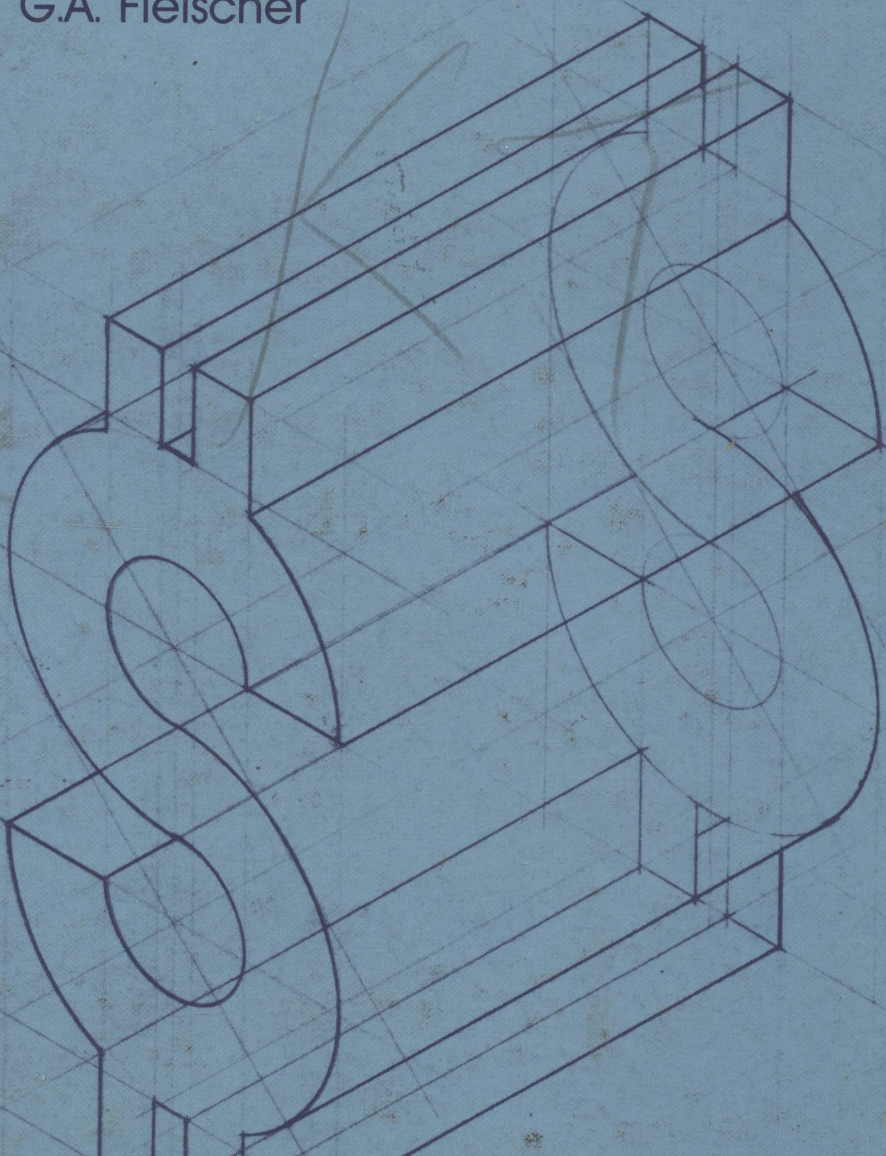
ENGINEERING ECONOMY

CAPITAL ALLOCATION THEORY

G.A. Fleischer



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PRINCIPAL NOTATION—PARTIAL LIST

For expanded list, see Appendix A

A	Cash flow, or equivalent cash flow, occurring uniformly at the *end* of every period for a specified number of periods.
A_j	Cash flow at *end* of period j.
$\overline{A}$	Amount of money (or equivalent value) flowing continuously and uniformly *during* each period for a specified number of periods.
$\overline{A}_j$	Cash flow occurring continuously and uniformly *during* the j^{th} period.
a	Depreciation rate used with the declining balance method. Fraction of total earnings retained within the firm each period (Chapter 11).
B	(Incremental) benefits.
B_j	Book value after j years of depreciation. (Includes the depreciation expense for the j^{th} year.)
b	Rate of return on book value for retained earnings.
C	(Incremental) costs.
C_j	Loan repayment at end of period j. (C_0 is cost associated with underwriting.)
CC	Capitalized cost: the equivalent present value of an infinite series of cash flows.
CR	Capital recovery.
D	Annual depreciation expense.
d	Imaginary uniform deposit into an imaginary sinking fund.
D_j	Depreciation expense for year j. (No subscript if constant for all j).
D_s	Uniform annual "deposit" into imaginary sinking fund.
e	Base of the Napierian logarithm system, the "exponential," approximately equal to 2.71828.
E/C	Ratio of system effectiveness to system cost. (Sometimes known as "bang for the buck.")
F	Amount of cash flow at end of Nth period. Equivalent future value (measured at end of Nth period) of prior cash flows.
$\overline{F}$	Amount of money (or equivalent value) flowing continuously and uniformly during the Nth period.
f	General rate of inflation: uniform rate of increase/decrease of prices.
G	Arithmetic gradient: amount of cash flow increase/decrease from period to period.

g	Geometric gradient: rate of cash flow increase/ decrease from period to period.
I	Interest paid on debt. Annual interest payment (uniform over each year).
i	Effective interest rate per interest period.
i_a	Effective interest rate per year (per *annum*).
i_m	Effective interest rate per subperiod.
i_s	Rate of interest "earned" by imaginary sinking fund.
i^*	Internal rate of return.
i_e^*	External rate of return.
i	After tax (internal) rate of return.
IRR	(Internal) rate of return. Sometimes written as *RoR* for "rate of return."
k	Auxiliary interest rate used when computing the external rate of return. The minimum attractive rate of return.
k^*	Cost of capital, reflecting inflation.
L_j	Lease payment at end of period j.
M	Number of compounding subperiods per period (each of which is assumed to be of equal length). Market value of the firm's equity.
MARR	Minimum attractive rate of return.
N	Number of compounding periods (each of which is assumed to be of equal length): the length of the "planning horizon" (study period). Life of investment.
P	Initial investment. Equivalent present value of future cash flow(s). Loan principal.
$\overline{P}$	Amount of money (or equivalent value) flowing continuously and uniformly during the first period of the planning horizon.
P_j	Amount of loan principal unpaid at the start of period j.
Q	Amount of loan.
r	Nominal interest rate per period; usually, the nominal interest rate per year.
S	Net salvage value of capital investment.
SIR	Savings-investment ratio.
SYD	Sum of the years digits.
t	Effective income tax rate.
Ø	The do-nothing alternative.
λ	Leverage, the ratio of debt to the total value of the firm.

ENGINEERING ECONOMY

CAPITAL ALLOCATION THEORY

To those of blessed memory
Louis S. Fleischer, 1900–1940
Maurice L. Bashkow, 1898–1975
and to my mother
Rita Bloch Fleischer Bashkow, 1903–

PREFACE

As an area of special concern, the study of optimal investment decisions is of relatively recent interest to both academicians and industrial managers. Although the general problem of allocating limited resources among a variety of competing alternatives must surely have occurred to societies since the beginning of recorded history, it is only within the last century that the evaluation process has been formalized and analytical procedures developed.

Engineering economy, the analysis of economic effects of *engineering* decisions, has its genesis in Arthur M. Wellington's classic text, *The Economic Theory of Railway Location,* published in 1887.* Engineers subsequently expanded and refined the techniques of engineering economy, notably through the work of Professors J. C. L. Fish in the 1920s and E. L. Grant in the 1930s.† In parallel, certain (classical) economists and financial managers were developing scholarly material that, in large measure, both supplemented and complemented the work of the engineering economy community. The resulting literature has been classified under a variety of descriptive terms, usually depending on the professional discipline of the author and/or the target audience: engineering economy (or engineering economics), capital budgeting, economic analysis, life cycle costing, financial decision making, and managerial economics, among others. The common element shared by all titles is concern with the fundamental problem of allocating limited financial resources among competing investment alternatives.

*A. M. Wellington, *The Economic Theory of Railway Location*, (New York; John Wiley & Sons), 1887

†E. L. Grant's first edition of *Principles of Engineering Economy* was published in 1930. He retired from Stanford University in 1962, and at this writing (October 1983) Grant is still active. The 7th edition of *Principles of Engineering Economy* was published in 1982.

This book is a substantially revised version of *Capital Allocation Theory: The Study of Investment Decisions,* originally published by Appleton-Century-Crofts in 1967. The initial title was selected to reflect my view that, although the notation and theoretical structure are most closely related to the classical literature of engineering economy, applications are by no means limited to investment alternatives arising from engineering and technological decisions. Capital allocation problems stem from alternative plans, programs, and projects, irrespective of whether a technology component is present. Nevertheless, since the examples, problems, and exercises are most directly related to engineering decisions, I have elected to adopt the title *Engineering Economy* for this edition. Although the title has changed, the principal emphasis remains a consolidation of current and relevant views of engineering economists, financial managers, and others to present a unified theory of capital allocation appropriate to all levels within the business enterprise or governmental activity.

It should be noted that the theory presented here is as appropriate to individual (personal) investment decisions as to those of private firms, government agencies, or nonprofit organizations. These techniques are suitable whenever decisions must be made concerning the selection from alternative investment opportunities.

This book is intended for upper-division undergraduates or graduate-level students. There are no prerequisites, although prior exposure to accounting and microeconomics would be helpful. Knowledge of integral and differential calculus is not strictly necessary; with few exceptions, development of mathematical models uses only algebra. Some understanding of the elements of probability theory is useful in the discussion of risk and uncertainty (Chapter 8). For students who have not been exposed to this topic previously, an elementary presentation of probability and expectation is provided in the chapter (Section 8.2). Otherwise, this material may be omitted without loss of continuity.

This book may be used as either a primary or a secondary reference in a first course in engineering economy, financial management, capital budgeting, managerial economics, and the like. Most of these applications are found in schools of engineering and business. However, the text may also be used elsewhere when it is desired to explore concepts, principles, and procedures for examining the economic consequences of proposed plans, programs, and projects. Examples include a "systems analysis" course in a school of public administration or short course in "economic analysis" offered by an industrial firm or government agency.

This book begins with the role of capital allocation theory within the larger framework of systems analysis. The introductory chapter presents a qualitative discussion of certain principles from which a unified theory may be developed. The necessary mathematics of compound interest, including discrete and continuous assumptions for cash flows and discounting, are developed in Chapter 2. Chapter 3 presents the principal methods of economic evaluation: annual worth, present worth, (internal) rate of return, and the benefit-cost ratio method. The first three chapters, then, form the theoretical basis for the remainder of the text. Chapter 4 treats the multiple alternative problems, that is, selection of an optimal alternative from a set of alternatives using the methods of Chapter 3. Chapter 5 discusses a number of evaluation techniques that, although widely used in industry and government, are inherently faulty; they are either fundamentally incorrect or they provide only approximations to the true values. Chapter 6 deals with the most common capital allocation application: problems of retirement of assets from service with replacement by new assets.

Chapter 7 is an extensive discussion of economy studies (economic analyses) that considers the effects of income taxes, including investment tax credits and taxes on gains and losses on disposal of depreciable assets. Since cash flows for taxes are related to taxable income, and since taxable income is in part a function of depreciation and depletion expenses, procedures for determining these expenses are presented. (Many engineering economy textbooks include discussion of *personal* income taxes. I have elected to omit this material, however, concentrating instead on the effects of taxes on the *corporate* business enterprise. Once learned, the methodology for after-tax economy studies for corporations is readily transferable to the noncorporate context. If the instructor wishes to include personal income taxes in his or her course, it is suggested that the current edition of *Your Federal Income Tax,* IRS Publication 17, be used as a supplementary reference.)

Chapter 7, ''Depreciation, Taxation and After-Tax Economy Studies,'' is the most lengthy chapter. Other authors frequently separate this material into two chapters: one dealing with depreciation and depletion and the other dealing with cash flows for taxes and after-tax analyses. I have chosen to combine this material into a single chapter, however, because the topics are directly related. Chapters are organized by subject matter—related topics are grouped—but there is no implication that class time should be equal for each chapter. In general, it is expected that about one week (three classroom hours) per chapter will be adequate. But instructors should devote a minimum of two weeks, and perhaps three, to the material in Chapter 7.

The first seven chapters assume that all parameters are known with certainty. This artificiality is akin to assuming a frictionless plane in physics. So Chapter 8 explores a number of techniques for formally considering the noncertain future, including sensitivity analysis, risk analysis, and a variety of principles of choice from decision theory.

The revenue requirement method is presented in Chapter 9. Although this method is equivalent to the more widely used procedures given in Chapter 3—indeed, this is demonstrated in Chapter 9—the revenue requirement method is of special interest to the utility industry, and thus it is free-standing in a separate chapter. Some instructors may choose to omit Chapter 9 because of time constraints and/or their view that the revenue requirement method is limited in application. If so, Chapter 9 may be omitted without loss of continuity with respect to the other topics covered.

Chapter 10 is an extensive treatment of yet another real-world consideration that has become increasingly important in modern society: incorporating price level changes (inflation) into the analysis. Included as an appendix to Chapter 10 is an introduction to index numbers, the statistics used to describe price level changes over time. A variety of methods for computing index numbers are described and contrasted.

Chapter 11 discusses the measurement and use of the "cost of capital" concept and describes procedures for measuring the costs of a number of elements of the capital structure. Chapter 11 also includes tax, risk, and inflation elements, which were covered previously. The primary purpose of this chapter is to introduce appropriate procedures for estimating the minimum attractive rate of return, which is the discount rate of critical importance in all economy studies.

Chapter 12, the final chapter, addresses an issue typically not included in traditional engineering economy textbooks: formal consideration in analyses of consequences for which monetary equivalence cannot readily be established. It has been my experience that, all too often, those who complete a course in engineering economy arrive at the misconception that analysis of the economic consequences alone is sufficient to identify the "optimal" choice from a set of investment alternatives. This view is naive and should be discouraged. Economic analysis is a decision-*assisting* process, not a decision-*making* process. Although it is not meant to serve as an exhaustive treatment of this subject, Chapter 12 incorporates a variety of procedures that might be employed when "irreducible" as well as monetary consequences are to be considered.

Engineering Economy incorporates a number of special features that, I believe, add significantly to the effectiveness of the text. These include

1. *A partial summary of principal notation.* Used consistently throughout the text, this list is shown inside the front cover

for ready reference. An expanded summary of symbols and key abbreviations is included in Appendix A. Moreover, the notation specific to the revenue requirement method (Chapter 9), and the discussion of inflation and index numbers (Chapter 10) are included in the appendixes to those two chapters.

2. *Definitions of key terms and principal notation.* These are generally consistent with those proposed by the American National Standards Institute Committee on Industrial Engineering Terminology (ANSI Committee Z-94) as published in 1983.
3. *A summary of principal mathematical models.* This summary is incorporated immediately inside the back cover to provide ready reference for the user. These models, accompanied by relevant cash flow diagrams, are keyed to the compound interest tables included in Appendix B.
4. *Compound interest tables.* These are included in Appendix B for nineteen separate interest rates, ranging from 1 percent to 50 percent. Each table spans two pages in the text and includes eleven factors: three single-payment factors, six uniform series factors, and two arithmetic gradient series factors. (Three of the eleven factors may be used when finding equivalent values of continuous cash flows under conditions of continuous compounding; these are shaded in the tables for ready identification.) The interest rates are *effective,* not nominal, in all cases. To assist the user in rapid selection of the appropriate table, the margins of the pages in Appendix B are tinted and the various interest rates are clearly marked within the margins.
5. *Problems at the back of each chapter.* There are 343 problems in this book, some of which afford the student an opportunity to work through numerical exercises directly related to the text material. Others are extensions of the text in that they illustrate some new application.
6. *An extensive discussion of depreciation, depletion, amortization, and taxes in Chapter 7.* This discussion incorporates the principal features of the Economic Recovery Tax Act of 1981, including the Accelerated Cost Recovery System (ACRS) required of federal taxpayers. Changes introduced by the Tax Equity and Fiscal Responsibility Act of 1982 are also included where appropriate.
7. *A discussion of the revenue requirement method in Chapter 9.* This discussion is extensive and complex. To assist the reader, a separate glossary and summary of principal equations are included as appendixes to this chapter.

8. *A discussion of relative price change (inflation).* This topic is of considerable importance, and thus this issue is presented extensively in Chapter 10. An appendix to this chapter includes a discussion of *index numbers* used to measure changes over time of prices, quantities, and values. Index numbers are defined and various methods for computing index numbers are summarized. Other appendixes to this chapter include a separate glossary and summary of principal equations.
9. *Computer programs.* These are included at the back of Chapters 2, 3, 4, 6, and 7. The programs for Chapters 2, 3, and 4 are written in BASIC; the program for Chapter 6 is written in Applesoft BASIC; and the program for Chapter 7 is written in IBM BASIC-A. Worked-out examples using the programs are also included. Students will find these programs useful in solving many, but not all, of the problems included at the ends of chapters. (Although computer programs have been included to suggest opportunities for "automated" data analysis, the calculations required for problem solving in this book are of modest complexity; computers are helpful but not necessary. Any hand-held slide rule calculator should be adequate in all instances. Indeed, even in cases for which a microcomputer is required or recommended by the instructor, students should solve at least some of the problems "long hand" to insure that underlying concepts are understood.)
10. *Answers to problems.* With the exception of Chapters 1 and 12, answers are shown for all odd-numbered problems. The solutions to all problems are provided in a separate Solutions Manual.

I would like to thank the following reviewers for their comments and suggestions: Stanford Baum, University of Utah; Peter Gardiner, University of Southern California; A. K. Mason, California Polytechnic State University, San Luis Obispo; Wayne M. Parker, Mississippi State University; and T. L. Ward, University of Louisville. I am also indebted to my many colleagues, both past and present, without whose encouragement, inspiration, and critical judgment this text would not have been written.

G. A. Fleischer

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