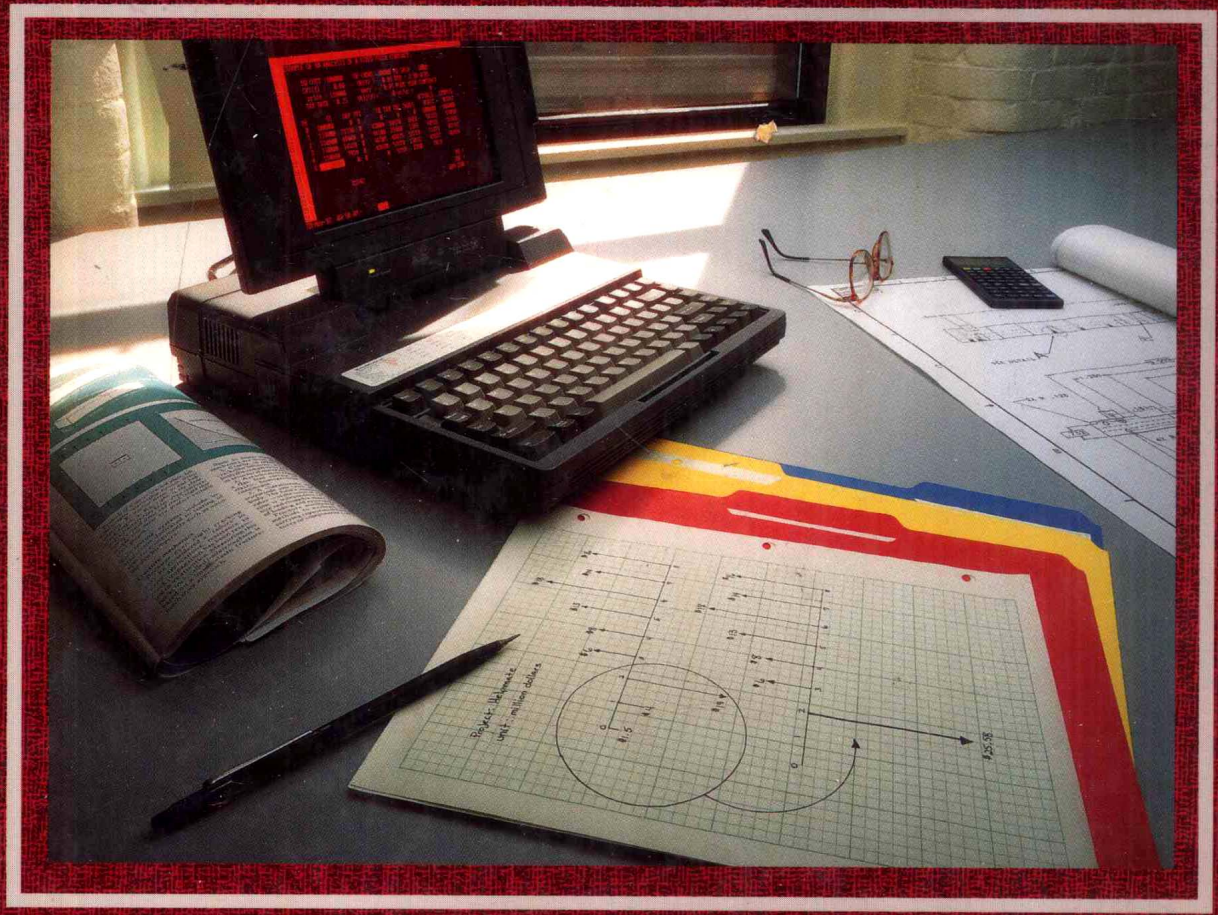
Contemporary Engineering Economics

Chan S. Park



Includes integrated analysis software for the IBM® PC

Contemporary Engineering Economics

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Dedicated to my beloved family
Kim (Inkyung), Michael (Dongwoo),
and Edward (Sungwoo)

PREFACE

What's "Contemporary" About Engineering Economics?

Decisions made during the engineering design phase of product development determine the majority (some say 85%) of the costs of manufacturing that product. As design and manufacturing processes become more complex, the engineer is making decisions that involve money more than ever before. Thus, the competent and successful engineer in the twenty-first century must have an improved understanding of the principles of science, engineering, and economics, coupled with relevant design experience. Increasingly, in the new world economy, successful businesses will rely on engineers with such expertise.

Economic and design issues are inextricably linked in the product/service life cycle. Therefore, one of my strongest motivations in writing this text was to bring the realities of economics and engineering design into the classroom and to help students integrate these issues when contemplating product development problems.

Another compelling motivation was to introduce the computer as a productivity tool for modeling and analyzing engineering decision problems once students have mastered fundamental concepts. Spreadsheets are currently the undisputed standard for automating complex engineering economic problems in industry and they are used increasingly in the classroom. This text introduces spreadsheets in dedicated sections at the ends of chapters.

In addition to spreadsheets, the end-of-chapter sections introduce the software, CASH, that is packaged with this text. Conventional engineering economic software has been less than completely successful for two reasons: (1) Programs often present knowledge in rigid ways with few possibilities for adapting to the needs of the individual student, and (2) the structure of the knowledge is usually hidden from the student. CASH was developed to open *visually* the economic computing environment to the student's understanding. CASH is an integrated package that includes the most frequently used economic analysis methods. It organizes information via graph-based structures that can be explored independently by a student.

Of course, my underlying motivation for writing this book was not simply to address contemporary needs, but to address as well the ageless goal of all educators: to help students to learn. Thus, thoroughness, clarity, and accuracy of presentation of essential engineering economics were my aims at every step in the development of the text.

Overview of the Text

Although it contains little advanced math and few truly difficult concepts, the introductory engineering economics course is often a curiously challenging one for the sophomores, juniors, and seniors who take it. There are several likely explanations for this difficulty:

- The course is the student's first analytical consideration of money (a resource with which he or she may have had little direct contact beyond paying for tuition, housing, food, and textbooks).
- An emphasis on theory—while critically important to forming the foundation of a student's understanding—may obscure for the student the fact that the course aims, among other things, to develop a very practical set of analytical tools for measuring project worth. This is unfortunate since, at one time or another, virtually every engineer—not to mention every individual—is responsible for the wise allocation of limited financial resources.
- The mixture of industrial, civil, mechanical, electrical, manufacturing, and other engineering undergraduates who take the course often fail to "see themselves" in the skills the course and text are intended to foster. This is perhaps less true for industrial engineering students, whom many texts take as their primary audience, but other disciplines are often motivationally shortchanged by a text's lack of applications that appeal directly to them.

Goals of the Text

This text aims not only to build a sound and comprehensive coverage of the *concepts* of engineering economics but also to address the student difficulties outlined above, all of which have their basis in an inattentiveness to the practical concerns of engineering economics. More specifically, this text has the following chief goals:

1. To build a thorough understanding of the theoretical and conceptual basis on which the practice of financial project analysis is built.
2. To satisfy the very practical need engineers have to make informed financial decisions when acting as a team member or project manager for an engineering project.
3. To incorporate all the critical decision-making tools—including the most contemporary, computer-oriented ones—that engineers bring to the task of making informed financial decisions.
4. To appeal to the full range of engineering disciplines for which this course is often required: industrial, civil, mechanical, electrical, computer, aerospace, chemical, and manufacturing engineering, as well as engineering technology.

Prerequisites

The text is intended for undergraduate engineering students at the sophomore level or above. The only mathematical background required is elementary

calculus. (For Chapter 15, a first course in probability or statistics is helpful but not necessary, since the treatment of basic topics there is essentially self-contained.)

Content and Approach

Educators generally agree upon the proper contents and organization of an engineering economics text. A glance at the table of contents will show you that this text matches the standard embraced by most instructors and reflected in competing texts. However, one of my driving motivations was to supersede the standard in terms of depth of coverage and care with which difficult concepts are presented. Accordingly, the content and approach of *Contemporary Engineering Economics* reflect the following goals:

Thorough development of the concept of the time value of money

The notion of the time value of money and the interest formulas that model it form the foundation upon which all other topics in engineering economics are built. Because of their great importance, and because many students are being exposed to an analytical approach to money for the first time, interest topics are carefully and thoroughly developed in Chapters 2 and 3.

- Chapter 2 carefully examines the *conceptual* underpinnings of interest—the time value of money—including more "what-if" and graphical exploration than any other text.
- An understanding of the time value of money is extended via its real world complexities—effective interest, noncomparable payment and compounding periods, etc.—in Chapter 3.

Thorough, reasonably paced coverage of the major analysis methods

The equivalence methods—present worth, annual worth, and future worth—and rate of return analysis are the bedrock methods of project evaluation and comparison. This text carefully develops these topics in Chapters 4, 5, and 6, pacing them for maximum student comprehension of the subtleties, advantages, and disadvantages of each method.

- A separate, dedicated chapter (Chapter 5) on annual worth is presented to emphasize the circumstances in which that method of project analysis is preferred to other methods.
- The difficulties and exceptions associated with rate of return analysis are thoroughly covered in Chapter 6.
- Coverage of internal rate of return for nonsimple projects is included in Chapter 6 but marked as optional for those who wish to avoid this complication in an introductory course. The section can be omitted without disrupting the flow of topics.

More emphasis than competitive texts on developing after-tax project cash flows

Estimating and developing project cash flows is the first critical step in conducting an engineering economic analysis—further analysis, comparison of projects, and decision making all depend on intelligently developed project cash flows. A particularly important goal of this text is to build confidence in developing *after-tax* cash flows.

- Chapter 9 is a unique synthesis of previously developed topics (analysis methods, depreciation, and taxes) and is dedicated to building skill and confidence in developing after-tax cash flows for a series of fairly complex projects.
- The investment tax credit is covered briefly in text and examples in Chapter 9 in case this feature is returned to the tax code in the near future.

Complete coverage of the special topics that round out a comprehensive introduction to engineering economics

A number of special topics are important to a comprehensive understanding of introductory engineering economics. Chapters 10–15 cover the following topics, respectively:

- Inflation
- Project financing
- Replacement analysis
- Capital budgeting
- Public sector analysis
- Sensitivity and risk analyses

Recognizing that time availability and priorities vary from course to course and instructor to instructor, each one of these chapters is sufficiently self-contained that it may be skipped or covered out of sequence, as needed.

Addressing Educational Challenges

The features of *Contemporary Engineering Economics* were selected and shaped to address key educational challenges. It is the observation of both author and publisher—based on many conversations with engineering educators—that certain challenges consistently frustrate both instructors and students across the engineering curriculum. Low student motivation and enthusiasm, student difficulty in developing problem-solving skills and intuition, challenges to integrate technology without shortchanging fundamental concepts and traditional methods, and student difficulty in prioritizing and remembering enormous amounts of information are among the key educational challenges that drove the features program in *Contemporary Engineering Economics.*

Building problem-solving skills and confidence

The examples in the text are formatted to maximize their usefulness as guides to problem solving. Further, they are intended to stimulate student curiosity to look beyond the mechanics of problem solving to "what-if" issues, alternative solution methods, and interpretation of solutions.

Example titles promote ease of student reference and review.

Example 2.19 A uniform series problem with "too much" information

On August 23, 1985, a *New York Times* headline stated "21 Share New York Jackpot." The article revealed that 21 factory workers had agreed to pool $21 to play the New York lottery and split any winnings. Their winning ticket was worth $13,667,667, which would be distributed in 21 annual payments of $650,793. That meant each member of the pool would receive 21 annual payments of about $24,000 after taxes, according to their lawyer. John Brown, one of the lucky workers, wanted to quit the factory and start his own business, which required him to secure a $250,000 bank loan. Brown offered to put up his future lottery earnings (as collateral) to secure the loan. If the bank's interest rate is 10% per year, how much can he borrow against his future lottery earnings?

Discussion sections at the beginning of complex examples help students begin organizing a problem-solving approach.

Discussion: We need to identify the relevant data in this problem, because some numbers ultimately have nothing to do with the solution method. Basically, Brown wants to borrow $250,000 from a bank, but there is no assurance from the bank that he will get the full amount. (Normally a lending officer determines the maximum amount that one can borrow based on the borrower's capability of repaying the loan.) If the bank views Brown's lottery earnings as his only source of future income for repaying the loan, the bank must find the equivalent present worth of his 21 annual payments of $24,000 in order to set the maximum loan amount.

Given and **Find** heads help students identify critical data. This convention is employed in Chapters 2–10, then omitted in Chapters 11–15 after student confidence in setting up solution procedures has been established.

Solution

Given: $i = 10\%$ per year, $A = \$24{,}000$, and $N = 21$ years

Find: P

$$P = \$24{,}000(P/A, 10\%, 21) = \$24{,}000(8.6487) = \$207{,}569.$$

The bank would lend Brown a maximum of $207,569. He would have to borrow the remaining balance from other sources.

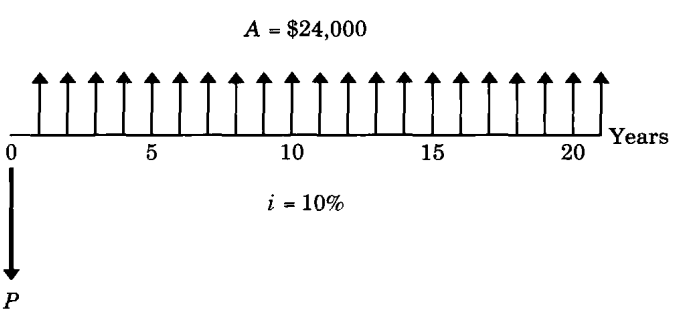

Figure 2.29 ■ Cash flow diagram (Example 2.19)

Comments sections at the ends of examples add additional insights—an alternative solution method, a short-cut, an interpretation of the numerical solution—and extend the educational value of the example.

Comments: *Note that the critical data included the actual cash flow over the time rather than the total sum of the winnings because of the different time values of the payments.*

Capturing the student's imagination

Students want to know how the conceptual and theoretical knowledge they are acquiring will be put to use. *Contemporary Engineering Economics* incorporates real world applications and contexts in a number of ways to stimulate student enthusiasm and imagination:

Feature	Purpose	Sample References
Real-world, conceptual overview of engineering economics established in Chapter 1	To provide an engaging introduction to engineering economics via examples of its practical use	p. 4: GM's decision to build an electric car pp. 21–22:Motorola's investment in a global portable phone network
Chapter-opening scenarios	To establish an interest and need to know chapter concepts within the context of a practical application	pp. 192–193, Chapter 4: Construction of a hydroelectric plant pp. 458–459, Chapter 9: Flexible manufacturing of electronic circuit boards
An abundance of homework problems involving real engineering projects	To stimulate student interest and motivation with actual engineering investment projects, many taken from today's headlines	pp. 190–191, Prob. 3.79: Electronic "anti-noise" system for car interiors pp. 456–457, Prob. 8.27: Microwave plasma reactor for creating synthetic diamonds
A full range of engineering disciplines represented in problems, examples, chapter openers, and case studies	To illustrate the many disciplines that require engineering economics. Industrial, civil, mechanical, electrical, manufacturing, and other areas are all represented.	pp. 368–369, Prob. 6.50: Mechanical engineering pp. 114–115, Prob. 2.57: Electrical engineering p. 248, Prob. 4.22: Civil engineering p. 299, Prob. 5.40: Industrial engineering. Also see summary table on inside text cover.

Harnessing the power of the computer

Three years ago, when I began work on this text and Addison-Wesley began examining market desires and demands, the integration of the computer into the course and text was a sensitive issue, with most instructors' opinions varying

from ambivalent to negative. A tremendous evolution appears to have swept the course since then: Students have greater access to and familiarity with the appropriate hardware and software tools, and instructors have greater inclination either to treat these topics explicitly in the course or to encourage students to experiment independently.

A remaining concern is that the computer will undermine true understanding of course concepts. This text does *not* promote the trivial or mindless use of computers as a replacement for genuine understanding of and skill in applying traditional solution methods. Rather, it focuses on the computer's productivity-enhancing benefits for complex project cash flow development and analysis. Specifically, *Contemporary Engineering Economics* includes a robust introduction to computer automation in the form of **Computer Notes**, which appear at the end of most chapters.

Spreadsheets are introduced via Lotus 1-2-3 examples. Where appropriate, conversion tables are included so that the built-in functions of both Excel and QuattroPro can be compared to Lotus 1-2-3 for ease in "translating" the example to another software.

CASH, an interactive analysis tool included free with this text, is demonstrated immediately after each spreadsheet example, using the same data and problem context. CASH is a productivity tool intended to streamline complex and time-consuming analytical tasks within a user-friendly environment.

For both spreadsheet and CASH coverage, the emphasis is on demonstrating a chapter concept that embodies some complexity that can be much more efficiently resolved by computer than by traditional longhand solutions. See, for example, Chapter 3 (pp. 173–176) in which the Computer Notes tackle the computational difficulty of generating a complete loan repayment schedule.

Synthesizing, reinforcing, and summarizing key ideas

Keeping "the forest and the trees" in perspective is always a challenge to engineering students. To facilitate the retention and understanding of important concepts, procedures, and reference items, *Contemporary Engineering Economics* utilizes a wide range of devices:

Feature	Purpose	Sample references
Point-by point chapter summaries	To highlight and reiterate key equations, terms, and concepts in an easy-to-digest format	pp. 287, Chapter 5: In addition to reviewing important chaper concepts, this feature includes a summary table comparing payback, equivalence, and rate of return methods.

Feature	Purpose	Sample references
Interpretive cash flow diagrams	To reinforce important concepts visually—a medium students are often more comfortable with than the written word.	p. 49, Fig. 2.8: Compounding effects on periodic interest payments p. 146, Fig. 3.17: Contrasting principal and interest portions of loan repayment cash flows
Summary tables	To capture and reiterate useful reference material and important concepts in a compact form	p. 87, Table 2.3: Discrete compounding formulas p. 416, Table 7.8: Book vs. tax depreciation
Flow charts, in-text lists	To reiterate important concepts in a brief, step-wise fashion	pp. 129–136, Section 3.2.2: Computational procedure for noncomparable compounding and payment periods p. 222, Fig. 4.11: Analysis period implied in comparing mutually exclusive alternatives
Inside-cover reference tables	To reference useful summary tables throughout the text	See inside text cover.

Flexibility of Coverage

For a typical three-credit-hour, one-semester course, the majority of topics in the text can be covered in the depth and breadth in which they are presented. For other arrangements—quarter terms or fewer credit-hours—Chapters 1–9 present the essential topics, with subsequent chapters presenting optional coverage. By varying the depth of coverage and supplementing the reading with *Case Studies in Engineering Economics*, there are enough materials for a continuing, two-term engineering economics course.

Because the topics of the time value of money and interest relationships are so basic to the overall subject of engineering economics, they are treated in depth in Chapters 2 and 3. For those wishing a briefer coverage of these topics, we suggest covering all of Chapter 2, and Sections 3.1 and 3.2 of Chapter 3. Remaining topics in Chapter 3 may be omitted entirely or assigned as additional readings.

Supplements

An **Instructor's Manual** (ISBN #14509) is available to adopters of this text. In addition to complete solutions to all problems, it contains:

- Categorization of problems by concept tested.
- Transparency masters for key cash flow diagrams from the text.
- A selection of Engineering-in-Training (E.I.T.) questions and solutions which may be photocopied and distributed to students.

Contemporary Engineering Economics Case Studies (ISBN #53277) is a collection of two personal-finance and six industry-based, actual cases. The investment projects detailed in the cases relate to a variety of engineering disciplines. Each case is based on multiple text concepts, thus encouraging students to synthesize their understanding in the context of complex, real world investments. Each case begins with a list of engineering economics concepts utilized in the case and concludes with discussion questions to test students' conceptual understanding.

A package consisting of the main text and casebook is available at a special price to instructors wishing to integrate case studies in their course. The casebook is also sold as a separate item.

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CONTENTS