Engineering Economics

Financial Decision Making for Engineers

Seventh Edition

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9780135728826

ScoutAutomatedPrintCode

Library and Archives Canada Cataloguing in Publication

Title: Engineering economics : financial decision making for engineers / Niall M. Fraser (Open Options Corporation), Elizabeth M. Jewkes (University of Waterloo), Mehrdad Pirnia (University of Waterloo), Ketra Schmitt (Concordia University).

Other titles: Engineering economics in Canada | Financial decision making for engineers

Names: Fraser, Niall M., author. | Jewkes, Elizabeth M., 1958– author. | Pirnia, Mehrdad, author. | Schmitt, Ketra, author.

Description: Seventh edition. | Includes index. | Revision of: Fraser, Niall M. (Niall Morris), 1952–. Engineering economics in Canada.

Identifiers: Canadiana 20200285947 | ISBN 9780135728826 (softcover)

Subjects: LCSH: Engineering economy—Canada—Textbooks. | LCSH: Engineering economy—Canada—Decision making—Textbooks. | LCGFT: Textbooks.

Classification: LCC TA177.4 .F725 2020 | DDC 658.15—dc23

Brief Contents

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Preface

Courses on engineering economics are found in engineering curricula in Canada and throughout the world. The subject matter generally deals with deciding among alternative engineering projects with respect to expected costs and benefits. This area of study is so fundamental to engineering knowledge that the Canadian Engineering Accreditation Board requires all accredited professional engineering programs provide in depth studies in engineering economics. Many engineers have perceived that a course in engineering economics can be as useful in their practice as some of their more technical courses.

There are several important stages involved in making a good decision. The viability stage identifies whether a solution to a problem is technically feasible. Appropriately, this is one of the many roles assigned to the engineer, who has the specialized training required to make such technical judgments. Another stage entails deciding which of several technically feasible alternatives is likely to be best. Deciding among alternatives often does not necessitate the technical competence needed to determine which alternatives are feasible, but it is equally essential in making the final choice. Engineers have found that choosing among competing alternatives can sometimes be more difficult than deciding what possibilities actually exist.

The role of engineers in Canadian society has changed over time. In the past, engineers tended to have a fairly narrow focus, concentrating on the technical aspects of a problem and on strictly computational aspects of engineering economics. As a result, many engineering economics texts focused mainly on the mathematics of the subject. Today, engineers are more likely to be involved in many stages of an engineering project, to be starting their own businesses, or to have varying levels of equity within an enterprise. Thus, they need to be acquainted with strategic methodology and policy issues.

This text is designed for teaching a course on engineering economics, and intended to match engineering practiced in Canada today. It recognizes the role of the engineer as a decision maker who has to make and defend sensible recommendations. Such choices must not only take into account a correct assessment of costs and benefits, they must also reflect an understanding of the environment in which the decisions are made.

This text has had six previous editions. We have striven in every edition to meet and/or exceed the changing needs of our users. This has necessitated accommodating an increasingly global perspective in business. Updates have also included changes in the expectations for engineering training, such as project management and case-based learning, as required by the Canadian Engineering Accreditation Board, and responding to the fervent interest many engineering students now have in starting new innovative companies. Our adaptability and willingness to incorporate user input is probably one of the many reasons *Engineering Economics* has been the text of choice for Canadian educators for over twenty years.

As the world shifts to a greater reliance on digital media, it is appropriate that this text evolves as well. This seventh edition is the first fully digital version of *Engineering Economics*. Instructors and students will find that, although the medium has changed, the content is fully consistent with prior editions.

Canadian engineers have a unique set of circumstances that warrant a text with a specific Canadian focus. Canadian firms make decisions according to norms and standards that reflect Canadian views on social responsibility, environmental concerns, and cultural diversity. This perspective is reflected in the content and tone of much of the material in this text. Furthermore, Canadian tax regulations are complicated and directly affect engineering economic analysis. These regulations and their effect on decision making are covered in detail in Chapter 8.

This text also relates to students' everyday lives. In addition to examples and problems with an engineering focus, there are a number of scenarios involving decisions that many students might face, such as renting an apartment, getting a job, or buying a car. Other references in the text are adapted from familiar sources, such as Canadian newspapers and websites, and well-known Canadian companies.

Content and Organization

Since the mathematics of finance has not changed dramatically over the past number of years, there is a natural order to the presentation of course material. Nevertheless, a modern view of the role of the engineer flavours this entire resource and provides a balanced exposure to the subject.

Chapter 1 frames the problem of engineering decision making as one involving many issues. Manipulating the cash flows associated with an engineering project is an important process for which useful mathematical tools exist.

These tools form the bulk of the remaining chapters. However, throughout the text, students are continually reminded that the eventual decision depends not only on the cash flows, but also relies on less easily quantifiable considerations related to business policy, social responsibility, and ethics.

Chapters 2 and 3 present tools for manipulating monetary values over time. Chapter 2 also explains the idea of depreciation. Chapters 4 and 5 show how students can use their knowledge of manipulating cash flows to make comparisons among alternative engineering projects.

Chapter 6 provides an understanding of the environment in which the decisions are made by focusing on two aspects of business. The first half of the chapter discusses financial accounting and the role of financial statements. The second half provides information about the uses of a business plan and how to write one.

Chapter 7 deals with the analysis of replacement decisions. Chapters 8 and 9 are concerned with taxes and inflation, which affect decisions based on cash flows. Chapter 10 provides an introduction to public sector decision making.

Chapter 11 presents the fundamentals of project management. It is intended to impart an appreciation of the phases that all engineering projects pass through, and to meet the requirements of the CEAB.

Most engineering projects involve estimating future cash flows as well as other project characteristics. Since estimates can be made in error and the future is unknown, it is important for engineers to take uncertainty and risk into account as completely as possible. Chapter 12 addresses several approaches for dealing with uncertainty and risk in economic evaluations.

After a 12-year hiatus, we are re-introducing our chapter reviewing formal decision-making methods for qualitative considerations and multiple criteria. This final chapter underscores the fact that engineering economics is not just about making the economically best decision, it is about integrating economics with other considerations, such as environmental impact, health and safety, and broader social concerns. Chapter 13 provides some mechanisms for formally assessing decisions where there are several incommensurable criteria to consider.

New to This Edition

In addition to updating material and correcting errors, we have made the following important changes in the seventh edition:

- We have added learning goals to each chapter. The learning goals are also mapped to the end-of-chapter questions. This helps educators to assess students on specific learning goals of interest.
- We have updated several of our Case in Point features. Each Case in Point addresses a circumstance appropriate to the chapter material and raises difficult and sometimes unanswerable questions. They provide an opportunity for the individual student to challenge their own thinking. They also are ideal material for initiating lively class discussions intended to enhance the students' understanding of the core topics as well as broaden their perspectives generally.
- Similarly, we have updated several of our Mini-Case features. These end-of-chapter case studies are similar to the Case in Point features, but are deeper views of significant Canadian issues.
- A new section on calculation of levelized cost has been added to Chapter 5. This method has become very popular in recent years, especially in studying the feasibility of energy resource planning projects.
- Chapter 13, "Qualitative Considerations and Multiple Criteria," has been restored to the text. This topic has become more critical as a tool for engineers in recent years as engineers have taken on more responsibility for managing decisions in the public interest.
- We have expanded the use of colour to help communicate ideas.
- A selection of graphs in the text are now interactive, so that students can explore key relationships more fully by testing out changes in parameters.
- Minor changes to all other chapters have been made to update and improve the overall flow and presentation of the material.
- We have created a robust MyLab Engineering to accompany the text. For a full description of the MyLab, please see the Supplements section, below.
- Some educators have reported that students have trouble seeing and appreciating the relevance of the content covered in the Engineering Economics course. We have added a completely new set of experiential learning simulations that provide a novel way to integrate material across chapters and to help students engage more deeply with the course content. Each simulation engages the student in an activity that mimics the decision making that the student could undertake as an active engineer. The student interacts with their employer and fellow employees, or external parties, and is guided through a learning process that brings to life the academic material studied.

Special Features

We have created special features for this text in order to facilitate the learning of the material and an understanding of its applications:

- **Engage!** boxes near the beginning and end of each chapter recount the fictional experiences of a young

engineer at a Canadian company. These vignettes reflect and support the chapter material. The first box in each chapter usually portrays one of the characters trying to deal with a practical problem. The second box demonstrates how the character has solved the problem by applying material discussed in the chapter above. All these vignettes are linked to form a narrative that runs throughout the text. The main character is Naomi, a recent engineering graduate. In the first chapter, she starts her job in the engineering department at Canadian Widgets and is given a decision problem by her supervisor. Over the course of the text, Naomi learns about engineering economics on the job. There are several other supporting characters, who relate to one another in various ways, exposing students to practical, ethical, and social issues as well as mathematical problems.

Engage!, Part 1A

Naomi Arrives

Naomi's first day on the job wasn't really her first day on the job. Ever since receiving the acceptance letter three weeks earlier, she had been reading and rereading all her notes about the company. Somehow she had arranged to walk past the plant entrance going on errands that never would have taken her that route in the past. So today wasn't the first time she had walked through that tidy brick entrance to the main offices of Canadian Widgets—she had done it the same way in her imagination a hundred times before.

Clement Sheng, the engineering manager who had interviewed Naomi for the job, was waiting for her at the reception desk. His warm smile and easy manner helped break the ice. He suggested that they could go through the plant on the way to her desk. She agreed enthusiastically. "I hope you remember the engineering economics you learnt in school," he said.

Naomi did, but rather than sound like a know-it-all, she replied, "I think so, and I still have my old textbook. I suppose you're telling me I'm going to use it."

"Yes. That's where we'll start you out, anyhow. It's a good way for you to learn how things work around here. We've got some projects lined up for you already, and they involve some pretty big decisions for Canadian Widgets. We'll keep you busy."

- **Case in Point** boxes present material relevant to the appropriate chapter. The issues raised can be difficult, curious, and possibly disquieting. There may be no obvious "right" answer or "correct" application of principles. Students are invited to challenge rigidity, and encouraged to exercise flexibility in their problem-solving approaches. The questions posed are intended to be thought provoking, with the hope of inspiring lively classroom discussions and perhaps reflective contemplation. Ideally, the boxes will enrich the students' understanding of the core topics and broaden their general perspectives.

CASE IN POINT 1.1 Loss of Life in Engineering Projects

Whenever an engineering project is undertaken, there are always safety risks. Injuries and accidents are often unavoidable. Although sometimes large projects are completed without loss of life, there is always the chance that the decision of proceeding with an engineering project will result in one or more deaths.

For example, a rule-of-thumb for building skyscrapers once was that one could expect to lose one life per floor of the building. This was borne out with the John Hancock Building in Chicago as late as 1970: it has 100 floors and 109 lives were lost building it. Similarly, for the construction of aqueduct tunnels to New York City in the 1930's, the rule was to expect one life lost per mile of tunnel.

In modern times, the safety record for engineering projects has improved considerably. In building the CN Tower, for example, only one man died. Three people died building the Confederation Bridge. However, no matter how careful people are, most engineering projects are dangerous, and people will likely perish.

Discussion Questions

1) What is an acceptable death rate for an engineering project?
2) How can an engineer know whether to approve a project that is sure to cause deaths that would otherwise not occur?
3) How can an engineer decide how much money to spend on improving safety in an engineering project?

- **Close-Up** boxes in the chapters present additional material about concepts that are important but not essential to the chapter.

CLOSE-UP 2.1 Financial Terminology

Annual Percentage Rate of Charge: An effective interest rate for the entire year that a borrower will pay to banks or financial institutions for a loan or on credit card debt.

Disbursement: Money paid out or spent.

Fixed term investment: An investment mechanism in which the investor is paid his/her initial investment, plus a specific amount of interest after a fixed period. The investor cannot withdraw his or her money before the fixed period without facing penalties.

GIC: A Guaranteed Investment Certificate is a specific fixed-term investment, usually issued by a Canadian bank or trust company.

Receipt: Money received or earned.

- At the end of each chapter, a Canadian **Mini-Case**, complete with discussion questions, relates interesting stories about how familiar Canadian companies have used engineering economic principles in practice.

MINI-CASE 4.1

Rockwell International

The Light Vehicle Division of Rockwell International makes seat-slide assemblies for the automotive industry. It has two major classifications for investment opportunities: developing new products to be manufactured and sold, and developing new machines to improve production. The overall approach to assessing whether an investment should be made depends on the nature of the project.

In evaluating a new product, it considers the following:

1. *Marketing strategy:* Does it fit the business plan for the company?
2. *Workforce:* How will it affect human resources?
3. *Margins:* The product should generate appropriate profits.
4. *Cash flow:* Positive cash flow is expected within two years.

In evaluating a new machine, it considers the following:

1. *Cash flow:* Positive cash flow is expected within a limited time period.
2. *Quality issues:* For issues of quality, justification is based on cost avoidance rather than positive cash flow.
3. *Cost avoidance:* Savings should pay back an investment within one year.

Discussion

All companies consider more than just the economics of a decision. Most take into account the other issues—often called *intangibles*—by using managerial judgment in an informal process. Others, like Rockwell International, explicitly consider a selection of intangible issues.

The trend today is to carefully consider several intangible issues, either implicitly or explicitly. Human resource issues are particularly important since employee enthusiasm and commitment have significant repercussions. Environmental impacts of a decision can affect the image of the company. Health and safety is another intangible with significant effects.

However, the economics of the recommendation is usually (but not always) the single most important factor in a decision. Also, economics is the factor that is usually the easiest to measure.

Questions

1. Why do you think Rockwell International has different issues to consider depending on whether an investment is a new product or a new machine?
2. For each of the issues mentioned, describe how it would be measured. How would you determine if it is worth investing in a new product or new machine with respect to that issue?
3. There are two kinds of errors that can be made. The first is that an investment is made when it should not be, and the second is that an investment is not made when it should be. Describe examples of both kinds of errors for both products and machines (four examples in total) if the issues listed for Rockwell International are strictly followed. What are some sensible ways to prevent such errors?

Additional Pedagogical Features

- Each chapter begins with a list of **learning goals**. Learning goals state what a learner will know or be able to do successfully after the lesson is completed.
- **Key terms** are boldfaced where they are defined in the body of the text. For easy reference, all these terms are defined in a glossary at the end of the text.

- Additional material is presented in **chapter appendices** at the ends of Chapters 3, 4, 6, 8, 9, 12, and 13.
- Numerous worked-out **Examples** are given throughout the chapters. Although the decisions have often been simplified for clarity, most of them are based on real situations encountered in the authors' consulting experiences.
- Worked-out **Review Problems** near the end of each chapter provide more complex examples that integrate the chapter material.
- A concise prose **Summary** is given for each chapter.
- Each chapter has 30 to 50 **Study Exercises** of various levels of difficulty covering all of the material presented. Like the worked-out Examples, many of the problems have been adapted from real situations. The problems are also mapped to the learning goals particular to each chapter.
- A **spreadsheet icon,** like the one shown here, indicates where examples or problems involve spreadsheets, which are available in MyLab.
- **Tables of Interest Factors** are provided in Appendix A.
- **Answers to Selected Problems** are provided in Appendix B.
- A **List of Symbols** used in the text is provided in Appendix C.
- A **List of Formulas** is provided in Appendix D.

Course Designs

This text is ideal for a one-term course, but with supplemental material it can also be appropriately used for a two-term course. It is intended to meet the needs of students in all engineering programs, including, but not limited to, aeronautical, chemical, computer, electrical, industrial, mechanical, mining, and systems engineering. Certain programs emphasizing public projects may wish to supplement Chapter 10, "Public Sector Decision Making," with additional material.

A course based on this text can be taught in the first, second, third, or fourth year of an engineering program. The text is also suitable for college technology programs. No more than high school mathematics is required for a course based on this text. The probability theory required to understand and apply the tools of uncertainty and risk analysis is provided in Chapter 12. Prior knowledge of calculus or linear algebra is not necessary.

This text is also suitable for self-study by a practitioner or individuals interested in the economic aspects of decision making. It is easy to read and self-contained, with many clear examples. It can serve as a permanent resource for practising engineers or anyone involved in decision making.

Supplements

MyLab Engineering

MyLab Engineering is a teaching and learning platform that empowers instructors to reach every student. By combining trusted author content with course-specific digital tools such as experiential simulations, and interactive assignments, MyLab Engineering personalizes the learning experience and improves results for each student.

A Powerful Homework and Test Manager. A powerful homework and test manager lets instructors create, import, and manage online homework assignments, quizzes, and tests that are automatically graded. Instructors can choose from a wide range of assignment options, including time limits, proctoring, and maximum number of attempts allowed. The new MyLab Engineering means less time grading and more time teaching.

Study Plan. The Study Plan gives personalized recommendations for each student, based on their ability to master the learning objectives in the course. This allows students to focus their study time by pinpointing the precise areas they need to review, and allows them to use customized practice and learning aids to help students stay on track.

MyLab Engineering also contains the following items for students and instructors:

For Students

- *Spreadsheet Savvy* contains features which indicate elements of Excel related to the chapter material. It shows how Excel can be used to support the computations necessary to implement the concepts covered. From the basics of computing interest rates or the present worth of a series of cash flows to a full-blown analysis of major projects, spreadsheets help engineers compute results, evaluate alternatives, document outcomes, and make recommendations to colleagues and other stake holders.
- *Excel spreadsheets* for selected Spreadsheet Savvy discussions, examples, and problems
- New Ametros Learning Simulations: Engineering Economics. The Engineering Economics simulation series provides students with a risk-free experiential setting to practise and apply theory while developing the skills they need to be successful in the workplace. Students are required to practice their critical thinking, problem-solving and decision-making skills in a series of four AI powered simulations.

This new Engineering Economics set of simulations can be added to your course at no cost to you or your

students. Contact your Pearson sales rep if you are interested in implementing the Ametros simulation for your course.

- *Interactive Graphs* enhance the student learning experience. Students can manipulate the coordinates and parameters of these graphs and watch the impact of these changes in real time, thereby deepening their conceptual understanding of the material covered. These interactive graphs can be assigned by instructors through our MyLab Multimedia Library.
- *Extended Cases*
- *Interest Tables:*
  - Compound Interest Factors for Continuous Compounding, Discrete Cash Flows
  - Compound Interest Factors for Continuous Compounding, Continuous Compounding Periods
- *Glossary Flashcards*

For Instructors

Instructor's Solutions Manual. The Solutions Manual contains full solutions to all the problems in the text, teaching notes for the Mini-Cases, and Excel spreadsheets for selected examples and problems. This manual was created by the text authors.

Digital Test Bank. Pearson's digital test banks allow instructors to filter and select questions to create quizzes, tests, or homework. Instructors can revise questions or add their own, and choose print or online options. These questions are also available in Microsoft Word format.

PowerPoint © Slides. PowerPoint slides have been created for each chapter and can be used to help present material in the classroom.

Image Library. We have compiled all of the figures and tables from the text in electronic format.

Acknowledgments

The authors wish to acknowledge the contributions of a number of individuals who assisted in the development of this text. First and foremost are the hundreds of engineering students at the University of Waterloo who have provided us with feedback on passages they found hard to understand, typographical errors, and examples they thought could be improved. There are too many individuals to name in person, but we are very thankful to each of them for their patience and diligence.

Other individuals who have contributed substantially to previous editions of the text include Irwin Bernhardt, May Tajima, Peter Chapman, David Fuller, J.B. Moore, Tim Nye, Ron Pelot, Victor Waese, Yuri Yevdokimov, and Peggy Fraser.

As always, the tolerance, support, and encouragement of family, friends, and colleagues is immensely appreciated. Your patience throughout this process has been invaluable. We owe you an ongoing debt of gratitude.

Finally, we want to express our appreciation to the team at Pearson Canada for their professionalism and support during the writing of this text. Content manager Kamilah Reid-Burrell expertly helped us get the project started. Our portfolio manager, Cathleen Sullivan, and our Senior marketing Executive, Kimberly Teska, were able and wise voices when they were needed. Our content developers, Kathryn O'Handley and Gurpreet Sohal, were capable and diligent support for the author team. If anything in this text is written clearly, it is probably because of the fine work of copy editor Julie vanTol. Sarah Gallagher, and the rest of the production team can similarly take credit for the fine resource you are using. We would also like to thank the team at Ametros, particularly Nora Delf, for their help in developing the new simulations for this edition.

To all of the above, thank you again for your help. To those we may have forgotten to thank, our appreciation is just as great, even if our memories fail us. Without doubt, some errors remain in this text despite the best efforts of everyone involved. Please help us improve the next edition by notifying us of any errors. Thank you.

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