

ENGINEERING ECONOMY

TENTH EDITION

E. PAUL DEGARMO
WILLIAM G. SULLIVAN
JAMES A. BONTADELLI
ELIN M. WICKS

Tenth Edition

Engineering Economy

E. Paul Degarmo

Emeritus, University of California, Berkeley

William G. Sullivan

*Virginia Polytechnic Institute and State
University*

James A. Bontadelli

The University of Tennessee, Knoxville

Elin M. Wicks

University of Missouri, Columbia



Prentice Hall
Upper Saddle River, New Jersey 07458

Library of Congress Cataloging-in-Publication Data

Engineering economy / E. Paul DeGarmo ... [et al.]—10th ed.

p. cm.

Rev. ed. of: Engineering economy / E. Paul DeGarmo, William G.

Sullivan, James A. Bontadelli. 9th ed. c1993.

Includes bibliographical references and index.

ISBN 0-13-382193-5

1. Engineering economy. I. DeGarmo, E. Paul (Ernest Paul), 1907–.

II. DeGarmo, E. Paul (Ernest Paul), 1907–. Engineering economy.

TA177.4.E539 1997

658.15'5—dc20

96-26501

CIP

Editor-in-Chief: **Marcia Horton**

Acquisitions editor: **Alice Dworkin**

Managing editor: **Bayani Mendoza de Leon**

Production editor: **Irwin Zucker**

Art director: **Amy Rosen**

Assistant art director: **Rod Hernandez**

Creative director: **Paula Maylahn**

Cover design: **Rosemarie Votta**

Cover illustration: **Joseph Taylor**

Interior design: **Elm Street Publishing Services**

Manufacturing buyer: **Donna Sullivan**

Editorial assistant: **Phyllis Morgan**



©1997 by Prentice-Hall, Inc.

Simon & Schuster / A Viacom Company

Upper Saddle River, New Jersey 07458

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher.

Earlier editions entitled *Engineering Economy*, copyright © 1993, 1988, 1984, 1979, 1973, 1967, and 1960 by Macmillan Publishing Company. Earlier editions entitled *Introduction to Engineering Economy*, copyright © 1953 by Macmillan Publishing Company, and copyright © 1942 by E. P. DeGarmo and B. M. Woods.

The author and publisher of this book have used their best efforts in preparing this book. These efforts include the development, research, and testing of the theories and programs to determine their effectiveness. The author and publisher make no warranty of any kind, expressed or implied, with regard to these programs or the documentation contained in this book. The author and publisher shall not be liable in any event for incidental or consequential damages in connection with, or arising out of, the furnishing, performance, or use of these programs.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

ISBN 0-13-382193-5

Prentice-Hall International (UK) Limited, London

Prentice-Hall of Australia Pty. Limited, Sydney

Prentice-Hall Canada Inc., Toronto

Prentice-Hall Hispanoamericana, S.A., Mexico

Prentice-Hall of India Private Limited, New Delhi

Prentice-Hall of Japan, Inc., Tokyo

Simon & Schuster Asia Pte. Ltd., Singapore

Editora Prentice-Hall do Brasil, Ltda., Rio de Janeiro

***This book is dedicated
to the ones we love.***

*E. Paul Degarmo
William G. Sullivan
James A. Bontadelli
Elin M. Wicks*

Preface

Engineering economy—what is it and why is it important? The initial reaction of many engineering students to these questions is “Money matters will be handled by someone else. It is not something I need to worry about.” In reality, any engineering project must be not only physically realizable but also economically feasible. For example, a child’s tricycle could be built with an aluminum frame or a composite frame. Some may argue that because the composite frame will be stronger and lighter, it is a better choice. However, there is not much of a market for thousand dollar tricycles. One might suggest that the above argument is ridiculously simplistic and that common sense would dictate choosing aluminum for the framing material. Although the scenario is an exaggeration, it reinforces the idea that the economic factors of a design weigh heavily in the design process, and that engineering economy is an integral part of that process, regardless of the engineering discipline.

In broad terms, for an engineering design to be successful, it must be technically sound and produce some benefits. These benefits must exceed the costs associated with the design in order for the design to enhance net value. The field of engineering economy is concerned with the systematic evaluation of the particular benefits and costs of projects involving engineering design and analysis. In other words, engineering economy quantifies the benefits and costs associated with engineering projects to determine if they make (or save) enough money to warrant their capital investments. Thus, engineering economy requires a coupling of technical analysis and economic feasibility to determine the best course of action for various engineering scenarios. As we shall see, engineering economy is as relevant to the design engineer who considers material selection as it is to the chief executive officer who approves capital expenditures for new ventures.



History of the Book

The original *Introduction to Engineering Economy*, authored by Woods and DeGarmo, appeared in 1942. This text has been in continuous classroom use for over 50 years, and over 400,000 students have learned about engineering economic analysis from its pages. The tenth edition of *Engineering Economy* has built upon the rich and time-tested teaching materials of earlier editions, and its publication makes it the second-oldest book on the market that deals exclusively with engineering economy.



Intended Use of the Book

This book has two primary purposes: (1) to provide students with a sound understanding of the principles, basic concepts, and methodology of engineering economy; and (2) to help them develop proficiency with these methods and with the process for making rational decisions regarding situations they are likely to encounter in professional practice. Consequently, *Engineering Economy* is intended to serve as a text for classroom instruction *and* as a basic reference for use by practicing engineers in all specialty areas (e.g., chemical, civil, electrical, industrial, and mechanical). The book is also useful to persons engaged in the management of technical activities.

As a textbook, the tenth edition is written principally for the first formal course in engineering economy. The contents of the book and the accompanying Instructor's Manual and Electronic Spreadsheets Supplement (both available from Prentice Hall) are organized for effective presentation and teaching of the subject matter. A three-credit-hour semester course should be able to cover the majority of topics in this edition, and there is sufficient depth and breadth to enable an instructor to arrange course content to suit individual needs. Moreover, because several advanced topics are included in this book, it can also be used for a second course in engineering economy.

Every chapter and appendix has been revised and updated to reflect current trends and issues. Also, numerous exercises that involve open-ended problem statements and iterative problem-solving skills are included throughout the book. A large portion of the 500+ end-of-chapter exercises are new, and many solved examples representing realistic problems that arise in various engineering disciplines are presented.

An engineering economy course may be classified, for Accreditation Board for Engineering and Technology (ABET) purposes, as part engineering science and part engineering design. It is generally advisable to develop and teach such a course at the upper division level, where the course incorporates the accumulated knowledge students have acquired in other areas of the curriculum also dealing with iterative problem solving, open-ended exercises/case studies, creativity in formulating and evaluating feasible solutions to problems, and consideration of realistic constraints (economic, esthetic, safety, etc.) in problem solving.



Instructional Features

The *Instructor's Manual* is designed as a comprehensive aid in teaching the text material. Full solutions of all problems at the end of each chapter are presented. Several *comprehensive examples (case studies)* have been included in the tenth edition. They provide the instructor with essential material for teaching both the first formal course and a second, more advanced course in engineering economy. These case studies demonstrate the integrated application of the principles, basic concepts, and methodologies that are needed by engineers in typical real-world situations. They also serve as a bridge from the classroom to professional practice.



Spreadsheet Supplement

A second supplement entitled *Electronic Spreadsheets for Engineering Economy Applications* is authored by James A. Alloway, Jr. Electronic spreadsheets are a mainstay in many undergraduate engineering economy courses; the spreadsheet supplement ensures that the tenth edition of *Engineering Economy* will maintain its leadership position by providing basic templates for all major topics in the text. In addition, it provides a concise summary of formulas and key concepts, which students will find invaluable for review and quick reference. To access the supplement, ftp to **ftp.prenhall.com**, log in as “anonymous” using your e-mail address as the password, and change to the directory: pub/ESM/industrial_engineering.s-047/sullivan/engineer.eco/alloway/spread.

The spreadsheet supplement marks the first time that a major engineering economy text has provided spreadsheet material at this level of detail via the Internet, and students and instructors will benefit in several ways. For instance, electronic publishing provides a means to increase the amount of material instructors can cover without increasing printing costs, and they do not have to make additional arrangements to provide access for their students. Enhancements and additions to the supplement will be available immediately. Students can “cut and paste” the chapter, notation, and formula summaries into their own study documents.

The greatest advantage is that it is no longer necessary to enter the spreadsheets by hand. The templates can be downloaded and opened directly in Lotus 1-2-3 Release 5 for Windows. Most other spreadsheet software packages (e.g., Excel) provide conversion utilities to convert these files into their respective native formats. Users can then modify the basic templates for the specific problem at hand. As a bonus, advanced templates have also been developed for such techniques as Monte Carlo simulation, three-factor simultaneous sensitivity analysis, and integer linear programming.



Acknowledgments

Many friends and associates have offered valuable and constructive ideas and concepts that have materialized into numerous improvements to the tenth edition.

To these individuals we express our most sincere appreciation. Also, to our students, who have unknowingly been the proving ground for much of this text, we offer our thanks. They have reacted, without compassion on some occasions, to make us aware of good and bad methods of presentation. It is our hope that they, and those who follow them, will find this book an invaluable guide to the study and practice of engineering economy.

We wish to thank the following individuals for their inputs to the tenth edition: Dr. Hampton R. Liggett of Northern Illinois University did an excellent job in updating Chapter 6; Dr. Dan Babcock, Professor Emeritus at the University of Missouri-Rolla provided invaluable contributions to virtually all chapters of the initial manuscript; Mr. Garry Coleman of Virginia Tech volunteered several end-of-chapter problems; Dr. Richard H. Bernhard of North Carolina State University made many helpful suggestions for improving our discussion of the benefit/cost ratio method in Chapter 6; Mr. James A. Brimson of ABM-I, Inc. was very constructive in his review of activity-based accounting (Appendix A); Ms. Tracy S. Turner, CPA, of Coulter & Justice, carefully examined the accuracy of income tax matter included in Chapter 7; Dr. James A. Alloway created a large number of the spreadsheets presented in this edition; and Dr. Samer Madanat of Purdue University was very encouraging in his review of an early manuscript.

Also for the many suggestions from other colleagues, students, and practicing engineers who have used the previous editions, we express our deep appreciation. We hope they will find this edition to be even more helpful.

E. P. D.

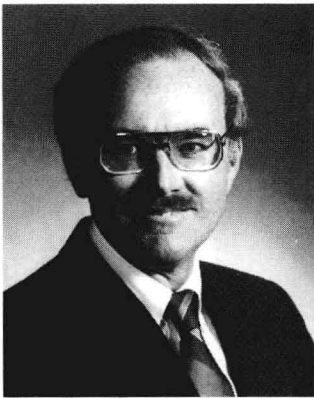
W. G. S.

J. A. B.

E. M. W.

About the Authors

William G. Sullivan



William G. Sullivan is professor of Industrial and Systems Engineering at Virginia Polytechnic Institute and State University. He is also a two-time recipient of the Eugene L. Grant Award for the best paper in *The Engineering Economist* (Volumes 29 and 36). Dr. Sullivan's current research interests include justification of advanced manufacturing technologies, the economic principles of engineering design, and activity-based costing applied to the design process. Dr. Sullivan is a registered professional engineer and a member of IIE, ASEE, IMA, and SME. He also serves as coeditor of the *International Journal of FAIM*. He is a fellow in the Institute of Industrial Engineers. His Ph.D. in Industrial and Systems Engineering was earned at the Georgia Institute of Technology.

James A. Bontadelli



James A. Bontadelli is a professor of Industrial Engineering at the University of Tennessee, Knoxville, and a former director of industrial engineering for the Tennessee Valley Authority. He obtained a Ph.D. in Industrial and Systems Engineering from The Ohio State University and is a registered professional engineer with more than thirty years of professional practice. He has been a co-author of *Engineering Economy* since the eighth edition.

Elin M. Wicks



Elin M. Wicks is an assistant professor of Industrial Engineering at the University of Missouri, Columbia. She obtained a Ph.D. in Industrial and Systems Engineering from the Virginia Polytechnic Institute and State University. Elin is a member of IIE and ACEE.

E. Paul DeGarmo

E. Paul DeGarmo is a professor emeritus of Industrial Engineering and Mechanical Engineering at the University of California, Berkeley. He was a co-author (with B. Woods) in 1942 of the first edition, entitled *Introduction to Engineering Economy*.

Engineering Economy

Contents

Preface xv

PART I

Background and Tools of Engineering Economy 1

CHAPTER 1

Introduction to Engineering Economy 2

- 1.1 Introduction 2
- 1.2 Origins of Engineering Economy 4
- 1.3 What Are the Principles of Engineering Economy? 4
- 1.4 Engineering Economy and the Design Process 8
- 1.5 Accounting and Engineering Economy Studies 16
- 1.6 Overview of the Book 17
- 1.7 Summary 19
- 1.8 Problems 19

CHAPTER 2

Cost Concepts and the Economic Environment 21

- 2.1 Introduction 22
- 2.2 Cost Terminology 22

| | | |
|-----|----------------------------------|----|
| 2.3 | The General Economic Environment | 33 |
| 2.4 | Cost-Driven Design Optimization | 43 |
| 2.5 | Present Economy Studies | 50 |
| 2.6 | Summary | 56 |
| 2.7 | References | 56 |
| 2.8 | Problems | 56 |

CHAPTER 3

| | | |
|------|---|-----|
| | <i>Principles of Money–Time Relationships</i> | 63 |
| 3.1 | Introduction | 63 |
| 3.2 | Why Consider Return to Capital? | 64 |
| 3.3 | The Origins of Interest | 65 |
| 3.4 | Simple Interest | 65 |
| 3.5 | Compound Interest | 66 |
| 3.6 | The Concept of Equivalence | 67 |
| 3.7 | Notation and Cash Flow Diagrams/Tables | 70 |
| 3.8 | Interest Formulas Relating Present and Future Equivalent Values of Single Cash Flows | 73 |
| 3.9 | Interest Formulas Relating a Uniform Series (Annuity) to Its Present and Future Equivalent Values | 78 |
| 3.10 | Interest Formulas for Discrete Compounding and Discrete Cash Flows | 85 |
| 3.11 | Deferred Annuities (Uniform Series) | 85 |
| 3.12 | Equivalence Calculations Involving Multiple Interest Formulas | 87 |
| 3.13 | Interest Formulas Relating a Uniform Gradient of Cash Flows to Its Annual and Present Equivalents | 91 |
| 3.14 | Interest Formulas Relating a Geometric Sequence of Cash Flows to Its Present and Annual Equivalents | 97 |
| 3.15 | Interest Rates That Vary with Time | 101 |
| 3.16 | Nominal and Effective Interest Rates | 102 |
| 3.17 | Interest Problems with Compounding More Often Than Once per Year | 104 |
| 3.18 | Interest Problems with Cash Flows Less Often Than Compounding Periods | 106 |
| 3.19 | Interest Formulas for Continuous Compounding and Discrete Cash Flows | 110 |
| 3.20 | Interest Formulas for Continuous Compounding and Continuous Cash Flows | 112 |
| 3.21 | Additional Solved Problems | 115 |
| 3.22 | Spreadsheet Applications | 120 |
| 3.23 | Summary | 121 |
| 3.24 | References | 122 |
| 3.24 | Problems | 122 |

PART II***Applications of Engineering Economy 139***

CHAPTER 4

Applications of Money–Time Relationships 140

- 4.1 Introduction 140
- 4.2 Determining the Minimum Attractive Rate of Return 141
- 4.3 The Present Worth Method 144
- 4.4 The Future Worth Method 149
- 4.5 The Annual Worth Method 150
- 4.6 The Internal Rate of Return Method 153
- 4.7 The External Rate of Return Method 162
- 4.8 The Payback (Payout) Period Method 164
- 4.9 Investment Balance Diagrams 166
- 4.10 An Example of a Proposed Capital Investment to Reduce Costs 168
- 4.11 An Example of a Large Industrial Investment Opportunity 169
- 4.12 Spreadsheet Applications 175
- 4.13 Summary 177
- 4.14 References 177
- 4.15 Problems 177
- Appendix 4-A The Multiple Rate of Return Problem with the IRR Method 185

CHAPTER 5

Comparing Alternatives 188

- 5.1 Introduction 188
- 5.2 Basic Concepts for Comparing Alternatives 189
- 5.3 The Study (Analysis) Period 191
- 5.4 Case 1: Useful Lives Are Equal to the Study Period 193
- 5.5 Case 2: Useful Lives Are Different Among the Alternatives 208
- 5.6 Comparison of Alternatives Using the Capitalized Worth Method 217
- 5.7 Defining Mutually Exclusive Investment Alternatives in Terms of Combinations of Projects 219
- 5.8 Spreadsheet Applications 225
- 5.9 Summary 228
- 5.10 References 228
- 5.11 Problems 229

CHAPTER 6*Evaluating Projects with the Benefit/Cost Ratio Method* 239

- 6.1 Introduction 239
- 6.2 Perspective and Terminology for Analyzing Public Projects 241
- 6.3 Self-Liquidating Projects 242
- 6.4 Multiple-Purpose Projects 242
- 6.5 Difficulties in Evaluating Public Sector Projects 244
- 6.6 What Interest Rate Should Be Used for Public Projects? 246
- 6.7 The Benefit/Cost Ratio Method 248
- 6.8 Evaluating Independent Projects by B/C Ratios 254
- 6.9 Comparison of Mutually Exclusive Projects by B/C Ratios 256
- 6.10 Criticisms and Shortcomings of the Benefit/Cost Ratio Method 261
- 6.11 Spreadsheet Applications 263
- 6.12 Summary 265
- 6.13 References 265
- 6.14 Problems 266

CHAPTER 7*Depreciation and Income Taxes* 271

- 7.1 Introduction 272
- 7.2 Depreciation Concepts and Terminology 272
- 7.3 The Classical (Historical) Depreciation Methods 275
- 7.4 The Modified Accelerated Cost Recovery System 281
- 7.5 A Comprehensive Depreciation Example 287
- 7.6 Depletion 291
- 7.7 Introduction to Income Taxes 294
- 7.8 The Effective (Marginal) Corporate Income Tax Rate 296
- 7.9 Gain (Loss) on the Disposal of an Asset 300
- 7.10 General Procedure for Making After-Tax Economic Analyses 300
- 7.11 Illustration of Computations of ATCFs 305
- 7.12 After-Tax Analyses That Include Specific Financing Arrangements 313
- 7.13 The After-Tax Effect of Depletion Allowances 316
- 7.14 Summary 319
- 7.15 References 319
- 7.16 Problems 320

CHAPTER 8*Estimating Cash Flows* 328

- 8.1 Introduction 328

| | | |
|-----|---|-----|
| 8.2 | An Integrated Approach | 329 |
| 8.3 | Selected Estimating Techniques (Models) | 340 |
| 8.4 | Estimating Total Product Costs and Selling Price | 348 |
| 8.5 | Estimating Cash Flows for a Typical Small Project | 353 |
| 8.6 | Developing Cash Flows (A Case Study) | 356 |
| 8.7 | Summary | 362 |
| 8.8 | References | 362 |
| 8.9 | Problems | 363 |

CHAPTER 9

| | | |
|------|--|-----|
| | <i>Inflation and Price Changes</i> | 368 |
| 9.1 | General Price Inflation | 368 |
| 9.2 | Terminology and Basic Concepts | 370 |
| 9.3 | Differential Price Inflation or Deflation | 381 |
| 9.4 | Application Strategy | 386 |
| 9.5 | A Comprehensive Example | 386 |
| 9.6 | Foreign Exchange Rates and Purchasing Power Concepts | 390 |
| 9.7 | Spreadsheet Applications | 392 |
| 9.8 | Summary | 394 |
| 9.9 | References | 395 |
| 9.10 | Problems | 395 |

CHAPTER 10

| | | |
|-------|--|-----|
| | <i>Dealing with Uncertainty</i> | 402 |
| 10.1 | Introduction | 402 |
| 10.2 | What Are Risk, Uncertainty, and Sensitivity? | 403 |
| 10.3 | Sources of Uncertainty | 404 |
| 10.4 | Common Nonprobabilistic Methods for Dealing with Uncertainty | 405 |
| 10.5 | Breakeven Analysis | 406 |
| 10.6 | Sensitivity Analysis | 412 |
| 10.7 | Analyzing a Proposed Business Venture | 414 |
| 10.8 | Optimistic–Pessimistic Estimates | 417 |
| 10.9 | Risk-Adjusted Minimum Attractive Rates of Return | 421 |
| 10.10 | Reduction of Useful Life | 423 |
| 10.11 | Spreadsheet Applications | 425 |
| 10.12 | Summary | 427 |
| 10.13 | References | 428 |
| 10.14 | Problems | 428 |

PART III*Special Topics in Engineering Economy 435*

CHAPTER 11*Replacement Analysis 436*

- 11.1 Introduction 436
- 11.2 Reasons for Replacement Analysis 437
- 11.3 Factors That Must Be Considered in Replacement Studies 438
- 11.4 A Typical Replacement Problem 441
- 11.5 A Decision Roadmap for Replacement Analysis 445
- 11.6 Determining the Economic Life of a New Asset (Challenger) 447
- 11.7 Determining the Economic Life of a Defender 452
- 11.8 Comparisons in Which the Defender's Useful Life Differs from That of the Challenger 455
- 11.9 Retirement Without Replacement (Abandonment) 459
- 11.10 A Comprehensive Example 460
- 11.11 Spreadsheet Applications 463
- 11.12 Summary 465
- 11.13 References 467
- 11.14 Problems 468

CHAPTER 12*Capital Financing and Allocation 475*

- 12.1 Introduction 475
- 12.2 Capital Financing 476
- 12.3 Financing with Debt Capital 478
- 12.4 Financing with Equity Capital 481
- 12.5 Leasing as a Source of Capital 484
- 12.6 Capital Allocation 488
- 12.7 Allocating Capital Among Independent Projects 490
- 12.8 Linear Programming Formulations of Capital Allocation Problems 493
- 12.9 An Overview of Corporate Capital Allocation Policy and Procedures 497
- 12.10 Summary 500
- 12.11 References 501
- 12.12 Problems 501

CHAPTER 13*Engineering Economy Studies in Investor-Owned Utilities 504*

- 13.1 Background 504