ENGINEERING ECONOMY

sixth edition

Leland Blank • Anthony Tarquin

th Edition

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ENGINEERING ECONOMY

McGraw-Hill Series in Industrial Engineering and Management Science

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Niebel and Freivalds: Methods, Standards, and Work Design

This book is dedicated to our mothers for their ever-present encouragement to succeed in all aspects of life.

PREFACE

The primary purpose of this text is to present the principles and applications of economic analysis in a clearly written fashion, supported by a large number and wide range of engineering-oriented examples, end-of-chapter exercises, and electronic-based learning options. Through all editions of the book, our objective has been to present the material in the clearest, most concise fashion possible without sacrificing coverage or true understanding on the part of the learner. The sequence of topics and flexibility of chapter selection used to accommodate different course objectives are described later in the preface.

EDUCATION LEVEL AND USE OF TEXT

This text is best used in learning and teaching at the university level, and as a reference book for the basic computations of engineering economic analysis. It is well suited for a one-semester or one-quarter undergraduate course in engineering economic analysis, project analysis, or engineering cost analysis. Additionally, because of its behavioral-based structure, it is perfect for individuals who wish to learn the material for the first time completely on their own, and for individuals who simply want to review. Students should be at least at the sophomore level, and preferably of junior standing, so that they can better appreciate the engineering context of the problems. A background in calculus is not necessary to understand the calculations, but a basic familiarization with engineering terminology makes the material more meaningful and therefore easier and more enjoyable to learn. Nevertheless, the building-block approach used in the text's design allows a practitioner unacquainted with economics and engineering principles to use the text to learn, understand, and correctly apply the principles and techniques for effective decision making.

NEW TO THIS EDITION

The basic design and structure of previous editions have been retained for the sixth edition. However, considerable changes have been made. The most significant changes include:

- More than 80% of the end-of-chapter problems are new or revised for this edition.
- Time-based materials such as tax rates and cost indexes have been updated.
- The international dimension of the book is more apparent.
- Many of the Fundamentals of Engineering (FE) Review Problems are new to this edition.

STRUCTURE OF TEXT AND OPTIONS FOR PROGRESSION THROUGH THE CHAPTERS

The text is written in a modular form, providing for topic integration in a variety of ways that serve different course purposes, structures, and time limitations.

There are a total of 19 chapters in four levels. As indicated in the flowchart on the next page, some of the chapters have to be covered in sequential order; however, the modular design allows for great flexibility in the selection and sequencing of topics. The chapter progression graphic (which follows the flowchart) shows some of the options for introducing chapters earlier than their numerical order. For example, if the course is designed to emphasize after-tax analysis early in the semester or quarter, Chapter 16 and the initial sections of Chapter 17 may be introduced at any point after Chapter 6 without loss of foundation preparation. There are clear primary and alternate entry points for the major categories of inflation, estimation, taxes, and risk. Alternative entries are indicated by a dashed arrow on the graphic.
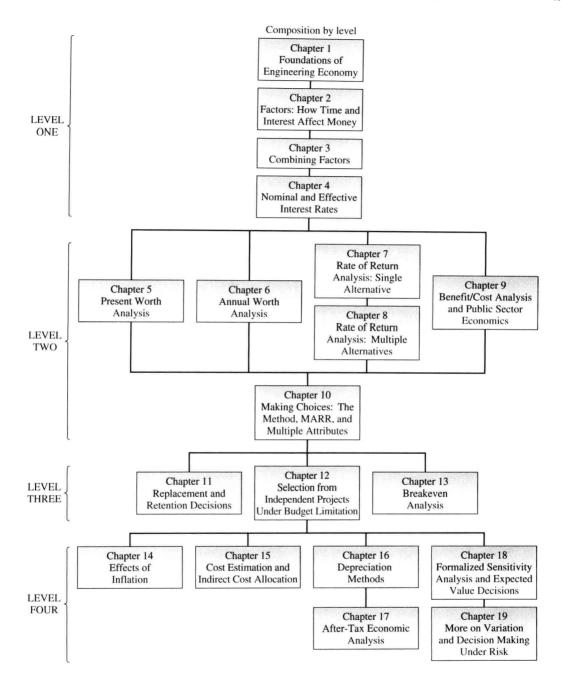
The material in Level One emphasizes basic computational skills, so these chapters are prerequisites for all the others in the book. The chapters in Level Two are primarily devoted to the most common analytical techniques for comparing alternatives. While it is advisable to cover all the chapters in this level, only the first two (Chapters 5 and 6) are widely used throughout the remainder of the text. The three chapters of Level Three show how any of the techniques in Level Two can be used to evaluate presently owned assets or independent alternatives, while the chapters in Level Four emphasize the tax consequences of decision making and some additional concepts in cost estimation, activity-based costing, sensitivity analysis, and risk, as treated using Monte Carlo simulation.

Organization of Chapters and End-of-Chapter Exercises   Each chapter contains a purpose and a series of progressive learning objectives, followed by the study material. Section headings correspond to each learning objective; for example, Section 5.1 contains the material pertaining to the first objective of the chapter. Each section contains one or more illustrative examples solved by hand, or by both hand and computer methods. Examples are separated from the textual material and include comments about the solution and pertinent connections to other topics in the book. The crisp end-of-chapter summaries neatly tie together the concepts and major topics covered to reinforce the learner's understanding prior to engaging in the end-of chapter exercises.

The end-of-chapter unsolved problems are grouped and labeled in the same general order as the sections in the chapter. This approach provides an opportunity to apply material on a section-by-section basis or to schedule problem solving when the chapter is completed.
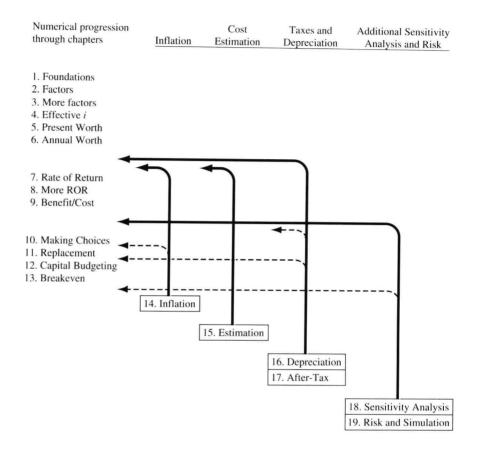
Appendices A and B contain supplementary information: a basic introduction to the use of spreadsheets (Microsoft Excel) for readers unfamiliar with them and the basics of accounting and business reports. Interest factor tables are located at the end of the text for easy access. Finally, the inside front covers offer a quick reference to factor notation, formulas, and cash flow diagrams, plus a guide to the format for commonly used spreadsheet functions. A glossary of common terms and symbols used in engineering economy appears inside the back cover.

Composition by level

LEVEL
ONE

Chapter 1
Foundations of
Engineering Economy

Chapter 2
Factors: How Time and
Interest Affect Money

Chapter 3
Combining Factors

Chapter 4
Nominal and Effective
Interest Rates

LEVEL
TWO

Chapter 5
Present Worth
Analysis

Chapter 6
Annual Worth
Analysis

Chapter 7
Rate of Return
Analysis: Single
Alternative

Chapter 8
Rate of Return
Analysis: Multiple
Alternatives

Chapter 9
Benefit/Cost Analysis
and Public Sector
Economics

Chapter 10
Making Choices: The
Method, MARR, and
Multiple Attributes

LEVEL
THREE

Chapter 11
Replacement and
Retention Decisions

Chapter 12
Selection from
Independent Projects
Under Budget Limitation

Chapter 13
Breakeven
Analysis

LEVEL
FOUR

Chapter 14
Effects of
Inflation

Chapter 15
Cost Estimation and
Indirect Cost Allocation

Chapter 16
Depreciation
Methods

Chapter 18
Formalized Sensitivity
Analysis and Expected
Value Decisions

Chapter 17
After-Tax Economic
Analysis

Chapter 19
More on Variation
and Decision Making
Under Risk

OPTIONS FOR PROGRESSION THROUGH CHAPTERS

Topics may be introduced at the point indicated or any point thereafter
(Alternative entry points are indicated by ← – – –)

Numerical progression through chapters	Inflation	Cost Estimation	Taxes and Depreciation	Additional Sensitivity Analysis and Risk

1. Foundations
2. Factors
3. More factors
4. Effective *i*
5. Present Worth
6. Annual Worth

7. Rate of Return
8. More ROR
9. Benefit/Cost

10. Making Choices
11. Replacement
12. Capital Budgeting
13. Breakeven

14. Inflation

15. Estimation

16. Depreciation
17. After-Tax

18. Sensitivity Analysis
19. Risk and Simulation

APPRECIATION TO CONTRIBUTORS

Throughout this and previous editions, many individuals at universities, in industry, and in private practice have helped in the development of this text. We thank all of them for their contributions and the privilege to work with them. Some of these individuals are

Roza Abubaker, American University of Sharjah
Robyn Adams, 12th Man Foundation, Texas A&M University
Jeffrey Adler, MindBox, Inc., and formerly of Rensselaer
    Polytechnic Institute
Richard H. Bernhard, North Carolina State University
Stanley F. Bullington, Mississippi State University
Peter Chan, CSA Engineering, Inc.

GUIDED TOUR

CHAPTER EXAMPLES AND EXERCISES   Users of this book have numerous ways to reinforce the concepts they've learned. The end-of-chapter *problems, in-chapter examples, extended exercises, case studies, and FE (Fundamentals of Engineering) review problems* offer students the opportunity to learn economic analysis in a variety of ways. The various exercises range from working relatively simple, one-step review problems to answering a series of comprehensive, in-depth questions based on real-world cases. In-chapter examples are also helpful in reinforcing concepts learned.

PROBLEMS

Types of Projects

5.1 What is meant by *service alternative*?

5.2 When you are evaluating projects by the present worth method, how do you know which one(s) to select if the projects

are (a) independent and (b) mutually exclusive?

5.3 Read the statement in the following problems and determine if the cash flows define
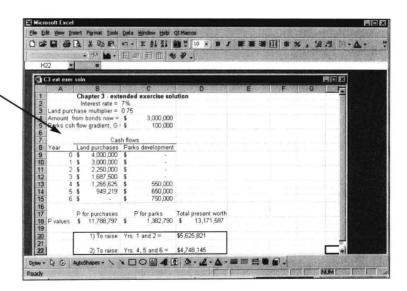
END-OF-CHAPTER PROBLEMS
As in previous editions, each chapter contains many homework problems representative of real-world situations. 80% of the end-of-chapter problems have been revised or are new to this edition.
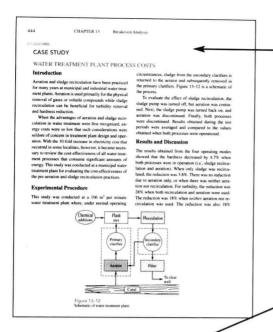
EXTENDED EXERCISES
The extended exercises are designed to require spreadsheet analysis with a general emphasis on sensitivity analysis.

FE REVIEW PROBLEMS

Note: The sign convention on the FE exam may be opposite of that used here. That is, on the FE exam, costs may be positive and receipts negative.

6.23 In comparing alternatives that have different lives by the annual worth method,
(a) The annual worth value of both alternatives must be calculated over a time period equal to the life of the shorter-lived one.
(b) The annual worth value of both alternatives must be calculated over a time period equal to the life of the longer-lived asset.
(c) The annual worth values must be calculated over a time period equal to the least common multiple of the lives.

(d) The annual worth values calculated over one life cycle of each alternative can be compared.

Problems 6.24 through 6.26 are based on the following estimates:

Alternative	A	B
First cost, $	−50,000	−80,000
Annual cost, $/year	−20,000	−10,000
Salvage value, $	10,000	25,000
Life, years	3	6

Use an interest rate of 10% per year.

6.24 The equivalent annual worth of alternative A is closest to:
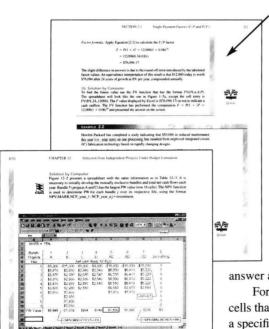(a) $−25,130
(b) $−37,100

FUNDAMENTALS OF ENGINEERING (FE) EXAM REVIEW PROBLEMS
The FE exam review problems cover the same topics as the FE exam and are written in the same multiple-choice format as the exam. *All of these problems are new to this edition.*
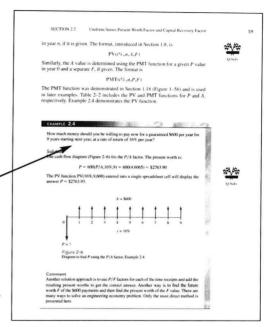
CASE STUDIES

All the case studies present real-world, in-depth treatments and exercises that cover the wide spectrum of economic analysis in the engineering profession.

IN-CHAPTER EXAMPLES

Examples within the chapters are relevant to all engineering disciplines that use this text, including industrial, civil, environmental, mechanical, petroleum, and electrical engineering as well as engineering management and engineering technology programs.

USE OF SPREADSHEETS

The text integrates spreadsheets and shows how easy they are to use in solving virtually any type of engineering economic analysis problem and how powerful they can be for altering estimates to achieve a better understanding of sensitivity and economic consequences of the uncertainties inherent in all forecasts. Beginning in Chapter 1, Blank and Tarquin illustrate their spreadsheet discussions with screenshots from Microsoft Excel™*.
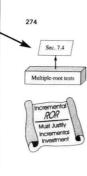
When a single-cell, built-in Excel function may be used to solve a problem, a checkered flag icon labeled *Q-Solv* (for *quick solution*) appears in the margin.

The thunderbolt *E-Solve* icon indicates that a more complex, sophisticated spreadsheet is developed to solve the problem. The spreadsheet will contain data and several functions and possibly an Excel chart or graph to illustrate the answer and sensitivity analysis of the solution to changing data.

For both Q-Solv and E-Solve examples, the authors have included cells that show the exact Excel function needed to obtain the value in a specific cell. The E-Solve icon is also used throughout chapters to point out descriptions of how to best use the computer to address the engineering economy topic under discussion.

CROSS-REFERENCING

Blank and Tarquin reinforce the engineering concepts presented throughout the book by making them easily accessible from other sections of the book. Cross-reference icons in the margins refer the reader to additional section numbers, specific examples, or entire chapters that contain either foundational (backward) or more advanced (forward) information that is relevant to that in the paragraph next to the icon.

Sec. 7.4

Multiple-root tests

Incremental
ROR
Must Justify
Incremental
Investment

Figures
7–6 and 7–7

Use of "guess" in IRR

App.
A

4. Count the number of sign changes in the incremental cash flow series to determine if multiple rates of return may be present. If necessary, use Norstrom's criterion on the cumulative incremental cash flow series to determine if a single positive root exists.
5. Set up the PW equation for the incremental cash flows in the form of Equation [7.1], and determine Δi^*_{B-A} using trial and error by hand or spreadsheet functions.
6. Select the economically better alternative as follows:

     If Δi^*_{B-A} < MARR, select alternative A.

     If Δi^*_{B-A} ≥ MARR, the extra investment is justified; select alternative B.

If the incremental i^* is exactly equal to or very near the MARR, noneconomic considerations will most likely be used to help in the selection of the "best" alternative.

In step 5, if trial and error is used to calculate the rate of return, time may be saved if the Δi^*_{B-A} value is bracketed, rather than approximated by a point value using linear interpolation, provided that a single ROR value is not needed. For example, if the MARR is 15% per year and you have established that Δi^*_{B-A} is in the 15 to 20% range, an exact value is not necessary to accept B since you already know that Δi^*_{B-A} ≥ MARR.

The IRR function on a spreadsheet will normally determine one Δi^* value. Multiple guess values can be input to find multiple roots in the range −100% to ∞ for a nonconventional series, as illustrated in Examples 7.4 and 7.5. If this is not the case, to be correct, the indication of multiple roots in step 4 requires that the net-investment procedure, Equation [7.6], be applied in step 5 to make $\Delta i' = \Delta i^*$. If one of these multiple roots is the same as the expected reinvestment rate c, this root can be used as the ROR value, and the net-investment procedure is not necessary. In this case only $\Delta i' = \Delta i^*$, as concluded at the end of Section 7.5.

INTERNATIONAL APPEAL

The international dimensions of this book are more apparent throughout the sixth edition. Examples and new sections on international corporate depreciation and taxation considerations and international forms of contracts, such as the BOT method of subcontracting, are included. The impact of hyperinflation and deflationary cycles are discussed from an international perspective.

17.9   AFTER-TAX ANALYSIS FOR INTERNATIONAL PROJECTS

Primary questions to be answered prior to performing a corporate-based after-tax analysis for international settings revolve on tax-deductible allowances—depreciation, business expenses, capital asset evaluation—and the effective tax rate needed for Equation [17.6], taxes = TI(T_e). As discussed in Chapter 16, most governments of the world recognize and use the straight line (SL) and declining balance (DB) methods of depreciation with some variations to determine the annual tax-deductible allowance. Expense deductions vary widely from country to country. By way of example, some of these are summarized here.
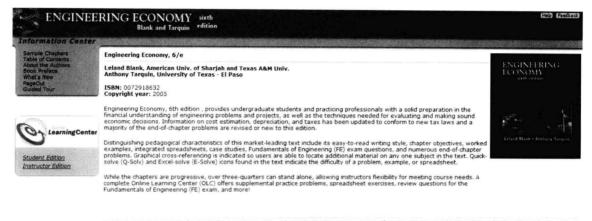
Canada

Depreciation: This is deductible and is normally based on DB calculations, although SL may be used. An equivalent of the half-year convention is applied in the first year of ownership. The annual tax-deductible allowance is termed *capital cost allowance (CCA)*. As in the U.S. system,

ADDITIONAL RESOURCES

The sixth edition of Blank and Tarquin features an Online Learning Center (OLC) available to students and professors who use the text. The URL for the site is http://www.mhhe.com/blank6.

The OLC will house the solutions to end-of-chapter problems, FE (Fundamentals of Engineering) exam prep quiz, spreadsheet exercises, matching and true/false quizzes, links to important websites, chapter objectives, lecture slides, end-of chapter summaries and more!

New to this edition is McGraw-Hill's new database management tool. Complete Online Solutions Manual Organization System (C.O.S.M.O.S.). C.O.S.M.O.S. is delivered via CD-ROM and helps instructors to organize solutions and distribute and track problem sets as they are assigned to students in the course. This helps instructors to quickly find solutions and keep a record of problems assigned, to avoid duplication of tests and quizzes in subsequent semesters. The ISBN for the *Engineering Economy* C.O.S.M.O.S. CD-ROM is 0–07–298450–3. Contact your McGraw-Hill representative to get a copy.

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