Engineering Economic Principles

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The George Washington University

McGraw-Hill, Inc.
New York St. Louis San Francisco Auckland Bogotá Caracas
Lisbon London Madrid Mexico Milan Montreal New Delhi
Paris San Juan Singapore Sydney Tokyo Toronto

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2 3 4 5 6 7 8 9 DOC DOC 9 0 9 8 7 6 5 4 3 2

P/N 061243-9
PART OF
ISBN 0-07-911385-0

The editor was Eric M. Munson;
the production supervisor was Al Rihner.
R.R. Donnelley & Sons Company was printer and binder.

Library of Congress Cataloging-in-Publication Data

Steiner, Henry Malcolm.
Engineering economic principles / Henry Malcolm Steiner. – Rev. ed.
p. cm.
Rev. ed. of: Basic engineering economy / Henry Malcolm Steiner.
© 1988.
Includes index.
ISBN 0-07-911385-0 (set)
1. Engineering economy. I. Steiner, Henry Malcolm. Basic engineering economy. II. Title.
TA177.4.S74 1992 <MRC RR>
658. 1'5 – dc20

About the Author

Henry Malcolm Steiner received a B.A. in Engineering with a specialization in Aeronautical Engineering from Stanford, an M.S. in Construction Engineering from Stanford, and a Ph.D. in Engineering-Economic Planning, also from Stanford. After 15 years experience as a practicing engineer, he taught at the University of the Americas in Mexico, at the Escuela Superiór de Administración de Negócios (ESAN) in Peru, where he gave courses in classical economics and economic development under the auspices of the Graduate School of Business at Stanford. In the United States, he taught in the Management Department of the School of Business at the University of Texas at Austin, before joining the Department of Engineering Administration at The George Washington University in Washington, D.C. He has served as a Visiting Professor at Stanford, both in the Graduate School of Business and the Engineering School. Most recently he served in the Department of Industrial Engineering and Operations Research at the University of California, Berkeley, as a Visiting Professor and Scholar. Dr. Steiner was Fulbright Professor at the University of Guadalajara, Facultad de Economia.

Professor Steiner is the author of four previous books, the most recent being *Public and Private Investments.* He has written many case studies, articles, and papers. The founder and first president of the International Chapter of the Transportation Research Forum, he has served as consultant to the World Bank and to private companies and organizations.

He is a member of Tau Beta Pi, Sigma Xi, the Transportation Research Forum, and the American Society of Civil Engineers.

Preface

Why has another book on engineering economy come into existence? The usual reasons are present: to include the most recent advances in the subject, to remove extraneous material better treated in other disciplines, and to introduce new areas of study. But there is an additional reason: The advent of the personal computer provides a new tool which widens the scope of what can be done with the concepts of engineering economy.

Adaptation to the personal computer is not enough to justify a new textbook, even though, as a tool, it is far more useful than the electronic calculator. It makes problems like the determination of the internal rate of return of a cash flow simple to solve. With only a slide rule or an unprogrammed calculator and tables at hand, such problems take more time. For example, sensitivity analysis, one of the most useful notions in helping an analyst to make decisions, is much facilitated by the use of a personal computer. Calculations which take many hours can be reduced to seconds. Chapter 18 discusses sensitivity analysis. Appendix A, in conjunction with the computer diskette provided with this book, shows an important example from that chapter and the knowledge that can be gained from it when a computer is available. However, it should be mentioned that this book can be used without a computer, personal or otherwise. The usual compound interest tables are available in Appendix C. The diskette is provided, but may be ignored.

This textbook includes new subjects and new expositions of old ones:

The area of loans is new to engineering economy books, at least as a subject in itself. Variable loan rates, differing loan periods, balloon payments, interest-only loans, and other variations have made the subject worthy of treatment. How to choose among loan alternatives is fully covered in this book.

The effect of the viewpoint of the analyst, and its implications for engineering economic analysis, is rarely treated in textbooks on the subject. In the cases where it is discussed, the very important implications are not. Analysis of projects in the public sector is particularly affected by the concepts of welfare economics, which are closely associated with the concept of viewpoint. The proper consideration of viewpoint can cause vital changes in project decisions, changing a "yes" to a "no," or vice versa, and make all the difference between a naive and a sophisticated analysis.

Capital budgeting is an area relatively new to engineering economy, and one that has not been properly appreciated. It also happens to be one that requires the use of mathematical programming, and thus the use of computer, for the solution of problems. Of particular importance is the effect of the capital budget on the opportunity cost of capital, an area not completely covered by existing engineering economy textbooks, to the best of this writer's knowledge.

The title of this book, *Engineering Economic Principles*, describes exactly what it is about. However, it may be useful to delineate precisely where the subject matter of this text lies in the much larger area of economics. Economics, whose subject is the optimal use of resources in society, is divided into two parts, microeconomics and macroeconomics. Microeconomics is the study of the producing unit, the firm, whether public or private, in its various aspects and activities, among them, demand for its product, supply of resources to produce the product, and capital investment to provide the land, buildings, and machinery for production. Macroeconomics is the study of the economics of a society as a whole; we will not be concerned with it here except tangentially in the chapters on inflation and sector analysis and viewpoint.

Engineering economy is a special area of microeconomics, specifically the part concerned with capital investment. In other, more or less similar guises, it is known as economic analysis by the economists, capital budgeting—something of a misnomer—by businessmen, management accounting by the accountants, and by other titles not connected with any particular group or profession, such as life-cycle costing, value engineering, and discounted cash flow analysis. In its origins, engineering economy was concerned with the relationship between engineering and economics. Asking not how to design a dam nor how to build it, engineering economy considered the question, "Should we build this dam at all in this spot at this time, and how much will it pay off if we do?" Such a question could be applied to many engineering situations: alternative railroad locations, choices among building heights, whether to buy or lease one make of machine or another, and so forth. No matter what the situation, engineering economy was involved with the capital investment question, but only in the microeconomic area.

Later on, it became obvious that a great many problems of engineering economy were also encountered in ordinary life. "Should I keep my present car or buy a new one?" is a question faced by countless car owners in the modern world. The methods of engineering economy can be used to answer it. "Given the projected inflation rate over the next few years, should I invest in this piece of real estate or in that?" is another question not infrequently asked these days. Engineering economy can answer it. Thus the reader will see in this book many examples and problems that reflect the economic questions we all confront in our daily lives and that cannot be classified under the practice of engineering. So, engineering economy has use not only in engineering but also in our personal economic decisions.

Now that "economics" and "engineering economy" have been dealt with, it is time to ask the meaning of "basic." It should be emphasized that this text is limited, as its title indicates, to basics. The material explained could easily be amplified, in every chapter, to cover the controversies surrounding the subject. The book would then overreach its intended scope. For this reason, the author had to restrain himself with the question, posed time after time, "Is this idea basic to the subject?" Many times, the answer was, "No."

The basics of this subject are those aspects of it that must be well understood in order to solve those problems most likely to be encountered in the practice of engineering. Evident as this approach to the subject may seem, the fact is that considerable room exists for personal opinion in this matter. Not surprisingly, a list of basics for one engineer may differ markedly from the list compiled by another. The degree of importance attached to each entry in a list of essentials is also a matter of opinion. For example, I have included a chapter on viewpoint. Some recognized experts in engineering economy may not only disagree on including viewpoint, but also argue that it should not be present at all in a book on fundamentals. Some, indeed, may not even be aware that viewpoint can be a part of the subject. It appears that some sort of consensus on what is basic to the subject is itself a basic.

In an attempt to decide the question, I have carefully read the prefaces to the following texts in engineering economy and tried to assemble a consensus. Then I have allowed my own opinion to enter.

Barish and Kaplan, *Economic Analysis for Engineering and Managerial Decision Making*, Second Edition.

DeGarmo, Canada, and Sullivan, *Engineering Economy,* Seventh Edition.

Grant, Ireson, and Leavenworth, *Principles of Engineering Economy,* Seventh Edition, Revised.

Newnan, *Engineering Economics Analysis*, Third Edition.

Riggs, *Engineering Economics*, Second Edition.

Taylor, *Managerial and Engineering Economy,* Third Edition.

White, Agee, and Case, *Principles of Engineering Economic Analysis*, Second Edition.

The Table of Contents is the result.

A possible selection of topics for a one semester course of three hours per week is:

Chapter

1 Introduction
2 Investment Choice
3 Equivalence
4 Interest and Financial Mathematics
5 Present Worth
6 Annual Worth
7 The Benefit/Cost Ratio
8 The Internal Rate of Return
9 Multiple Alternatives
10 Income Tax Effects and Depreciation
11 Inflation
12 Risk and Uncertainty
13 Loans
15 The Cost of Capital
16 Replacement Analysis
17 Sector Analysis and Viewpoint

This selection leaves out only the chapters on sensitivity analysis and capital budgeting. Both of these are considered to be advanced topics by most writers on the subject.

A less intensive course might exclude the chapters on loans and replacement analysis from the above list. It is possible, too, to spend less time on each topic.

The book contains 143 solved examples. Many of these refer to situations encountered in developing countries. In these countries, costs, revenues, rates of return, inflation rates, tax laws, and so forth, are often different from those found in the United States. More and more students from such countries are attending engineering schools in the United States. It is hoped that such examples will aid them to understand the subject in the context of their homelands. For the American student, in this age of multinational corporations, familiarity with conditions overseas may be of considerable assistance in an engineering career.

At the ends of the chapters are 261 problems, some with answers supplied. *An Instructor's Manual* is available from the publisher. It provides solutions to all problems.

Appendix A contains instructions on how to use the diskette, available with this textbook, in your personal computer to assist in solving problems. The diskette may be used with an IBM AT, XT, PS/2, Macintosh, or a compatible machine, and operates in conjunction with *Lotus 1-2-3,®* *Quattro,®* or *Excel.®* The capital budgeting chapter uses *Lindo®* as well. A step-by-step instruction in the use of the personal computer in engineering economic analysis is provided. It employs selected examples from the text, solves them, and allows space for the reader's problem solutions.

My thanks go to the many university instructors in the subject who reviewed the chapters in this book as they came into existence. Their comments were invaluable. I wish to thank especially Mr. Thomas Tsimberdonis for his help in creating the software of Appendix A. My editor, Aileen Landeros, deserves my gratitude for her dedicated work on this book. James Fay, Mohammed Mustafa, Charles G. Vandervoort, Carlos A. Velarde, and Thawat Watanatada gave valuable criticism.

My many students at the Escuela Superiór de Administración de Negocios (ESAN), Stanford, the University of Texas at Austin, the George Washington University, and the University of California at Berkeley also helped me. Each class I gave was, in a real sense, an examination in the subject, and they the examiners, commentators, and advisors. I thank them.

My oldest debt I owe to Professor Eugene L. Grant who taught me the subject during my undergraduate days at Stanford, and who elaborated on it during my later master's and doctoral studies there. Professor

Clarkson H. Oglesby, also of Stanford, deserves equal gratitude for his interest and encouragement.

Inevitably I have forgotten some who helped. Those I also thank.

HENRY MALCOLM STEINER

Washington, D.C., November 1991

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1

Introduction: Investments Explained

What is engineering economy? Until recently the answer was easy—it is the application of certain principles of economics to the problem of investments—principally engineering-related investments. Today, this simple definition needs to be widened considerably, as the subject itself has widened over the years since the last century when Wellington wrote of railway location in the United States. To economics must be added mathematics—and particularly the applied version known as operations research. When more complicated problems are encountered—planning the entire transport system of a developing country, for example—sociology, anthropology, urban planning and other disciplines must be combined with economics and mathematics in order to arrive at satisfactory solutions. Although such a comprehensive approach will not be treated in an elementary text such as this one, the reader should be aware of the necessity for such multi-disciplinary approaches in order to avoid an overly narrow view of the subject. A good rule is that a broad enough view should be taken, by including disciplines other than engineering and economics, that an optimal solution of the problem can be determined. To clarify this remark, let us imagine a situation in which a cross-town freeway is proposed in a major city. The engineering and economic studies completed, the city government is called upon to decide whether or not the project will be built. A member of the city government asks a question concerning the effect of the proposed freeway on the form of the city: Will the project cause the city to spread out even further, thus increasing transportation distances between working places and residences? Will the freeway erect barriers to movement across it, create poverty pockets, or cut existing neighborhoods in two? Evidently some aspects of the effects of the project have been disregarded. An urban planner is needed to combine his views with those of the engineers and economists in order that an optimal solution may even have the opportunity of being discovered.

In this book, we will concentrate on the economic aspect of projects, leaving aside the engineering design problems and those of all other disciplines, but never forgetting that they exist.

Investment means using resources to create an addition to the facilities at present in existence. In the example of the preceding paragraph a certain number of miles of urban freeway are to be added to the existing mileage. If we decide to divide the economy of a nation into two parts, public and private, the freeway investment is a *public sector* project because the necessary funds will come from public monies. The purchase of ten new Euclid end-dump trucks by the Nevada Construction Company is an example of a *private sector* investment because the addition to the supply of dump trucks for this company is financed from private funds. Such a conception of investment is not at all the usual one, entertained by many people, that investment is the purchase of real estate, or stocks, or bonds in order to receive a return of so much per year. The latter is, of course, also investment, but in a narrower definition.

Investment from an economist's standpoint is the diversion of resources from consumption to uses that will better the efficiency of the production process. Consumption is postponed so that more consumption will be possible in the future. The traditional example of Robinson Crusoe and his fish hooks makes the matter clear. Crusoe consumes fish, which he catches with a spear. It takes all his waking hours to feed himself by this primitive method. If he forgoes spear fishing for one day, thus going to bed hungry, he can make enough hooks to improve his production of eatable fish by a large amount and thus have more time for rest and the improvement of his living conditions. The time and effort of one day in the production of fish hooks is invested. Consumption of production that would have resulted from the time and effort is forgone, but the production process is improved. This is investment, in simple terms.

Notice that money is in no way involved in Robinson Crusoe's world, yet investment is possible. The general term "resources" is a more exact description of Crusoe's time and effort. The fish hooks cost, not money, but time taken away from fishing, and more particularly, the amount of fish not caught. The *opportunity cost* of the fish hooks, that is, the investment cost, is one day's catch. Opportunity cost, therefore, is the benefit given up by Crusoe in order to make his investment in fish hooks. We will use this concept frequently in our study of engineering economy.

It may occur to some readers that investment and the capital goods resulting from it are measurable in terms of the amount of human effort required to produce them. This is Karl Marx's Labor Theory of Value. Unfortunately for its continuing validity, an objection is apparent when one inquires into the case of a capital good immediately available for use as soon as produced in distinction from one that must be stored for a time before it can be used. Lumber, for example, must be dried out in yards and wine must be aged in casks or bottles before they can be used. Take one example, a good like fish hooks, that uses 1000 units of labor to produce. Another example, wine, also uses 1000 units of labor to produce. The wine must be aged; the fish hooks need not be. Should both be costed in proportion to 1000 units of labor? Of course, the answer is, "No, the wine should cost more." Why? Because the 1000 units of labor, invested in the wine, were not available for use until a certain amount of time had passed. The 1000 units of labor became capital whose use must be paid for. In general, investment requires a forgoing of consumption; it is measurable in terms of the consumption forgone; and it is not always directly measurable by the amount of labor involved in making the investment good.

Evidently benefits of an investment must exceed costs if the investment is to be approved. If Crusoe estimates that fish hooks will be less efficient than a fish spear in catching fish, he will certainly not invest in them. Time is inevitably involved in this judgement. Imagine that fish hooks are more efficient than fish spears in fish catching. But how does Crusoe know this? Observations must be made over time. He will compare, for example, the amount of fish he will catch in a day or a week or a year by hooks with the amount of fish he will catch in the same period by using a spear. The value of capital goods is measured not only by their first cost but also by how long they will last. If Crusoe's hooks must be made of wood and will last for but one fish each, they will certainly be less attractive than those made of metal that will last a year.

What Crusoe really does, then, is compare the benefits and costs over time of continuing the present method of fishing with the benefits and