external rate of return

A project is acceptable when external rate of return is greater than or equal to the firm's M.A.R.R..

2.3.6. Payback Period Method

The payback method which is often called the simple payout method indicates a project's liquidity rather than profitability. The payback method calculates the number of years required for positive cash flows to equal the initial investment. Hence, the simple payback period is the smallest value of (θ) for which the relationship is satisfied under end-of-year cash flow convention.

$$\sum_{k=1}^{\theta} (R_k - E_k) - P \geq 0 \quad (2.3.6)$$

The payback period method ignores the time value of money and all cash flows that occur after (θ) .

2.3.7. The Discounted Payback Period Method

This method calculates the discounted payback period so that the time value of money is considered.

$$\sum_{k=0}^{\theta} (R_k - E_k) (1+i)^{-k} - P \geq 0 \quad (2.3.7.)$$

where i = minimum attractive rate of return
 θ = discounted payback period

2.4. Depreciation

2.4.1. Introduction

Depreciation is the decrease in value of physical properties with the passage of time.

Depreciation is considered in economy studies primarily for two reasons.

- i. To provide for the recovery of capital that has been invested in physical property
- ii. To enable the cost of depreciation to be charged to the cost of producing products or services that results from the use of that property. Depreciation methods included in the package program are explained briefly in the following sections.

2.4.2. The Straight Line Method

The straight line method of computing depreciation assumes that the loss in value is directly proportional to the age of the asset. The depreciation allowed at the end of each period (D_k) is equal throughout the asset's useful life and is given by

$$D_k = \frac{P - S}{N} \quad (2.4.1)$$

The undepreciated or book value at the end of each period is given by

$$B_k = P - D_k \times k \quad (2.4.2)$$

where P = original cost

S = salvage value

N = depreciable life of the asset in years

k = number of period

2.4.3. The Declining Balance Method

The declining balance method of depreciation provides for an accelerated write-off (depreciation) during the early years of the life of an asset

with progressively smaller depreciation charges with increasing years. For this method, the depreciation charge for the k th year (D_k) is equal to a fixed percentage (d) of the book value at the beginning of the k th year. Thus

$$D_k = B_{k-1} \times d \quad (2.4.3.)$$

The book value at the end of $(k-1)$ th year is given by

$$B_{k-1} = P (1-d)^{k-1} \quad (2.4.4.)$$

Thus

$$D_k = P (1-d)^{k-1} d \quad (2.4.5.)$$

Since the declining balance method never reaches a book value of zero, it is permissible to switch from this method to the straight line method so that an asset's final book value will be zero or some other salvage amount.

2.4.4. The Sum-of-the-Years'-Digits Method

The sum-of-the-years'-digits method is an alternative depreciation method for achieving accelerated write-off during the early days of life of an asset. The digits corresponding to the number of years of estimated life are added together. This sum can also be conveniently obtained by

$$SYD = \frac{N(N-1)}{2} \quad (2.4.6)$$

where SYD is the sum of the years' digits.

The depreciation charged at the end of kth year is given by

$$D_k = (P - S) \frac{(N-k+1)}{SYD} \quad (2.4.7)$$

The book value at the end of k th year is

$$B_k = P - \frac{2(P-S)}{N} k + \frac{(P-S)(k+1)k}{N(N+1)} \quad (2.4.8)$$

2.4.5. The Sinking Fund Method

The sinking fund method assumes that a sinking fund is established in which funds will accumulate for replacement purposes. The total depreciation that has taken place up to any given time is assumed to be equal to the accumulated value of the sinking fund at that time. With this method, if the interest rate on the sinking fund is known a uniform yearly deposit can be computed. The cost of depreciation for any year is the sum of that deposit and accumulated interest for that year. The equations used for the sinking fund method are respectively

$$d = \frac{(P-S) i}{(1+i)^N - 1} \quad (2.4.9.)$$

$$D_k = d (1+i)^{k-1} \quad (2.4.10.)$$

$$B_k = P - (P-S) \frac{(1+i)^k - 1}{(1+i)^N - 1} \quad (2.4.11.)$$

where i : interest rate of sinking fund
 d : uniform yearly deposit

2.5. Consideration of Taxes

The taxes paid by a corporation represent a real cost of doing business and consequently affect the cash flow profile. For this reason it is wise to perform economic analyses on an after-tax basis. After-tax analysis procedures are identical to the before-tax evaluation procedures. However, the cash flows are adjusted for taxes paid or saved.

Among numerous kinds of taxes including property, sales, excise and income taxes, income taxes are usually the only significant taxes to be considered in an economic analysis.

Taxable income must first be determined before any tax rate can be applied. Basically taxable income is gross income less allowable deductions which commonly include items such as salaries, wages, repairs, rent, taxes (other than income), interest and depreciation.

After-tax cash flow is the amount remaining after income taxes and deductions, including interest but excluding depreciation, are subtracted from gross income. In equation form

$$A.T.C.F._k = B.T.C.F._k - T_k \quad (2.5.1)$$

$$T_k = tr \cdot T.I._k \quad (2.5.2)$$

$$T.I._k = B.T.C.F._k - D_k \quad (2.5.3)$$

where

$A.T.C.F._k$: After tax cash flow at period k

$B.T.C.F._k$: Before tax cash flow at period k

T_k : Tax at period k

$T.I._k$: Taxable income at period k

D_k : Depreciation at period k

tr : Tax rate

2.6. Consideration of Inflation

Inflation is the case where the increase in prices reduces the purchasing power of money. It is a fact of life and can significantly affect the economic comparison of alternatives.

If all cash flows in an economic comparison of alternatives are inflating at the same rate, inflation can be disregarded in before-tax studies. In cases where all incomes and all expenses are not inflating at the same rate, inflation gives rise to differences in economic attractiveness among alternatives that must be taken into account.

There are two fundamental types of interest rates employed for discounting/compounding cash flows.

The real interest rate (i_r) is the marginal cost of capital that does not include a market place adjustment for the expected general inflation rate. It is the increase in real purchasing power expressed as a percent per period. The real discount rate reflects potential earning power of money in the absence of general inflation.

Combined interest rate (i_c) is the marginal cost of capital that includes a market place adjustment for the anticipated inflation rate in the economy. Thus, it represents the increase in future cash flows to cover real interest and general inflation expectations. This annual rate takes into account both inflation and the potential earning power of money. The relationship between the real and combined interest rates is given by

$$i_c = i_r + f + i_r f \quad (2.6.1)$$

where f is the general inflation rate.

2.7. Capital Budgeting

Capital budgeting may be defined as series of decisions by individual economic units, as to how much and where resources will be invested and expended for future use, particularly in the production of future goods and services.

The capital budgeting problem is discussed extensively in (6), which includes mathematical programming formulation of many different type of capital budgeting problems.

In this section a mathematical programming formulation is given for a particular type of problem which is included in the package program.

$$\max \sum_{i=1}^n \sum_{j=1}^m P_{ij} X_{ij} \quad (2.7.1)$$

st

$$\sum_{i=1}^n C_{ij} X_{ij} \leq B_j \text{ for all } j \quad (2.7.2)$$

$$\sum_{i=1}^{l_k} \sum_{j=1}^m X_{ij} \leq 1 \quad \text{for all } k \quad (2.7.3)$$

$$\sum_{j=1}^m X_{ij} \leq 1 \quad \text{for all } i \quad (2.7.4)$$

where

X_{ij} : is a zero one variable

which is one if project i is selected and starts at period j ,
zero otherwise

P_{ij} : present worth of project i started at period j

C_{ij} : initial cost of project i started a period j

B_j : budget limitation at period j

k : number of mutually exclusive group

l_k : number of mutually exclusive projects in group k

m : time horizon

n : number of projects

The objective function, described by equation (2.7.1) is the total present worth of all projects implemented. If project i starts at period; it has a present worth of C_{ij} and X_{ij} takes the value one otherwise it is zero. Constraints described by eq (2.7.2) are budget limitation constraints. If project i starts at period j it requires C_{ij} amount of investment. The total amount of money spend at each

period cannot exceed B_j the budget available at that period. Constraint (2.7.3) indicate mutually exclusive projects. That is, at most one of the projects within a mutually exclusive group can be realized and those of (2.7.4) restricts project i to be implemented once only. The problem formulated can be solved by a LP package program. In this thesis LINDO (2) used for this purpose.

III. DECISION MATRICES

3.1. Introduction

The matrix model describes a set of mutually exclusive, feasible alternatives available, where a single alternative is to be selected at the present time. In addition to the set of alternatives, there are mutually exclusive states of nature, such that the occurrence of which is not influenced by the selected alternative, and the occurrence of which is not known with certainty by the decision maker. So for each alternative versus state combination, there is an outcome and a value associated with that outcome either a loss or a gain.

Decision matrix models can be classified on the basis of the amount of information available to the decision maker as decisions under assumed certainty, decisions under risk and decisions under uncertainty.

It is reasonable to assume in many decision situations that only one state is relevant and treat the decision as if the state were certain to occur. This kind of case is termed as decisions under assumed certainty.

The theory of decision matrices is discussed in references (11) and (24).

3.2. Decisions Under Risk

A decision situation is called a decision under risk, when the decision maker elects to consider several states and the probabilities of their

occurrences are explicitly stated. In some decision problems, the probability values may be objectively known from historical records or objectively determined from analytic calculations. The decision maker may not have past records available to arrive at objective probability values. If the decision maker can assign probability values subjectively to the occurrence of each state, the decision is still treated as one under risk.

3.2.1. Dominance

The dominance principle is formally described as follows: if the values are in terms of costs and there exists a pair of alternatives A_i and A_j such that

$$V(\theta_{jk}) \leq V(\theta_{ik}) \quad (3.2.1)$$

for all k , A_j is said to dominate A_i . Alternative A_i may then be discarded from the decision problem. If the values of a decision matrix are in terms of gains the condition for A_j to dominate A_i is that

$$V(\theta_{ij}) \geq V(\theta_{ik}) \quad (3.2.2)$$

for all k .

3.2.2. Expectation-Variance Principle

For the matrix model the expected value of an alternative A_j is

$$E(A_j) = \sum_{k=1}^N V(\theta_{jk}) P_k \quad (3.2.3)$$

where P_k : probability of state k occurring

$V(\theta_{jk})$: matrix value of alternative A_j when state k occurs.

The expected values for each of the alternatives are calculated. If the principle of maximizing (minimizing) the expected gain (loss) is followed, the alternative with maximum (minimum) expected value is chosen. A corollary of the expected-value criterion is that, in the event of a tie in expected value for two or more alternatives, the alternative having minimum variance should be chosen. The variance of an alternative is given by

$$v(A_j) = \sum_{k=1}^N (V(\theta_{jk}) - E(A_j))^2 / (N-1) \quad (3.2.4)$$

3.2.3. The Most Probable Future Principle

If, in a decision under risk, one state has a probability of occurrence considerably greater than any other, the most probable future principle is to consider this state as certain and all other states as having a zero chance of occurrence. The decision is thereby reduced to a decision under assumed certainty. Then an alternative is chosen that maximizes (or minimizes) the measure of effectiveness being used under the assumed certainty condition.

3.2.4. The Aspiration-Level Principle

In most real-world decisions, the complexity of the decision prevents the discovery and selection of an alternative that will yield the single best result, and the decision makers set aspiration levels and then evaluate alternatives against them. An interpretation of this philosophy is to select an alternative that maximizes the probability of achieving the desired aspiration level.

3.3. Decisions Under Uncertainty

A decision situation where several states are possible, and sufficient information is not available to assign probability values to their occurrence is termed a decision under uncertainty.

3.3.1. The Laplace Principle

The philosophy of the Laplace Principle is simply that, if one can not assign probabilities to the states, the states should be considered as

equally probable. Then, consider the decision as one under risk.

3.3.2. Maximin and Minimax Principles

The maximin and minimax principles represent a single philosophy, depending on whether matrix values are gains or losses, respectively. If the matrix values are gains, the minimum gain associated with each alternative is determined and the maximum value in the set of minimum values designates the alternative to be chosen. Formally stated, the maximin principle is to select the alternative, j , associated with the

$$\max_j \min_k V(\theta_{jk}) \quad (3.3.1)$$

In case of a decision dealing with costs, the minimax principle is applied. The maximum cost associated with each alternative is determined and the minimum value in the set of maximum values designates the alternative to be chosen.

3.3.3. Maximax and Minimin Principles

For the extreme optimist person, in a given decision, situation involving gains, maximax principle selects the alternative, that affords the opportunity to obtain the largest value given in the matrix.

If the matrix values were losses, an pessimistic philosophy of choice is to select the alternative that affords the opportunity to obtain the minimum

loss value given in the matrix.

3.3.4. Hurwicz Principle

The Hurwicz Principle considers that a decision maker's view may, in the case of gains (losses), fall between the extreme pessimism of the maximin (minimax) principle and the extreme optimism of the maximax (minimin) principle and offers a method by which various levels of optimism (pessimism) may be incorporated into the decision by defining an index of optimism x , on a scale from zero to one. The Hurwicz value (H_j) is computed for each alternative as

$$H_j = x \max_k V(\theta_{jk}) + (1-x) \min_k (V\theta_{jk}) \quad (3.3.2)$$

for a gain matrix and

$$H_j = x \min_k V(\theta_{jk}) + (1-x) \max_k V(\theta_{jk}) \quad (3.3.3)$$

for a loss matrix.

Thus, the alternative maximizing (minimizing) that value is selected.

3.3.5. Savage Principle

This principle introduces and defines a quantity termed regret. A matrix consisting of regret values is first developed. Then the maximum regret value for each alternative is determined and the alternative associated with the minimum regret value is chosen from the set of maximum regret values. The regret matrix is determined as follows.

- i. For each state search the matrix columns and determine the largest (smallest) gain (loss). Assign this gain (loss) a zero regret value.
- ii. For all other gain (loss) values subtract these from the gain value in (i) (subtract the smallest loss value in (i) from these). The difference is interpreted as units of regret.

IV. DECISION TREES

4.1. Introduction

In this chapter sequential decisions under risk is discussed, the decision-tree representation is used, and the logic of Bayes theorem is applied in the solution of the decision-tree problem. The concept of decision trees is discussed in references (2), (11) and (24).

Before presenting the graphic technique and solution procedure, it is necessary to define the symbols used.

Δ : a decision node.

Δ — : a branch emanating from a decision node which represents an alternative that can be chosen at this node.

\bigcirc : a chance node in the tree where chance events influence the outcomes of an alternative choice.

\bigcirc — : a branch representing a probabilistic outcome for a given alternative. It is assumed that branches emanating from a node in the tree represent mutually exclusive and collectively exhaustive outcomes such that their probabilities sum to one.

\square : an end node having a value associated with a particular outcome.

4.2. Evaluation of a Decision Tree

In Figure 4.1. a symbolic decision tree for a simple sequential decision problem is presented. The sequential decision problem depicted involves two decision points, D_1 and D_2 . If alternative A_1 is chosen it can have two outcomes, θ_1 , and θ_2 . If θ_1 occurs, then a decision, D_2 , is required. If alternative A_{11} is chosen, there can be the two outcomes, θ_{111} and θ_{112} . For each branch in the tree there is an associated value. For example, if alternative A_1 is chosen and outcome θ_1 occurs and alternative A_{11} is chosen and outcome θ_{111} occurs, then value V_{111} results with the conditional probability P_{111} . The first decision is made at decision point D_1 , and if alternative A_1 is chosen, then a second decision is required at D_2 .

The principle of maximizing expected gain or minimizing expected loss is adopted as the principle of choice at each decision point. The solution procedure advocated is to reach the best decision at the decision point most distant from the base (the first decision) of the tree. Then, replace this most distant decision point with the best expected value and work backward through decision nodes until the best decision is made at the initial decision node. At a decision node the choice is given formally for a given maximization problem

$$\max_k V(\theta_k) \quad (4.3.1)$$

For a cost minimization problem

$$\min_k (V\theta_k) \quad (4.3.2)$$

where

$V(\theta_k)$ value of sub node k.

4.3. Calculation of Probabilities

The required marginal, conditional and joint probabilities may be calculated using a fundamental theorem from the probability theory called the Bayes theorem.

$$P(B_i/A) = \frac{P(A/B_i) P(B_i)}{\sum_{u=1}^n P(A/B_u) P(B_u)} \quad (4.3.1)$$

where

B_i : i th partition of event B

n : number of partitions of event B.

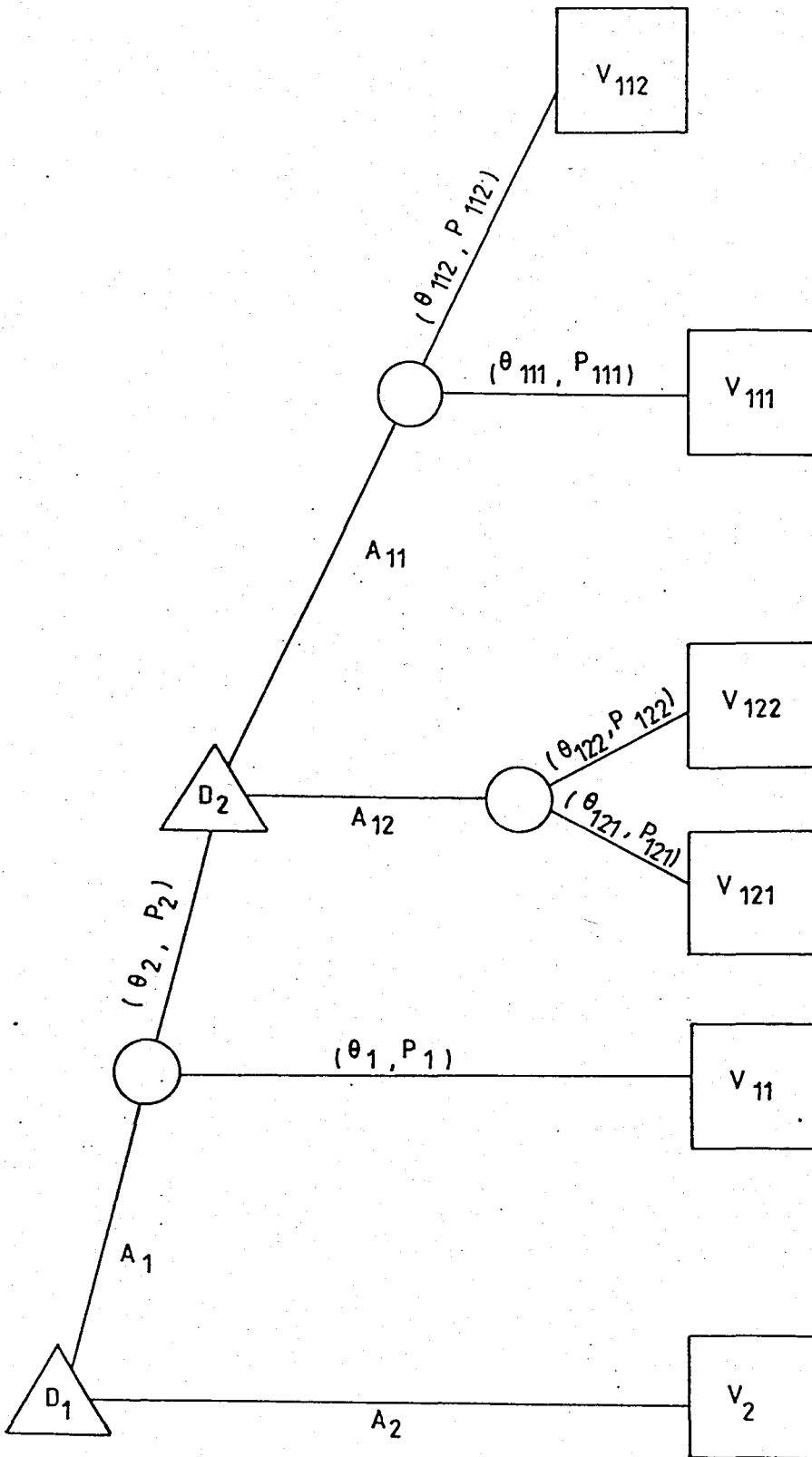


Figure 4.1. A Decision Tree

V. RISK ANALYSIS

5.1. Introduction

Risk analysis may be defined as the process of developing probability distributions for some measure of merit for an investment proposal. Typically, probability distributions are developed for either present worth, annual worth or the rate of return for an individual investment alternative. Consequently, probability distributions are required for random variables such as the cash flows, the planning horizon, and the discount rate. The probability distributions are then aggregated analytically or through simulation to obtain the desired probability distribution for the measure of merit.

The cash flow occurring in a given year is often a function of a number of other variables such as selling prices, size of market, share of the market, market growth rate, investment required, inflation rate, tax rates, operating and fixed costs, and salvage values of all assets. The values of a number of these random variables can be correlated with each other, as well as autocorrelated. Consequently, an analytical development of the probability distribution for the measure of merit is not easily achieved in most real-world situations. Thus, simulation is widely used in performing risk analyses.

The concept of risk analysis is discussed in references (1), (2), (11), (12), (13), (14) and (15) are excellent references for simulation techniques.

Probability distributions for the random variables are usually developed on the basis of subjective probabilities. Among the theoretical probability distributions commonly used in risk analysis are the normal distribution and the

beta distribution. In some situations the subjective probability distribution cannot be represented accurately using a well-known theoretical distribution. Instead, one must estimate directly the probability distribution for the random variable.

5.2. Risk Aggregation

Given the essential factors and their associated probability distributions, it requires to aggregate the distributions and obtain the probability distribution for the measure of merit. Three measures of merit have been mentioned: present worth, annual worth, and rate of return. In practice, a combination of the rate of return and either the present worth or the annual worth measures of merit are often used.

Risk aggregation is achieved in basically two ways: analytically and by using simulation. Analytic approaches can be used in a number of simple cases. For more complex situations involving a large number of variables simulation is used. In this thesis the simulation approach is implemented.

VI. DESCRIPTION OF THE PROGRAM

6.1. Introduction

In the thesis a user-oriented interactive package program is developed to perform economic analysis in the business and engineering environments.

The main advantage of the program developed is to contain many subprograms, dealing with different theoretical aspects of the broad engineering economy subject, and providing an integration among some of them so that the result obtained from one method can be used as an input in the other directly. The program enables the user to perform calculations about various practical problems by providing a flexible input possibility, and a richness in the selection of methods.

The program is written with Turbo Pascal version 4.0 suitable for IBM compatible P.C.'s. The version 4.0 of Turbo Pascal is the fourth generation of Borland's Flagship Language product (26). The user runs the program by typing the command ENGEC.

The main package program consists of five subprograms:

- i) The Basic Calculations Subprogram
- ii) Decision Matrices Subprogram
- iii) Decision Matrices Imbedded to Basic Calculations Subprogram
- iv) Decision Tree Analysis Subprogram
- v) Risk Analysis Subprogram

The first three are in one disk while the last two are in another. The user, must have also the LINDO package to run the capital budgeting unit.

The basic calculations program is in the file DCEE.EXE(72kbites). The decision matrices and D.M. Imbedded to B.C. program are in the same file DCEEM.EXE(58 kbites). The decision trees program is in the file DECTRE.EXE(31kbites) and risk analysis program is in the RISK.EXE(59kbites).

Some features of the package program are:

i) The program is designed for those who are just familiar to personal computers but does not assume the user to know programming. The information and messages can easily be understood.

ii) The program uses a menu driven structure that enables the user to recognize the options available to address a problem. The highest level menu is the subprogram menu. Once a subprogram is selected the user is enabled to enter a new problem, read an existing problem, or see the directory saved files formed by the subprogram. Several options also have associated menus to direct the user.

iii) The program enables users to enter data from the keyboard or read data from a diskette, if the data have been stored. Entry formats are designed to be compatible with most conventional textbook formats.

Therefore, users who have studied the basic concepts of engineering economy and management science will find the problem structuring and data entry easy. Every subprogram has the capacity to modify an existing problem.

6.2. Literature Survey

The theoretical aspects of engineering economy and decision theory may be found in references (1) through (11). (12) is an excellent monograph on risk analysis giving many practical examples.

Parallel to the development of theoretical and quantitative methods of engineering economy and decision theory, many computer programs have been prepared which are capable of performing capital investment and financial analysis. Some of the package programs and brief explanations about them are given below.

(16) provides Monte Carlo simulation to determine the distribution of measure of merit, includes many useful options on depreciation methods, sensitivity testing features, sample size determination, and plotted distribution functions. (17) determines the distribution of the rate of return and net present value for capital investments subject to uncertain incomes and expenses. (18) provides a means of generating the financial information required to evaluate the economic worth of potential business investments through the application of the present worth method. (19) and (20) make present worth comparison of leasing with the alternative of borrowing money to purchase an asset. Sensitivity analysis can be performed on purchase price, Lessee's income tax rate, interest on loan, after-tax opportunity rate, monthly rent, depreciable life of the asset, salvage value for tax purposes and actual salvage value. (21) and (23) provide evaluations for comparison of alternative plant expansions using Monte Carlo simulations with options regarding the measure of merit. (22) performs sensitivity analysis, varies inputs and calculates their impact on outputs. (24) is a computer package program for PC's including many units to perform calculations

in the fields of Operation Research and Management Science. This program has the Decision Tree and Decision Matrix Analysis subprograms. (25) is an interactive, user friendly, educational oriented decision support system that covers most topics in introductory courses in Management Science. This program contains a decision theory subprogram capable of performing mean variance, pay-off and decision tree analysis.

6. 3. Basic Calculations Subprogram

6.31. Introduction

The basic calculations subprogram calculates the present, annual and future worth, internal and external rate of return, payback and discounted payback period of a single or a set of mutually exclusive or independent projects, considering four different depreciation methods: straight line, declining balance, sinking fund and sum of the years' digits, as well as taxes and inflation. The subprogram has also a capital budgeting option considering budget limitations on periods of initial investment and mutually exclusive groups of projects. The solution of the capital budgeting problem determines not only the feasible projects but also the starting times of them within a planning horizon. Some projects may be mutually exclusive and initial investments are restricted with budget limitations at certain periods. The execution of the capital budgeting unit requires a second disk drive. The diskette containing DCEE.EXE is put in drive A, while the diskette containing LINDO is inserted to drive B; after the message "Insert the disk containing LINDO to drive B: and press any key." appears. The program makes an integer programming formulation of the capital budgeting problem, writes the formulation on a text file LIN IN. PAS,

calls LINDO (27) a package program to solve LP and ILPS which reads the text file, solves the problem and writes the solution to another text file LINOUT.PAS. Then the basic calculations subprogram reads the solution from LINOUT.PAS and evaluates and displays the results.

The theoretical concepts related to the basic calculations subprogram are discussed in Chapter II. The flowchart of the program is given in Figure 6.1 and 6.2, and four examples are included in Appendix A.

6.3.2. Inputs

i) Number of alternative projects: The maximum number of projects is 20 for basic economic calculations and 10 for capital budgeting problems.

ii) Whether a capital budgeting problem or a simple comparison problem to be solved.

iii) Type of input data of projects: There are two options of entering monetary data for projects:

1) The program requires the direct entry of the cash-flow values of each alternative period by period.

2) The initial value, salvage value, project life, annual revenue and cost are entered for each alternative project.

iv) Input data of projects: If option "1" is selected in "iii" then cash flow values are entered period by period for each alternative. The maximum number of periods is 50 if option "2" is selected the project name, initial investment, salvage value, project life, annual revenue and costs are entered for each project.

v) In case the user enters wrong data or wants to change some in a subsequent run, there is a "change data" facility for the related inputs.

vi) Minimum attractive rate of return, whether to use discrete or continuous interest, whether to consider inflation or not, if necessary, inflation rate are asked subsequently.

vii) The measure of merit: There are seven measures of merit as present worth, annual worth, future worth, internal rate of return, external rate of return, payback period, and discounted payback period.

viii) The program calculates cash flows for each project. The cash flows can be displayed if desired.

ix) The user is asked to indicate whether depreciation and taxes are considered or not. If the user enters "yes" the program asks to select a depreciation method among straight line, declining balance, sum of the years' digits and sinking fund methods. The new cash flow values after considering depreciation as well as book values at the end of each period can also be seen optionally.

x) Tax rate: A tax rate is asked to the user. The program calculates taxable income and after tax cash-flow for each project, which can be displayed on the screen.

Questions Related to the Comparison of Alternatives:

xi) If the number of projects is greater than one, the question whether they are mutually exclusive or independent is asked. In case of their being mutually exclusive the two possible assumptions to be selected are repeatability and cotermination. If the cotermination option is chosen a cotermination period is asked.

xii) See modified cash flows: The program calculates the modified cash-flows using the selected assumption and asks whether to display the results or not.

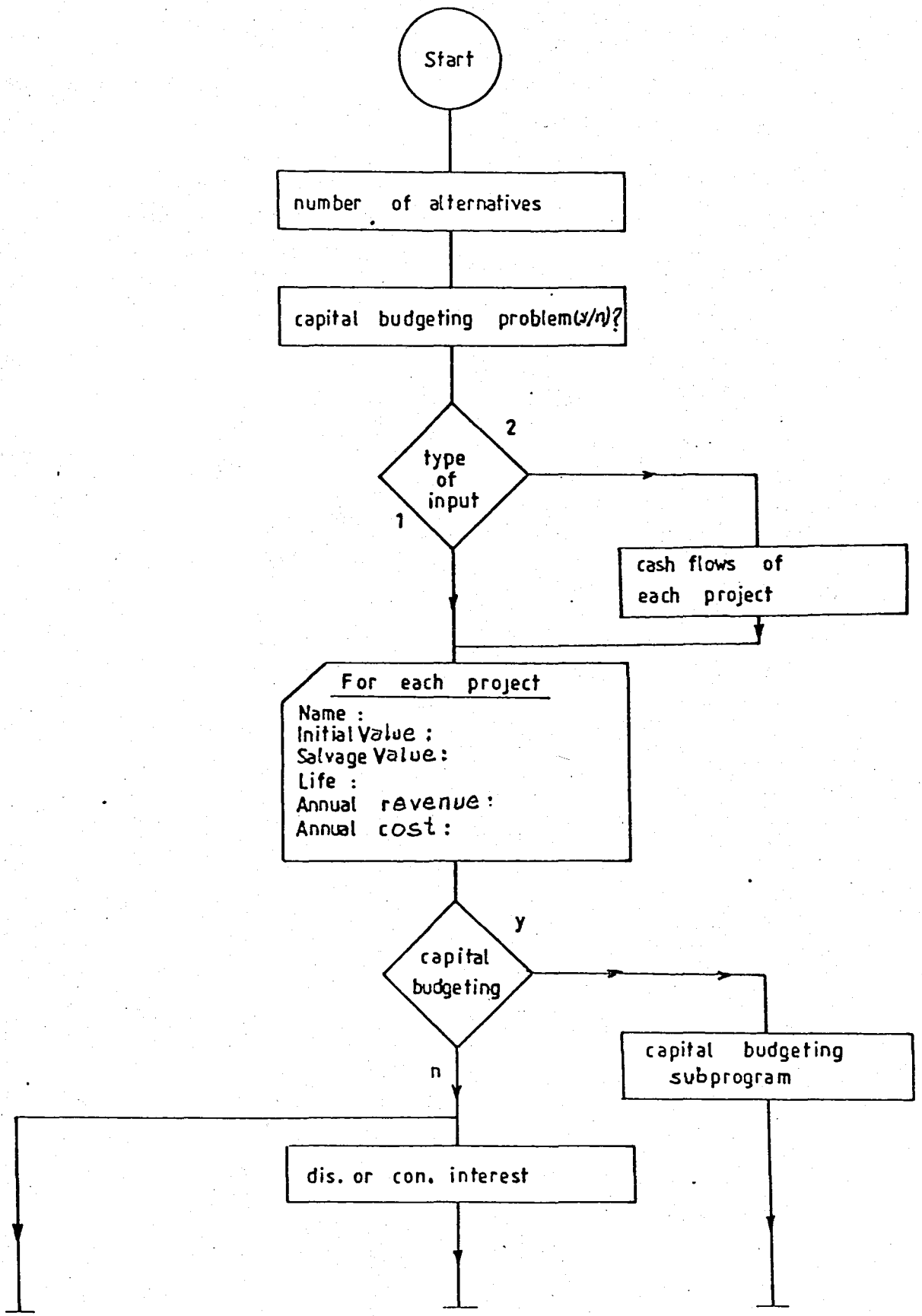
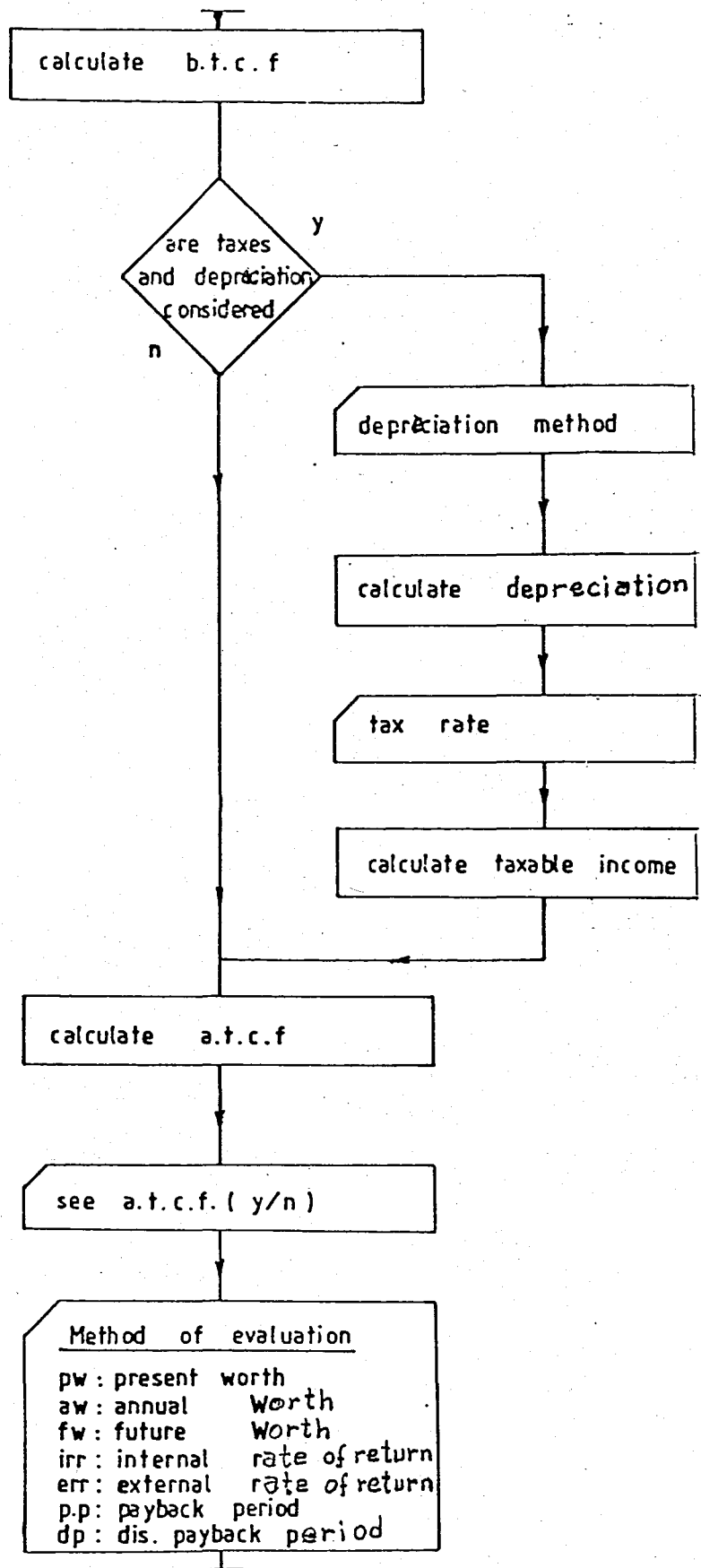
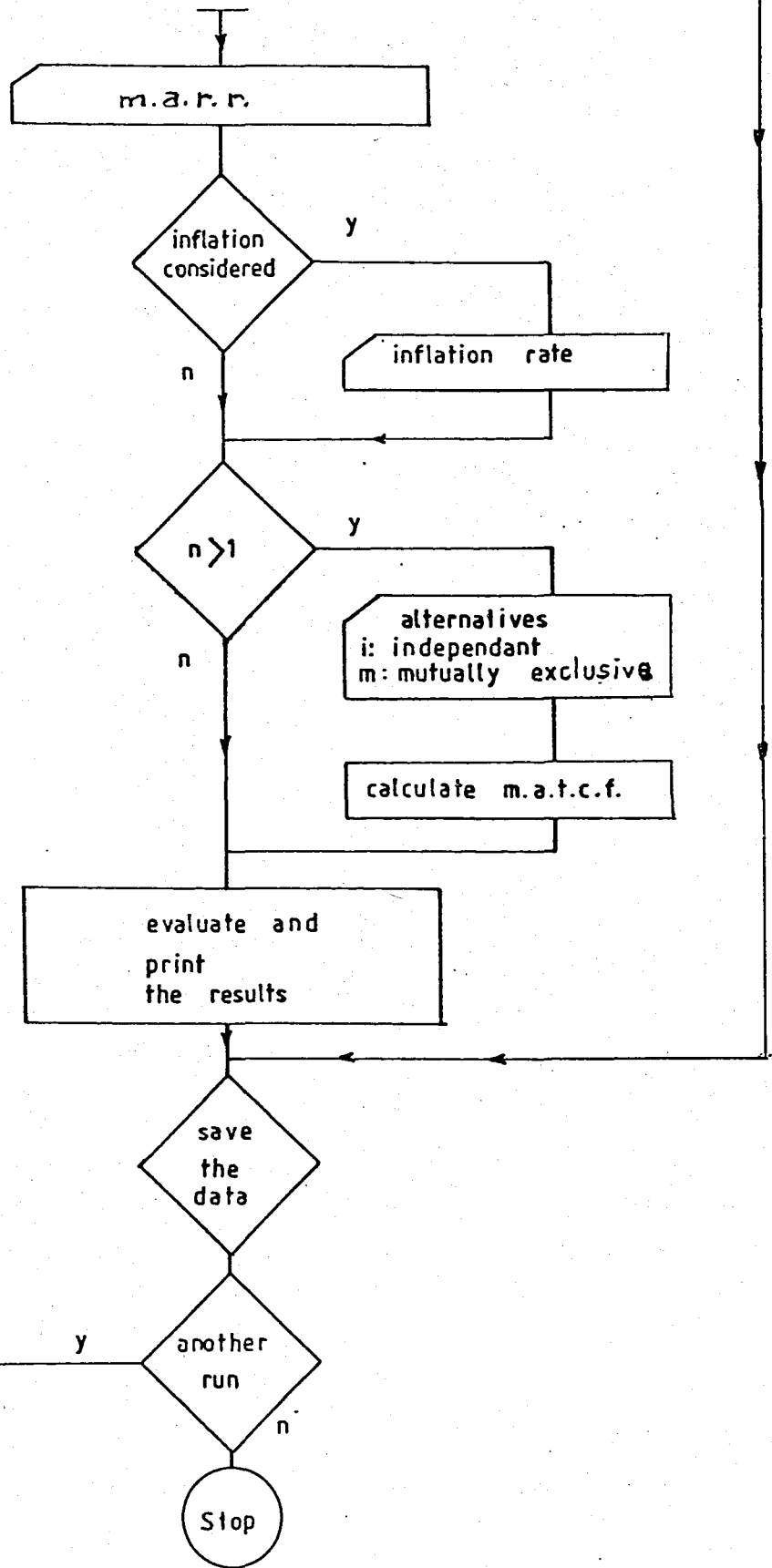


Figure 6.1. Flowchart of the Basic Calculations Subprogram



Continuation of Figure 6.1.



Continuation of Figure 6.1.

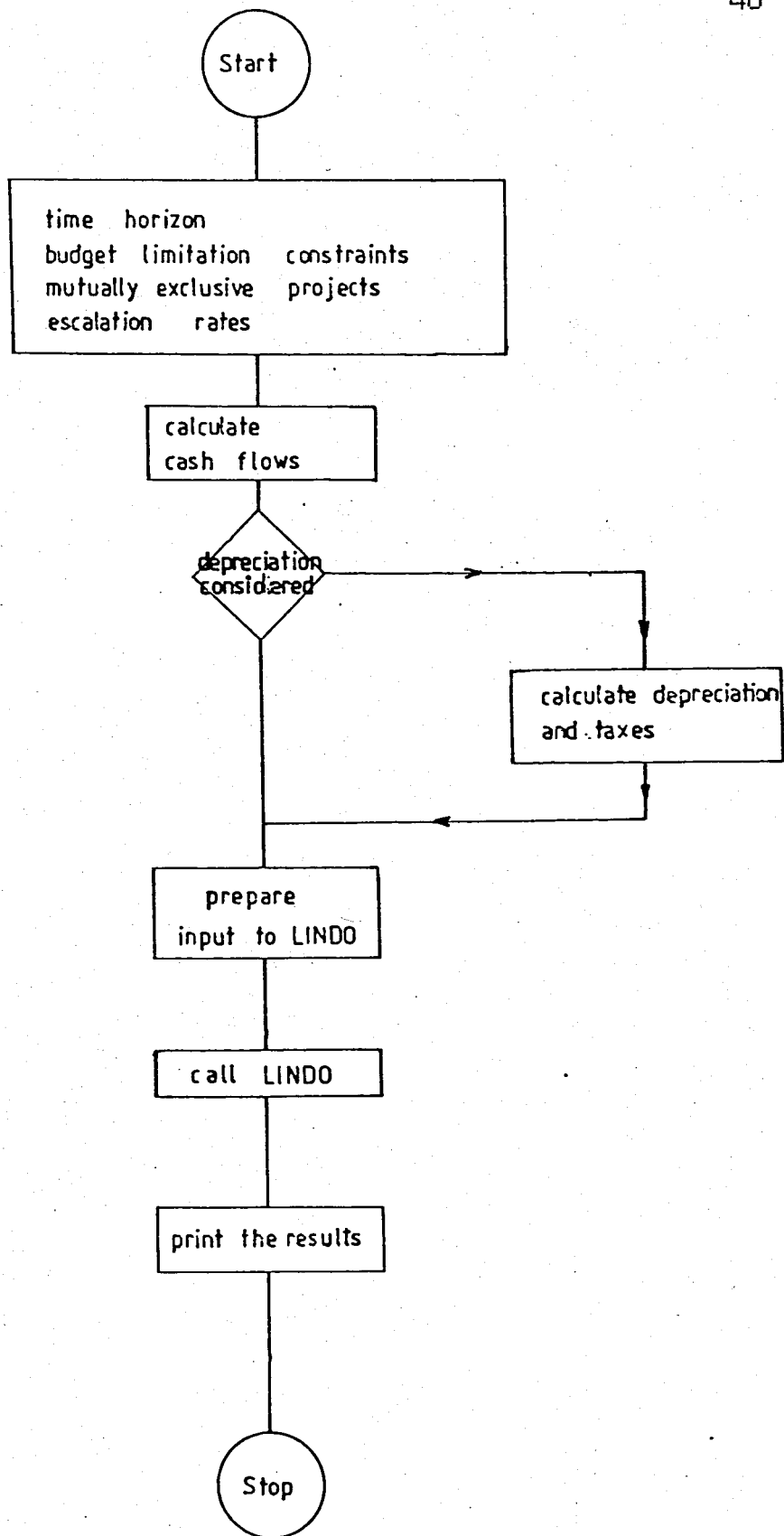


Figure 6.2. Flowchart of the Capital Budgeting Unit

Questions Related to the Capital Budgeting Option:

xiii) Planning horizon: The planning horizon must be less than the minimum project life.

xiv) Periods with limited budget: The number of periods with budget constraint is asked. The user enters the value of limited budget for each period.

xv) Mutually exclusive groups: Number of mutually exclusive groups, number and names of mutually exclusive projects in each group is asked.

6.3.3. Outputs

For each project the project name and the value of selected measure of merit are displayed. For the capital budgeting problems in addition to their names and present worths the selected projects are shown with their starting times.

6.4. Decision Matrices Subprogram

6.4.1. Introduction

The Decision Matrices Subprogram provides decision matrix analysis of the up to 20 alternatives and 20 states of nature. The decision problem can be either under risk or uncertainty. There are four criteria available; dominance, expectation-variance, most probable future, aspiration level for decisions under risk, while five criteria as Laplace, maximin-minimax, maximax-minimin, Savage and Hurwicz Principles for decisions under uncertainty.

The theory of decision matrices is discussed in Chapter III, the flow-chart of the subprogram is given in Figure 6.3, and an example problem is given in Appendix A.

6.4.2. Inputs

i) Number of alternatives and states: The program asks the number of alternatives, number of states and a name for each alternative. Maximum number of alternatives and states is limited with 20.

ii) The decision matrix: The elements of the decision matrix are entered such that for each state of nature and for each alternative a gain or a cost value is provided.

iii) Gain or cost problem: The question whether the matrix values are gains or costs is asked.

iv) Type of decision problem: The user is asked to choose either a decision under risk or uncertainty problem. If the former is chosen for each state a probability value is required. In case the sum of the probabilities is not equal to unity, the facility of reentering is provided.

v) Decision criteria: Depending on the choice in (iv) the program displays to select a decision criteria. If it is a decision under risk problem, the options are: dominance, expectation-variance, most probable future, and aspiration level. In case of an uncertainty decision, the choices are Laplace, maximin-minimax, maximax-minimin, Hurwicz and Savage Principles.

vi) Changing facilities: The decision matrix as well as the probability values can be updated and the problem can be resolved for the new values.

vii) Saving: The user can save the entries of the decision matrix in a binary file and can load the same file in a subsequent run.

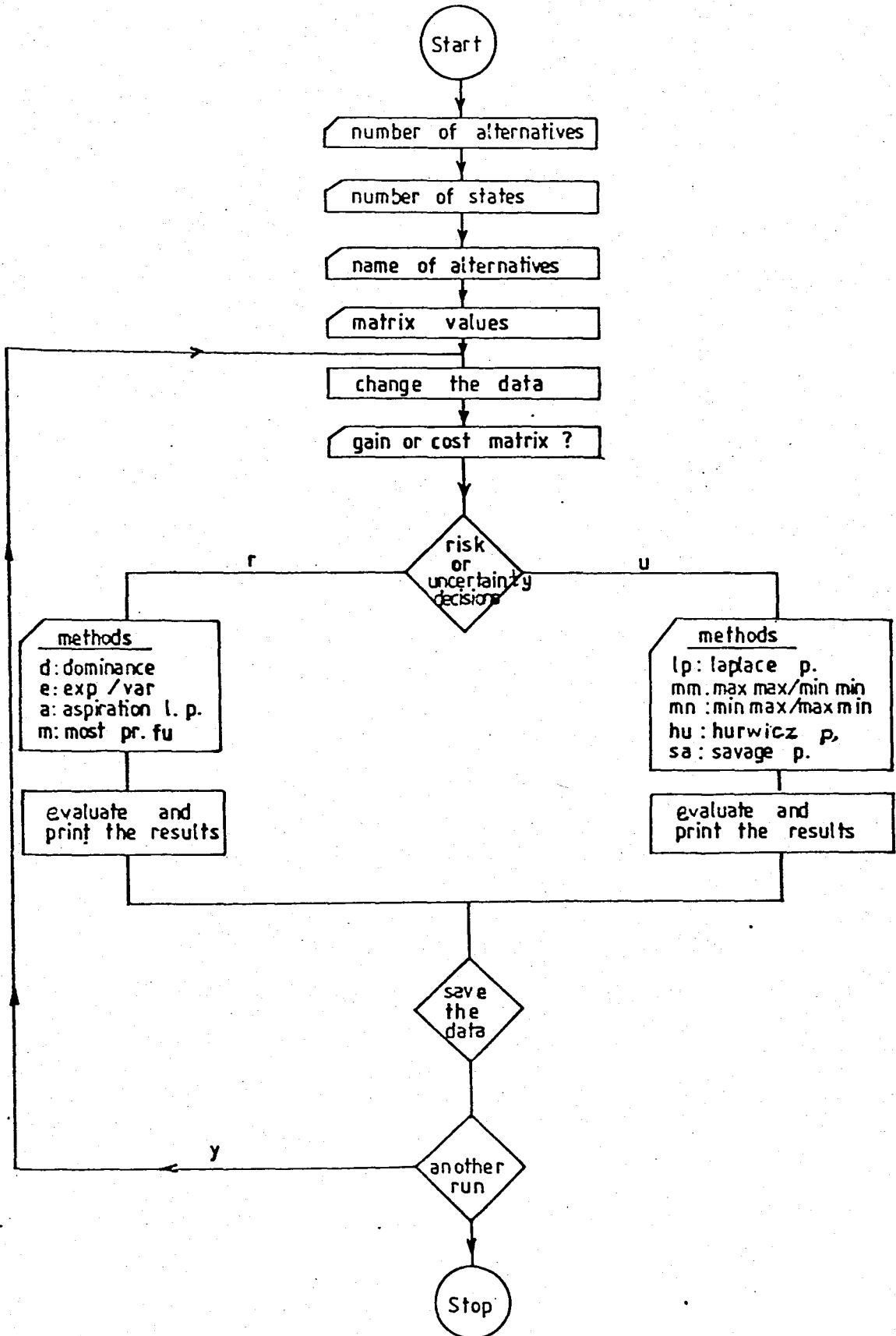


Figure 6.3. Flowchart of the Decision Matrices Subprogram

6.4.3. Outputs

The program displays the name of each alternative with their related figures, which depends on the chosen decision criteria, and indicates the selected alternatives with a crossmark.

6.5. Decision Matrices Imbedded to Basic Calculations Subprogram

6.5.1. Introduction

The subprogram imbeds decision matrices into the basic calculation unit in such a way that it forms a decision matrix from a set of alternative projects where the states may be initial value, salvage value, life, annual revenue, annual cost of projects, M.A.R.R. or inflation rate.

The program first calculates the selected measure of merit for each alternative, and each value of the state variable. The decision matrix formed is evaluated then with respect to a final decision criterion to select the best alternative(s). The flow chart of the subprogram and an example problem is given in Figure 6.4 and in Appendix A respectively.

6.5.2. Inputs

i) Number of alternatives and states: The maximum number of both alternatives and states is limited with 20. A name for each alternative is also asked.

ii) The random or uncertain variable: The random variable may be ini-

tial investment, salvage value, life, annual revenue, annual cost of projects, M.A.R.R. or inflation rate. Corresponding to each state of nature a value is entered for the random or uncertain variable.

iii) Measure of merit: The options for the measure of merit may be present, annual, future worth, internal or external rate of return, payback or discounted payback period.

iv) Type of decision: The problem may be a decision under risk or a decision under uncertainty.

v) Probability values: If the problem is a "decision under risk" type, a probability value is asked for each state. In case the sum of the probability values is not unity, the possibility of reentering is provided.

vi) Decision criteria: The options available for the decision criteria for problems of decisions under risk are dominance, expectation variance, most probable future and aspiration level principles while for decisions under uncertainty, the criteria are Laplace, minimax and maximin, maximax and minimin, Hurwicz and Savage principles.

6.5.3. Outputs

The decision matrix formed is displayed before the final decision criterion is asked. The selected alternatives and their related figures are indicated in the same way as the output of the decision matrix subprogram.

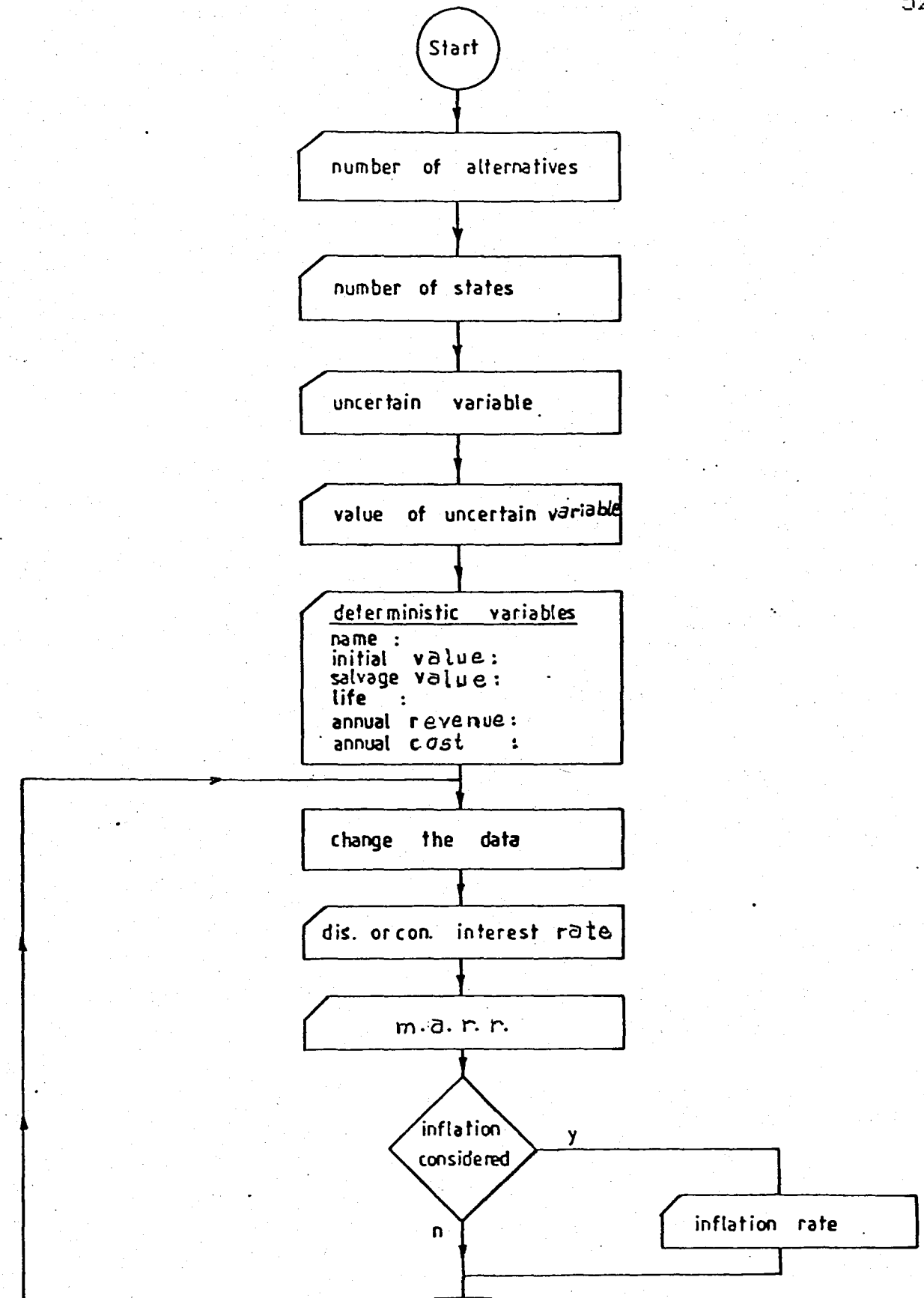
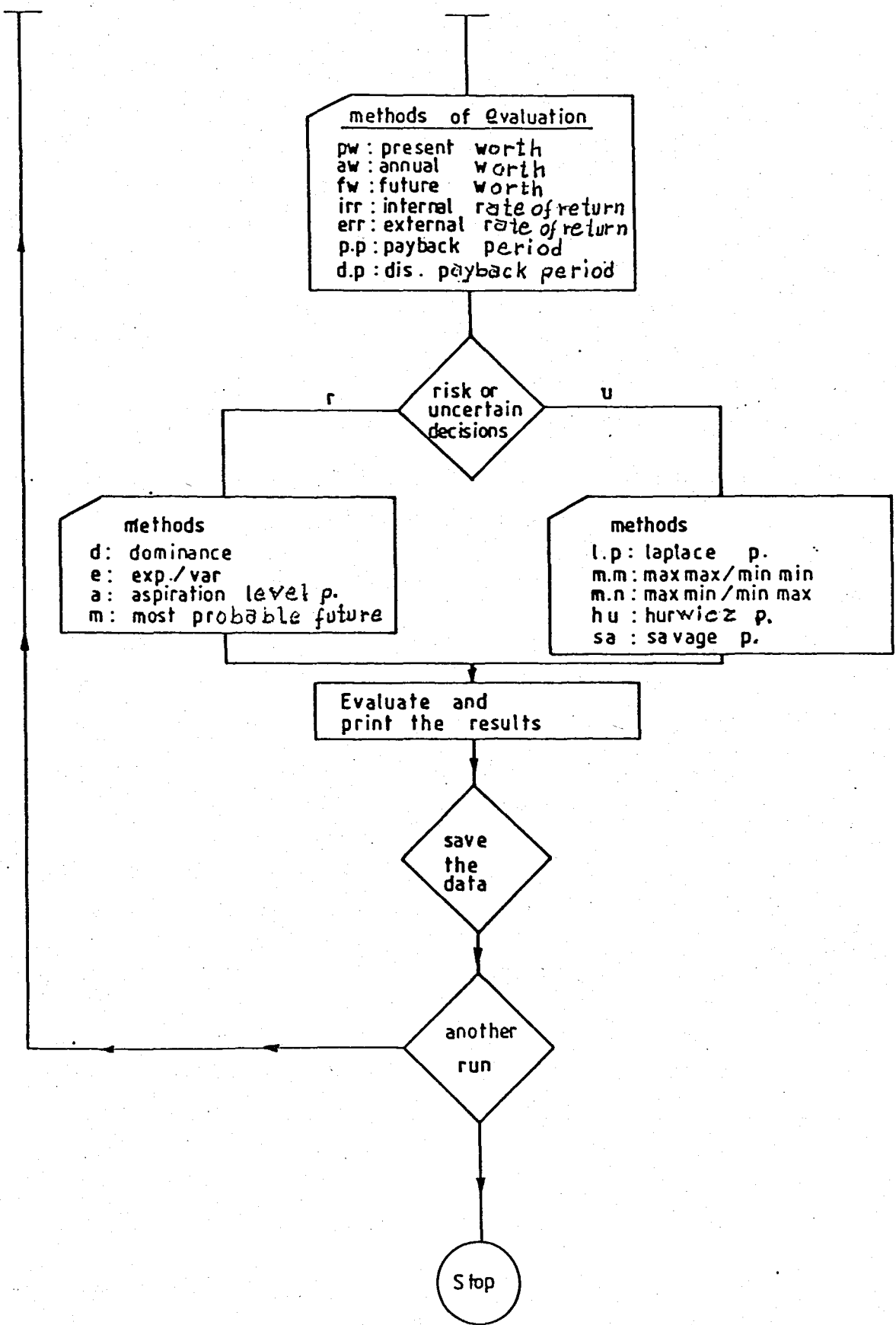


Figure 6.4. Flowchart of the Decision Matrices Imbedded to Basic Calculations Subprogram



Continuation of Figure 6.4.

6.6. The Decision Tree Subprogram

6.6.1. Introduction

The subprogram performs decision tree analysis for payoff and utility values and calculates posterior probabilities from priori probabilities.

Each node occupies 57 bytes of memory. The maximum size of memory available for pointer variables in Turbo Pascal depends on the memory available in the computer and is 64 kbytes so the program can handle problems upto 1000 nodes.

The theoretical background for the decision trees, and probability calculations are explained in Chapter IV. The flowcharts of the subprogram are shown in Figures 6.5 to 6.7 and an example is given in Appendix A.

6.6.2. The Decision Tree Subprogram

a. Inputs

i) Name of the base node: The program asks the name of the base node. The name cannot be more than 10 characters.

ii) Type of the base node: The base node can be a decision chance or an end node.

iii) Gain or cost problem: The decision problem can be a cost minimization or gain maximization one.

iv) Solution in terms of payoffs or utilities and payoffs: If the user selects utilities the program asks questions about the user's utility curve and pre-

sents solutions both in terms of payoffs and utiles.

The Utility Calculation Part: There are essentially two components of the utility analysis segment of the program. The first is concerned with the determination of the utility curve itself and the second is concerned with changing all payoffs to utiles. The utility analysis component of the program is activated when the user responds "u" to the question "solution in terms of payoffs or utiles and payoffs".

The program begins asking maximum and minimum payoff values and assigns the utile values 1 and 0 to them respectively. The smallest value possible is zero, the highest is one by convention. Hence all utile values are within the interval zero to one.

The following question is asked to the user three times and is aimed at determining the shape of the utility curve assuming the user in possession of a lottery ticket involving receipts of just one of the two possible money payoffs, each of which is considered equally likely. Hence each will occur with probability 0.5. The question asked to the user is as follows:

"Assume you are in possession of a lottery ticket involving receiving xxx or receiving yyy which are equally likely. How much would you be willing to sell the lottery for?"

Where xxx and yyy are related payoffs.

In the first question xxx and yyy are maximum and minimum values entered by the user previously. The utile value 0.5 is assigned to the payoff that the user responds to the question. In the second question xxx is the minimum

value and yyy is the payoff declared in the first question. The utility value of 0.25 is assigned to the response to the second question. Finally the utility value of 0.75 is assigned to the response to the third question in which xxx and yyy take the maximum value and payoff entered in the first question respectively. Then, the utility value corresponding to any payoff is obtained by interpolation.

b. Outputs

At each node the program displays the following information about the related node:

i) Path: The names of the intermediate nodes along the path, from the base node to the current one are written respectively.

ii) Name: Name of the current node.

iii) Node type: The node can be a chance decision or an end node. If the current node is a base node, the word "base" is written.

iv) Node value: If the current node is an end node or has a cost, the payoff value and the corresponding utility value are written.

v) Branch nodes: Names, probabilities and if possible payoff and/or utility values of each subnode are displayed.

vi) Evaluated value: If the tree can be evaluated at the current node that is all subnodes have been completed, the program evaluates the tree and writes the payoff and/or utility value.

vii) The choices: The user can choose the following options at each node:

1) Insert: The program inserts a new subnode or nodes at the current node, asking the user, name, type, value, and probability of that branch nodes if necessary.

2) Delete: Deletes a specified subnode.

3) Change: Changes the name, type, value of the current node or alters the probability values of branches if the type of the node is chance.

4) Back track: Back tracks one node. If the current node is the base node nothing happens.

5) Back to base: Goes and displays the base node.

6) Enter into subnode: Enters into a specified subnode.

7) Autoinsert: If the tree is not completed at any node, finds that node and displays information about it.

8) Complete subnode: If the tree is not completed at any subnode finds and displays information about that subnode.

9) Quit: Exit from the current tree.

10) Save: Saves the tree in a binary file.

6.6.3. The Probability Calculation Subprogram

This subprogram computes the conditional marginal and joint probabilities of the resultant outcomes from the given probabilities of the priori outcomes.

a) Inputs

i) Number of priori outcomes

ii) Number of resultant outcomes

iii) Names of priori outcomes

iv) Probabilities of priori outcomes: If the sum of the probabilities is not unity, it is possible to reenter the data.

v) Conditional probabilities of resultant outcomes on priori outcomes.

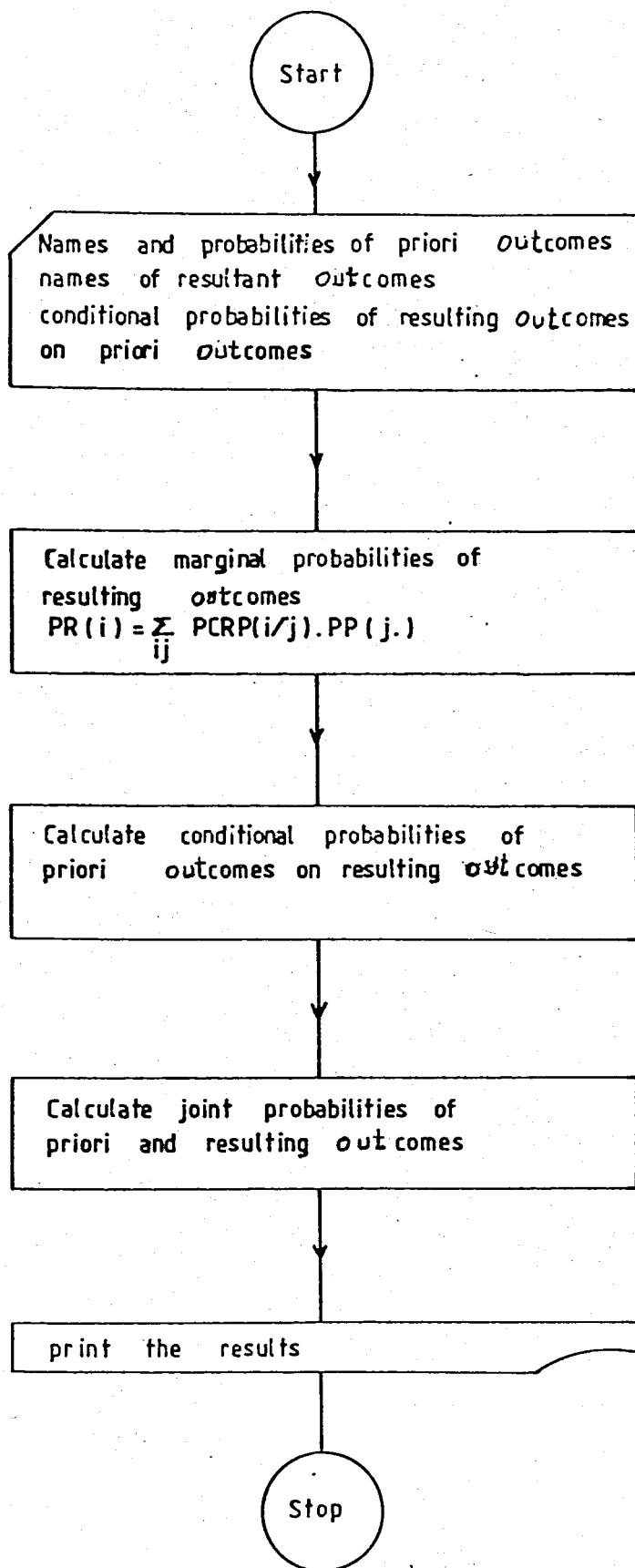


Figure 6.5. Flowchart of the Probability Calculation Unit

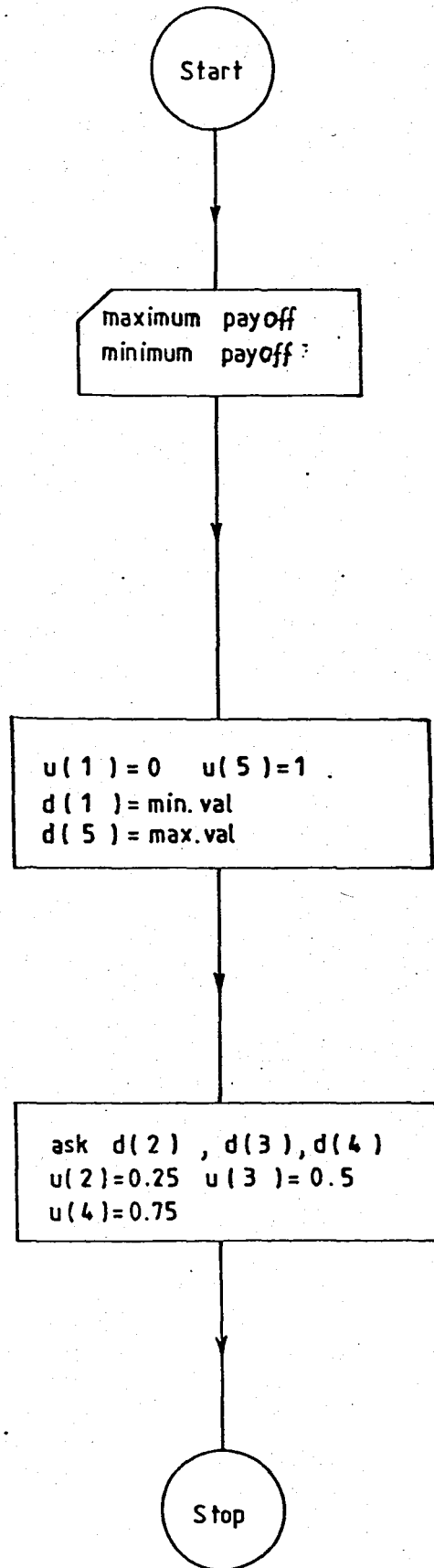


Figure 6.6. Flowchart of the Utility Calculation Unit

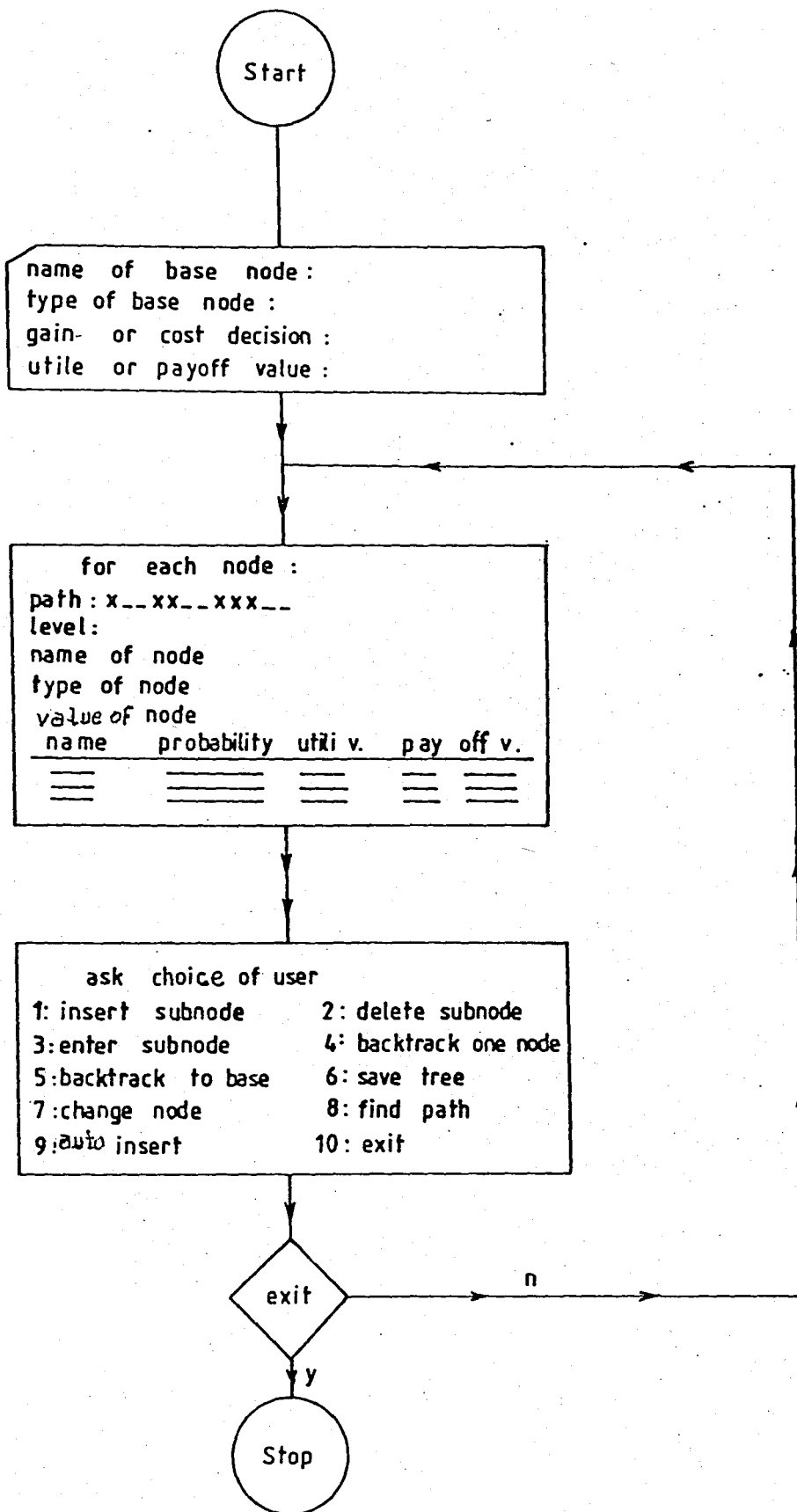


Figure 6.7. Flowchart of the Decision Tree Subprogram

b) Outputs

The program displays the following probabilities:

- i) Unconditional resultant (marginal) probabilities: Name and associated unconditional probabilities of each resultant outcome are displayed.
- ii) Conditional probabilities of priori outcomes on resultant outcomes.
- iii) Joint probabilities of resultant and priori outcomes.

6.7. The Risk Analysis Subprogram

6.7.1. Introduction

The risk analysis subprogram performs Monte Carlo simulation and determines the mean, standard deviation and distribution of the desired measure of merit for a cash flow subject to uncertain cash flow values which may be random variables with uniform, normal, beta discrete or triangular distributions as well as deterministic performing Monte Carlo simulation. The probability density functions of the distributions used in the program are shown in Table 6.1.

The theoretical aspects of risk analysis is discussed in Chapter V the flow chart of the subprogram is shown in Figure 6.8 and an example problem is given in Appendix A.

6.7.2. Inputs

i) Number of alternatives

ii) Input data: The input data can be entered in two ways.

1. The user enters distributions for the initial value, salvage value project life, annual revenue and annual cost of each project.

2. The user enters probability distributions for each cash flow period.

The probability distributions available are normal, triangular, uniform, beta and discrete. The annual revenues and cost may be autocorrelated in the case of correlation, the number and values of autoregressive and moving average parameters and the standard deviation of the white noise is to be indicated by the user. The cost or revenue at any period is related to the cost or revenue at the previous periods by

$$C(t) = \sum_{k=1}^{N_0} O_p(k) \times c(t-k) + W_n(t) - \sum_{k=1}^{N_m} m_p(k) \times W_n(t-k) \quad (6.7.1)$$

where

$C(t)$: cost of revenue at period t .

| Distribution | p.d.f. |
|--------------|---|
| Uniform | $\frac{1}{b-a}$ |
| Triangular | $\frac{4}{(b-a)^2} (x-a) \quad \text{for } x \leq \frac{b+a}{2}$ $\frac{4}{(b-a)^2} (b-x) \quad \text{for } x \geq \frac{b+a}{2}$ |
| Normal | $\frac{1}{\sqrt{\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$ |
| Beta | $\frac{\Gamma(a+b)}{\Gamma(a)\Gamma(b)} x^{a-1} (1-x)^{b-1}$ |

Table 6.1. Distributions Used in Simulation

n_m : number of moving average parameters

n_0 : number of autoregressive parameters

$D_p(k)$: value of autoregressive parameter k

$m_p(k)$: value of moving average parameter k

$W_n(t)$: white noise at period t .

The project life and salvage values may be conditionally dependent on initial value and project life respectively. For the independent variable the user specifies the number of intervals, a lower and an upper bound and a probability distribution for each interval. If the independent variable falls within the range of an interval, the dependant variable is generated from the distribution corresponding to that interval.

iii) The program asks number of batches, number of runs in each batch, a seed integer value and number of runs discarded at the beginning of each batch.

iv) The minimum attractive rate of return and inflation rate are indicated by the user which can also be random variables.

v) Measure of merit: Present worth, future worth, annual worth, I.R.R., E.R.R. payback period and discounted payback period methods can be chosen.

vi) The user may specify intervals to see the distribution of output in the final solution.

6.7.3. Outputs

The program displays the expected value, standard deviation and probability of greater than zero values of measure of merit for each batch and for the

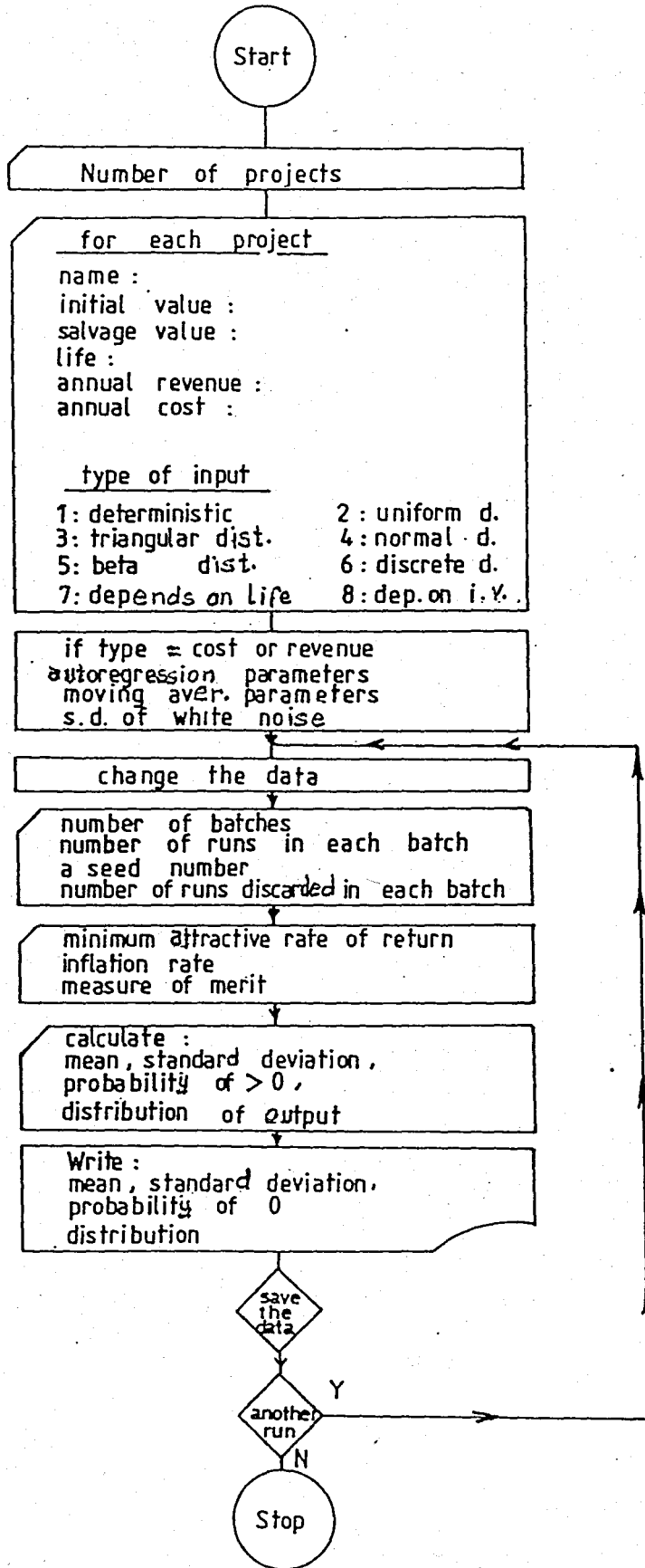


Figure 6.8. Risk Analysis Subprogram

total number of runs. If desired the number and probabilities of measure of merit corresponding to each specified interval are displayed.

6.8. Conclusion and Extentions

In this thesis a user oriented interactive program was developed for personal computers. The program consists of five subprograms Basic Calculations, Decision Matrices, Decision Matrices Imbedded to Basic Calculations, Decision Trees and Risk Analysis.

The package program can be extended in many ways; another subprogram about AHP. Analytical Hierarchical Processes may be added. By providing a utility function unit the decisions can be based on not only the payoffs but also the utile values. Sensitivity and parametric analysis can be included in the basic calculations subprogram. Another types of capital budgeting problems may be solved within the capital budgeting option. The decision trees subprogram may be extended to solve discounted trees and may calculate value of perfect and imperfect information. It is possible to exted the risk analysis subprogram so as to include more complicated relationships between random variables, for instance joint distributions of two variables such as costs and revenues.

APPENDIX A

EXAMPLES

Example 1 : Evaluation of a Project with Different Measures of Merit

Input

| | |
|--------------------|-------|
| Project name | a |
| Initial investment | 10000 |
| Salvage value | 1000 |
| Project life | 10 |
| Annual revenue | 3000 |
| Annual cost | 2000 |
| M.A.R.R. | 0.1 |

Output

| | |
|-------------------|-------|
| Present W. | 2674 |
| Future W. | 6937 |
| Annual W. | 435 |
| I.R.R. | 0.136 |
| E.R.R. | 0.157 |
| Payback Per. | 5 |
| Dis. Payback Per. | 8 |

Computer Solution of Example 1

number of alternatives : 1

capital budgeting problem (y/n) :

input data may be in two forms

- 1 : initial , salvage values , project life , annual revenues and costs are entered for each project
 - 2 : cash flow values are entered period by period for each project
- enter your choice :

for the project

project name : a
 initial investment : 10000
 salvage value : 1000
 project life : 10
 annual revenue : 3000
 annual cost : 1000

for project a

| period no | b t c f v |
|-----------|-----------|
|-----------|-----------|

| | |
|----|-----------|
| 0 | -10000.00 |
| 1 | 2000.00 |
| 2 | 2000.00 |
| 3 | 2000.00 |
| 4 | 2000.00 |
| 5 | 2000.00 |
| 6 | 2000.00 |
| 7 | 2000.00 |
| 8 | 2000.00 |
| 9 | 2000.00 |
| 10 | 3000.00 |

press any key to continue

discrete or continuous compounding (d/c) : d

minimum attractive rate of return : 0.1

inflation considered :

measure of merits :

-
- 1 : present worth
 - 2 : annual worth
 - 3 : future worth
 - 4 : internal rate of return
 - 5 : external rate of return
 - 6 : payback period
 - 7 : discounted payback period

enter your choice :

number of alternative projects : 1
 minimum attractive rate of return : 0.100

| alternative(s) | present worth |
|----------------|---------------|
|----------------|---------------|

| | |
|---|---------|
| a | 2674.68 |
|---|---------|

number of alternative projects : 1
 minimum attractive rate of return : 0.100

| alternative(s) | annual worth |
|----------------|--------------|
|----------------|--------------|

| | |
|---|--------|
| a | 435.29 |
|---|--------|

number of alternative projects : 1
 minimum attractive rate of return : 0.100

alternative(s) future worth

a 6937.42

alternative(s) payback period

a

5

alternative(s) dis. payback period

a

8

project name err

a

0.126

project name irr

a

0.157

Example 2 : Depreciation and Tax Calculations**Input**

| | |
|---------------|-------|
| Project name | a |
| Initial value | 10000 |
| Salvage value | 1000 |
| Project life | 10 |
| Tax rate | 0.1 |
| M.A.R.R. | 0.1 |

Output

Straight line and sum of the years digit depreciation methods are selected respectively. The depreciation book value, and after tax cash flows are shown in computer output.

Computer Solution of Example 2

discrete or continuous compounding (d/c) : 0

minimum attractive rate of return : 0.1

inflation considered :

depreciation methods

-
- 1 : straight line
 - 2 : declining balance
 - 3 : sum of the years digits.
 - 4 : sinking fund

enter your choice :

tax rate : 0.1

 for the project a

| period | b t c f | depreciation | book value |
|--------|-----------|--------------|------------|
| 0 | -10000.00 | 0.00 | 10000.00 |
| 1 | 2000.00 | 900.00 | 9100.00 |
| 2 | 2000.00 | 900.00 | 8200.00 |
| 3 | 2000.00 | 900.00 | 7300.00 |
| 4 | 2000.00 | 900.00 | 6400.00 |
| 5 | 2000.00 | 900.00 | 5500.00 |
| 6 | 2000.00 | 900.00 | 4600.00 |
| 7 | 2000.00 | 900.00 | 3700.00 |
| 8 | 2000.00 | 900.00 | 2800.00 |
| 9 | 2000.00 | 900.00 | 1900.00 |
| 10 | 3000.00 | 900.00 | 1000.00 |

 for the project a

| period | b t c f v | deprèciation | taxable inc | a t c f v |
|--------|-----------|--------------|-------------|-----------|
| 0 | -10000.00 | 0.00 | 0.00 | -10000.00 |
| 1 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 2 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 3 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 4 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 5 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 6 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 7 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 8 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 9 | 2000.00 | 900.00 | 110.00 | 1890.00 |
| 10 | 3000.00 | 900.00 | 110.00 | 2890.00 |

 for the project a

| period | b t c f | deprèciation | book value |
|--------|-----------|--------------|------------|
| 0 | -10000.00 | 0.00 | 10000.00 |
| 1 | 2000.00 | 1636.36 | 8363.64 |
| 2 | 2000.00 | 1472.73 | 6890.91 |
| 3 | 2000.00 | 1309.09 | 5581.82 |
| 4 | 2000.00 | 1145.45 | 4436.36 |
| 5 | 2000.00 | 981.82 | 3454.55 |
| 6 | 2000.00 | 818.18 | 2636.36 |
| 7 | 2000.00 | 654.55 | 1981.82 |
| 8 | 2000.00 | 490.91 | 1490.91 |
| 9 | 2000.00 | 327.27 | 1163.64 |
| 10 | 3000.00 | 163.64 | 1000.00 |

for the project a

| period | b t c f v | depreciation | taxable inc | a t c f v |
|--------|-----------|--------------|-------------|-----------|
| 0 | -10000.00 | 0.00 | 0.00 | -10000.00 |
| 1 | 2000.00 | 1636.36 | 36.36 | 1963.64 |
| 2 | 2000.00 | 1472.73 | 52.73 | 1947.27 |
| 3 | 2000.00 | 1309.09 | 69.09 | 1930.91 |
| 4 | 2000.00 | 1145.45 | 85.45 | 1914.55 |
| 5 | 2000.00 | 981.82 | 101.82 | 1898.18 |
| 6 | 2000.00 | 818.18 | 118.18 | 1881.82 |
| 7 | 2000.00 | 654.55 | 134.55 | 1865.45 |
| 8 | 2000.00 | 490.91 | 150.91 | 1849.09 |
| 9 | 2000.00 | 327.27 | 167.27 | 1832.73 |
| 10 | 3000.00 | 163.64 | 183.64 | 2816.36 |

Example 3 : Comparison of Mutually Exclusive Alternatives

| Input | 1 | 2 | 3 | 4 |
|----------------|------|------|-------|-------|
| Project name | a1 | a2 | a3 | a4 |
| Initial value | 6000 | 7600 | 12400 | 13000 |
| Salvage value | 0 | 0 | 0 | 0 |
| Project life | 5 | 5 | 5 | 5 |
| Annual revenue | 0 | 0 | 0 | 0 |
| Annual cost | 7800 | 7282 | 6298 | 5720 |
| M.A.R.R. | 0.1 | | | |

| Output | 1 | 2 | 3 | 4 |
|------------------------------|-------|-------|-------|-------|
| Project | a1 | a2 | a3 | a4 |
| Present W.C. | 35568 | 36205 | 36279 | 34683 |
| Δ Increment | | 1600 | 4800 | 5400 |
| Δ Annual saving | | 518 | 984 | 1562 |
| I.R.R. on Δ Increment | | 0.186 | 0.008 | 0.138 |
| Justified | | Yes | No | Yes |

Project a4 is selected with the I.R.R. and P.W. methods.

Computer Solution of Example 3

for the 1 . project

| | |
|--------------------|--------|
| project name | : a |
| initial investment | : 6000 |
| salvage value | : 0 |
| project life | : 5 |
| annual revenue | : 0 |
| annual cost | : 7800 |

for the 2 . project

| | |
|--------------------|--------|
| project name | : b |
| initial investment | : 7600 |
| salvage value | : 0 |
| project life | : 5 |
| annual revenue | : 0 |
| annual cost | : 7282 |

for the 3 . project

| | |
|--------------------|---------|
| project name | : c |
| initial investment | : 12400 |
| salvage value | : 0 |
| project life | : 5 |
| annual revenue | : 0 |
| annual cost | : 6298 |

for the 4 . project

| | |
|--------------------|---------|
| project name | : d |
| initial investment | : 13000 |
| salvage value | : 0 |
| project life | : 5 |
| annual revenue | : 0 |
| annual cost | : 5720 |

| from | to | irr |
|------|----|-------|
| a1 | a2 | 0.185 |

| from | to | irr |
|------|----|-------|
| a2 | a3 | 0.008 |

| from | to | irr |
|------|----|-------|
| a2 | a4 | 0.137 |

press any key

number of alternative projects : 4
minimum attractive rate of return : 0.100

the project to be chosen is a4

number of alternative projects : 4
minimum attractive rate of return : 0.100

| alternative(s) | present worth |
|----------------|---------------|
|----------------|---------------|

| | |
|---|-----------|
| a | -35568.14 |
| b | -35204.51 |
| c | -36274.38 |
| d | -34683.30 |

Example 4: Capital Budgeting

Input

Number of alternatives 4

| Project name | a1 | a2 | a3 | a4 |
|--------------------|-------|-------|-------|-------|
| Initial investment | 10000 | 12000 | 13000 | 14000 |
| Salvage value | 1000 | 3000 | 3000 | 4000 |
| Project life | 10 | 10 | 10 | 10 |
| Annual revenue | 2000 | 3000 | 4000 | 4500 |
| Annual cost | 0 | 0 | 0 | 0 |
| Escalation rate | 0.1 | 0 | 0 | 0 |
| M.A.R.R. | 0.1 | | | |

Budget Limitation Constraints

| No | Period | Budget |
|----|--------|--------|
| 1 | 0 | 12000 |
| 3 | 1 | 30000 |
| 3 | 2 | 15000 |

Mutually exclusive projects a1, a2 and a3, a4.

The selected projects and their starting times are shown in the computer output.

Computer Solution of Example 4

for the 1 . project

project name : a1
initial investment : 10000
salvage value : 1000
project life : 10
annual revenue : 2000
annual cost : 0

for the 2 . project

project name : a2
initial investment : 12000
salvage value : 2000
project life : 10
annual revenue : 3000
annual cost : 0

for the 3 . project

project name : a3
initial investment : 13000
salvage value : 3000
project life : 10
annual revenue : 4000
annual cost : 0

for the 4 . project

project name : a4
initial investment : 14000
salvage value : 4000
project life : 10
annual revenue : 4500
annual cost : 0

enter planning horizon : 3

number of periods with limited budget : 3

| no | period | limited budget |
|----|--------|----------------|
| 1 | 0 | 12000 |
| 2 | 1 | 20000 |
| 3 | 2 | 15000 |

number of mutually exclusive groups : 2

number of mutually exclusive projects in group 1 : 2

| no | name |
|----|------|
| 1 | a1 |
| 2 | a2 |

number of mutually exclusive projects in group 2 : 2

| no | name |
|----|------|
| 1 | a3 |
| 2 | a4 |

escalation rates for projects

| name | esc exist(y/n) | escalation rate |
|------|----------------|-----------------|
| a1 | | 0.1 |
| a2 | | 0.0 |
| a3 | | 0.0 |
| a4 | | 0.0 |

discrete or continuous compounding (d/c) :

minimum attractive rate of return : 0.1

inflation considered :

final solution

 number of alternative projects : 4
 minimum attractive rate of return : 0.100
 budget limitations

| period | limited budget |
|--------|----------------|
| 0 | 12000.00 |
| 1 | 20000.00 |
| 2 | 15000.00 |

mutually exclusive projects

| no | names |
|----|-------|
| 1 | a1 a2 |
| 2 | a3 a4 |

escalation rates

| project | escalation rate |
|---------|-----------------|
| a1 | 0.100 |
| a2 | 0.000 |
| a3 | 0.000 |
| a4 | 0.000 |

the selected projects

| name | starting time | p.w. |
|------|---------------|-----------|
| a2 | 3 | 5413.064 |
| a4 | 3 | 11414.519 |

Example 5 : A Decision Matrix

Number of states : 4

Number of alternatives : 4

Input

| States | 1 | 2 | 3 | 4 |
|---------------|-----|-----|-----|-----|
| Probabilities | 0.2 | 0.2 | 0.3 | 0.3 |
| Names | | | | |
| a1 | 2 | 3 | 4 | 5 |
| a2 | 3 | 4 | 5 | 6 |
| a3 | 4 | 5 | 6 | 7 |
| a4 | 5 | 6 | 7 | 8 |

The decision matrix is evaluated with dominance, expectation-variance, laplace and minimax-maximin principles.

Computer Solution of Example 5

number of alternatives : 4

number of states : 4

enter a name for each alternative

| no | name |
|----|------|
| 1 | a1 |
| 2 | a2 |
| 3 | a3 |
| 4 | a4 |

enter matrix values

| states alts. | 1 | 2 | 3 | 4 |
|-----------------|---|---|---|---|
| a1 | 2 | 3 | 4 | 5 |
| a2 | 3 | 4 | 5 | 6 |
| a3 | 4 | 5 | 6 | 7 |
| a4 | 5 | 6 | 7 | 8 |

decisions under risk or uncertainty (r/u) :

gain or cost matrix (g/c) :

enter a probability value for each state

| state | probability |
|-------|-------------|
| 1 | 0.2 |
| 2 | 0.2 |
| 3 | 0.3 |
| 4 | 0.3 |

methods of evaluation for decisions under risk :

- 1 ; dominance
- 2 : expectation - variance.
- 3 : aspiration level
- 4 : most probable future

enter your choice :

the final decision

number of alternatives : 4
 number of states : 4
 gain or cost decision : g
 risk or uncertainty decision : r

| name | expectations | variance | selected alternative(s) |
|------|--------------|----------|-------------------------|
| a1 | 3.700 | 1.210 | |
| a2 | 4.700 | 1.210 | |
| a3 | 5.700 | 1.210 | |
| a4 | 6.700 | 1.210 | x |

the final decision

number of alternatives : 4
 number of states : 4
 gain or cost decision : g
 risk or uncertainty decision : r

| name | selected alternative(s) |
|------|-------------------------|
| a1 | |
| a2 | |
| a3 | |
| a4 | x |

methods of evaluation for decisions under uncertainty :

- 1 : laplace
- 2 : maximax - minimin
- 3 : maximin - minimsx
- 4 : hurwicz
- 5 : savage

enter your choice :

the final decision

| | | |
|------------------------------|---|---|
| number of alternatives | : | 4 |
| number of states | : | 4 |
| gain or cost decision | : | c |
| risk or uncertainty decision | : | u |

| name | laplace values | selected alternative(s) |
|------|----------------|-------------------------|
| a1 | 3.500 | x |
| a2 | 4.500 | |
| a3 | 5.500 | |
| a4 | 6.500 | |

the final decision

| | | |
|------------------------------|---|---|
| number of alternatives | : | 4 |
| number of states | : | 4 |
| gain or cost decision | : | g |
| risk or uncertainty decision | : | u |

| name | min - max regret | selected alternative(s) |
|------|------------------|-------------------------|
| a1 | 3.000 | |
| a2 | 2.000 | |
| a3 | 1.000 | |
| a4 | 0.000 | x |

Example 6 : A Decision Matrix Imbedded to Basic Calculations Units

Inputs

Number of alternatives : 3

| Project name | a1 | a2 | a3 |
|----------------|-------|-------|-------|
| Initial value | 10000 | 12000 | 13000 |
| Salvage value | 1000 | 2000 | 3500 |
| Project life | 8 | 10 | 12 |
| Annual revenue | 2000 | 3000 | 4000 |
| Annual cost | 0 | 0 | 0 |

The uncertain variable : M.A.R.R.

| | Value | Probability |
|---|-------|-------------|
| 1 | 0.8 | 0.3 |
| 2 | 0.10 | 0.3 |
| 3 | 0.12 | 0.4 |

The decision matrix is evaluated with the expectation-variance principle. The matrix values and final solution are shown in the computer output.

Computer Solution of Example 6

number of alternatives : 3

number of states : 3

input data may be in two forms

1 : initial , salvage values , project life , annual revenues and costs are entered for each project

2 : cash flow values are entered period by period for each project

enter your choice :

type of uncertain variable

1 : min atr rate of return

2 : inflation rate

3 : investment value

4 : salvage value

5 : life

6 : anual cost

7 : anual revenue

enter your choice :

for the alternative 1

project name : a1
 initial investment : 10000
 salvage value : 1000
 project life : 8
 annual revenue : 2000
 annual cost : 0

for the alternative 2

project name : a2
 initial investment : 12000
 salvage value : 2000
 project life : 10
 annual revenue : 3000
 annual cost : 0

for the alternative 3

project name : a3
 initial investment : 13000
 salvage value : 3500
 project life : 12
 annual revenue : 4000
 annual cost : 0

discrete or continuous compounding (d/c) : d

inflation considered :

measure of merits :

-
- 1 : present worth
 - 2 : annual worth
 - 3 : future worth
 - 4 : internal rate of return
 - 5 : external rate of return
 - 6 : payback period
 - 7 : discounted payback period

enter your choice :

decisions under risk or uncertainty :

enter a probability value for each state

| state | probability |
|-------|-------------|
| 1 | 0.3 |
| 2 | 0.3 |
| 3 | 0.4 |

the decision matrix

| states alts. | 1 | 2 | 3 |
|-----------------|----------|----------|----------|
| a1 | 2033.55 | 1136.36 | 339.16 |
| a2 | 9056.63 | 7204.79 | 5594.62 |
| a3 | 18534.21 | 15369.98 | 12675.86 |

methods of evaluation for decisions under risk :

- 1 ; dominance
- 2 : expectation - variance
- 3 : aspiration level
- 4 : most probable future

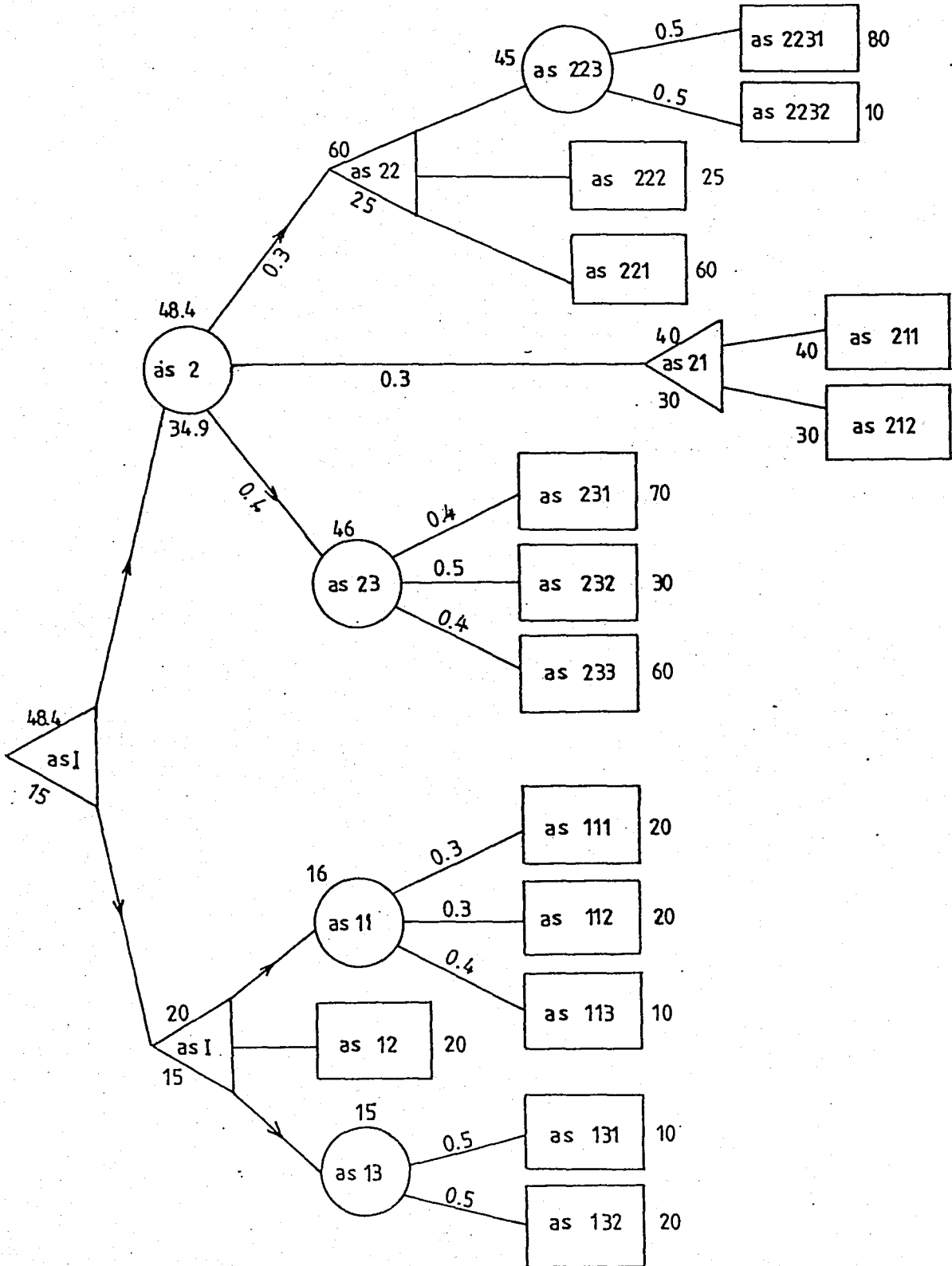
enter your choice :

the final decision

| | | |
|------------------------------|---|-------------|
| number of alternatives | : | 3 |
| number of states | : | 3 |
| risk or uncertainty decision | : | r |
| the uncertain variable | : | m. a. r. r. |

| name | expectations | variance | selected alternative(s) |
|------|--------------|-------------|----------------------------|
| a1 | 1086.637 | 493220.236 | |
| a2 | 7116.272 | 2058023.966 | |
| a3 | 15241.600 | 5890537.937 | x |

Example 7 : A Decision Tree



Computer Solution of Example 7

```

path      : as --
level     : 0
node name : as
node type : decision (base node)
value (payoff) : 0.00

```

| no | name | payoff |
|----|------|--------|
| 1 | as1 | 20.00 |
| 2 | as2 | 48.40 |

the choice is : as2 with payoff ; 48.40

the choices are

| | |
|----------------------------|---------------------------|
| 1 : insert subnode | 2 : delete subnode |
| 3 : enter subnode | 4 : backtrack one node |
| 5 : backtrack to base node | 6 : save the tree |
| 7 : change node | 8 : enter uncomplete node |
| 9 : oinsert | 0 : exit |

enter your choice :

```

path      : as -- as1 --
level     : 1
node name : as1
node type : decision
value (payoff) : 0.00

```

| no | name | payoff |
|----|------|--------|
| 1 | as11 | 16.00 |
| 2 | as12 | 20.00 |
| 3 | as13 | 15.00 |

the choice is : as12 with payoff ; 20.00

the choices are

| | |
|----------------------------|---------------------------|
| 1 : insert subnode | 2 : delete subnode |
| 3 : enter subnode | 4 : backtrack one node |
| 5 : backtrack to base node | 6 : save the tree |
| 7 : change node | 8 : enter uncomplete node |
| 9 : oinsert | 0 : exit |

enter your choice :

path : as -- as2 --
 level : 1
 node name : as2
 node type : chance
 value (payoff) : 0.00

| no | name | probability | payoff |
|----|------|-------------|--------|
| 1 | as21 | 0.300 | 40.00 |
| 2 | as22 | 0.300 | 60.00 |
| 3 | as23 | 0.400 | 46.00 |

the payoff : 48.40

the choices are

| | |
|----------------------------|---------------------------|
| 1 : insert subnode | 2 : delete subnode |
| 3 : enter subnode | 4 : backtrack one node |
| 5 : backtrack to base node | 6 : save the tree |
| 7 : change node | 8 : enter uncomplete node |
| 9 : oinsert | 0 : exit |

enter your choice :

path : as -- as1 -- as12 --
 level : 2
 node name : as12
 node type : end
 value (payoff) : 20.00

the choices are

| | |
|----------------------------|---------------------------|
| 1 : insert subnode | 2 : delete subnode |
| 3 : enter subnode | 4 : backtrack one node |
| 5 : backtrack to base node | 6 : save the tree |
| 7 : change node | 8 : enter uncomplete node |
| 9 : oinsert | 0 : exit |

enter your choice :

Example 8 : Risk Analysis

Input

| | | | | | |
|---------------|----------------------|-----|-----|-----|-----|
| Project name | a | | | | |
| Initial value | normal (50000; 1000) | | | | |
| Salvage value | det. 0 | | | | |
| Project life | discrete | | | | |
| life | 10 | 11 | 12 | 13 | 14 |
| prob. | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

| | | | |
|----------------|----------|-------|-------|
| Annual revenue | discrete | | |
| value | 35000 | 40000 | 45000 |
| prob. | 0.4 | 0.5 | 0.1 |

Annual cost normal (30000, 2000)

| | |
|-------------------|----------|
| Number of batches | 1 |
| Number of runs | 1000 |
| Measure of merit | P.W. |
| M.A.R.R. | det. 0.1 |

The final solution is shown at the computer output.

Computer Solution of Example 8

number of alternatives : 1

input data may be in two forms

1 : initial , salvage values , project life , annual revenues and costs are entered for each project

2 : cash flow values are entered period by period for each project

enter your choice :

for project : 1

project name : a

initial value

the choices for entering input

| | |
|-------------------|-----------------|
| 1 : deterministic | 2 : uniform d. |
| 3 : triangular d. | 4 : normal d. |
| 5 : beta d. | 6 : discrete d. |

enter your choice :

type of distribution : normal

enter the mean value : 50000

enter the standard deviation : 1000

salvage value

the choices for entering input

1 : deterministic 2 : uniform d.
 3 : triangular d. 4 : normal d.
 5 : beta d. 6 : discrete d.
 7 : dep on life

enter your choice :

type of distribution : deterministic

enter the deterministic value : 0

project life

the choices for entering input

1 : deterministic 2 : uniform d.
 3 : triangular d. 4 : normal d.
 5 : beta d. 6 : discrete d.
 7 : dep on in. val.

enter your choice :

type of distribution : discrete

enter number of discrete points : 5

| no | value | probability |
|----|-------|-------------|
| 1 | 10 | 0.2 |
| 2 | 11 | 0.2 |
| 3 | 12 | 0.2 |
| 4 | 13 | 0.2 |
| 5 | 14 | 0.2 |

| | | |
|---|----|-----|
| 1 | 10 | 0.2 |
| 2 | 11 | 0.2 |
| 3 | 12 | 0.2 |
| 4 | 13 | 0.2 |
| 5 | 14 | 0.2 |

type of distribution : discrete

enter number of discrete points : 3

| no | value | probability |
|----|-------|-------------|
| 1 | 35000 | 0.4 |
| 2 | 40000 | 0.5 |
| 3 | 45000 | 0.1 |

type of distribution : normal

enter the mean value : 30000

enter the standard deviation : 2000

number of batches : 1

number of runs in each batch : 1000

enter an integer for seed : 1000

number of runs to be disgarded at the beginning of each batch : 0

measure of merits :

- | | |
|---|-----------------------------|
| 1 | : present worth |
| 2 | : annual worth |
| 3 | : future worth |
| 4 | : internal rate of return |
| 5 | : external rate of return |
| 6 | : payback period |
| 7 | : discounted payback period |

enter your choice :

for the minimum attractive rate of return
discrete or continuous interest (d/c) :

the choices for entering input

1 : deterministic 2 : uniform d.
3 : triangular d. 4 : normal d.
5 : beta d. 6 : discrete d.
7 : dep on in. val.

enter your choice :

type of distribution : deterministic

enter the deterministic value : 0.1

final output of all batches

number of alternatives : 1
min. atr. rate. of ret. : det 0.10
number of batches : 1
number of runs per batch : 1000
total number of runs : 1000
number of runs discarded : 0
method of evaluation : present worth

| name | average of expected v. | average of standart d. | average of prob of > 0 |
|------|---------------------------|---------------------------|---------------------------|
| a | 7866.766 | 8932.862 | 0.79700 |

REFERENCES

TEXT BOOKS

1. Degarno E.P., Sullivan W.G., Canada J.R. "Engineering Economy" 7th ed Macmillan Publishing Company, 1984.
2. Canada J.R. "Intermediate Economic Analysis for Management and Engineering" Prentice-Hall, 1971.
3. Smith G.W. "Engineering Economy" 2nd ed. The Iowa State University Press, 1973.
4. Fleisher A.G. "Capital Allocation Theory" Meredith Corporation, 1969.
5. Hawkins C.J., Pearce D.W. "Capital Investment Appraisal" The Macmillan Press Ltd. ,1971.
6. Canada J.R., White J.A. "Capital Investment Decision Analysis for Management and Engineering" Prentice-Hall Inc., Englewood Cliffs,1980.
7. Masse P. "Optimal Investment Decisions" Prentice-Hall Inc., 1962.
8. Merret A.J., Sykes A. "The Finance and Analysis of Capital Projects" Halsted Press, 2th ed., 1972.
9. Alfred A.M., Evans J.B. "Discounted Cash Flow" Chapman and Hall Ltd. 3rd ed., 1971.
10. Stallworthy E.A. "The Control of Investment in New Manufacturing Facilities" Gower Press, 1973.
11. Kavrakoğlu İ. "Decision Economic" Boğaziçi University Press, 1988.
12. Hertz B.D., Thomas H. "Risk Analysis and Its Applications" John Wiley and Sons, 1984.
13. Naylor T.H., Balintfy J.L., Burdick D.S., Chu K. "Computer Simulation Techniques" John Wiley and Sons, 1968.
14. Poole T., Szymankiewicz J. "Using Simulation to Solve Problems" McGraw Hill Book Company, 1977.

15. Gordon G. "System Simulation" 2nd ed Prentice-Hall, 1978.

COMPUTER PROGRAMS

16. "The Capital Risk Program". Control Data Corporation, Data Centers Division.

17. "Capital Investment Risk Analysis Applied to Real Estate" IBM 360.
Catalog of Programs No. 360D-19.11.002.

18. "Discounted Cash Flow Economic Evaluation". IBM 360 Catalog of Programs No. 360D-15.1.006.

19. "Lesses". GE 265 Time-Sharing System.

20. "Lesors". GE 265 Time-Sharing System.

21. "Parsim". GE 265 Time-Sharing System.

22. "Parsen". GE 265 Time-Sharing System.

23. "Parent". GE 265 Time-Sharing System.

24. "Management Science Models and the Microcomputer". Burns J.R., Austin L.M., Macmillan Publishing Company, 1985.

25. "QSB-Quantitative Systems for Business". Chang Y.L., Robert S. Sullivan, Prentice-Hill, 1986.

26. "Turbo Pascal Owners Handbook Version 4.0.", Barland International, 1987.

27. "User's Manual Linear Integer and Quadratic Programming with LINDO" The Scientific Press, 1986.