Eighth Edition

ENGINEERING ECONOMY

G. J. Thuesen
W. J. Fabrycky

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To H. G. Thuesen—
the founding author of this text—
whose wisdom as an educator, writer,
inventor, friend, and parent has
inspired those he influenced

Preface

This Eighth Edition of *Engineering Economy* continues to emphasize the concepts and techniques of analysis useful in evaluating the worth of systems, products, and services in relation to their cost. Our objective is to help the reader appreciate the significance of the economic aspects of engineering and to become proficient in the evaluation of engineering proposals in terms of worth and cost. Economic feasibility is the essential prerequisite of successful engineering for the increasingly competitive global marketplace.

The engineering approach to problem solution has advanced and broadened to the extent that success often depends upon the ability to deal with both economic and physical factors. Being accustomed to the use of facts and being proficient in computation, engineers should accept the responsibility for providing interpretation of their work. It is easier for engineers to master the fundamental concepts of economic analysis necessary to bridge the gap between the physical and economic aspects of engineering application than for persons who are not technically trained to acquire the necessary technical background. To aid the engineer in so doing is the primary aim of this book.

A secondary aim of this book is to acquaint the engineer with operations and operational feasibility. Economic factors in the operation of systems and equipment can no longer be left to chance, but must be considered during the design process. A basic understanding of mathematical modeling of operation is becoming more important as complex operational systems require the attention of a larger number of engineers. Accordingly, the section entitled Operation Economy has been broadened to emphasize the connection between design and operations.

Those familiar with earlier editions of this text will note that we have retained the basic conceptual approach with considerable emphasis on examples. Also retained is the functional factor designation system originated by the late H. G. Thuesen. Symbols in the system have been changed as was suggested by the American National Standards Institute Committee on Industrial Engineering Terminology.

Significant format changes have been made in this edition. Most equations are now numbered and key equations are displayed. Definitions are set apart and displayed. Principles are highlighted. Also, the reader will find key points listed at the end of each chapter.

We have had no difficulty in teaching this material to engineering sophomores as well as to upper-division students in management, economics, and the physical sciences who wish to obtain an introduction to engineering from the economic point of view. Elementary calculus is the only mathematical background required.

This text contains more than enough material for a three-semester-hour course. For a course of shorter duration some material will have to be omitted. This may be easily done, since the foundation topics are concentrated in the first ten chapters.

We would like to acknowledge those who recieved earlier versions of the manuscript for this book: Theo A. DeWinter of Boston University, Lawrence M. Seiford of the University of Massachusetts at Amherst, Sheng-Hsien Teng of the University of Wisconsin at Madison, James M. Daschbach of the University of Toledo, and John Malindretos of the New Jersey Institute of Technology.

It is our pleasure to acknowledge the very useful comments offered by students and practicing professionals who used prior editions of this text over many years. Also, we acknowledge the expert editorial and word-processing assistance provided by Mrs. LaVonda Matherly and Mrs. Joene Owen.

G. J. Thuesen
W. J. Fabrycky

Contents

Part One

INTRODUCTION TO ENGINEERING ECONOMY

The first part of this text introduces engineering economy—its relationship to engineering and to the engineering process. The focus is on technical concepts to support the process for performing engineering economy studies. Selected economic concepts and cost classifications are then provided as a foundation for quantitative methods that will appear in subsequent chapters. Next, interest and interest rate are introduced as the basis for time value analysis. Finally, Part One presents the concept of the earning power of money as the primary justification for borrowing to increase productivity.

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Engineering and Engineering Economy

Engineering activities of analysis and design are not an end in themselves. They are a means for satisfying human wants. Thus, engineering has two concerns: the materials and forces of nature, and the needs of people. Because of resource constraints, engineering must be closely associated with economics. It is essential that engineering proposals be evaluated in terms of worth and cost before they are undertaken. In this chapter and throughout the text, we emphasize that an essential prerequisite of successful engineering application is economic feasibility.

1.1 ENGINEERING AND SCIENCE

Engineering is not a science, but an application of science. It is an art composed of skill and ingenuity in adapting knowledge to the uses of humanity. The Accreditation Board for Engineering and Technology has adopted the definition

> **Engineering** is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

This, like most other accepted definitions, emphasizes the applied nature of engineering.

The role of the scientist is to add to mankind's accumulated body of sys-

tematic knowledge and to discover universal laws of behavior. The role of the engineer is to apply this knowledge to particular situations to produce products and services. To the engineer, knowledge is not an end in itself but is the raw material from which he or she fashions structures, systems, products, and services. Thus, engineering involves the determination of the combination of materials, forces, information, and human factors that will yield a desired result. Engineering activities are rarely carried out for the satisfaction that may be derived from them directly. With few exceptions, their use is confined to satisfying human wants.

Modern civilization depends to a large degree upon engineering. Most products and services used to facilitate work, communication, transportation, and national defense and to furnish sustenance, shelter, and health are directly or indirectly a result of engineering activity. Engineering has also been instrumental in providing leisure time for pursuing and enjoying culture. Through the development of instant communication and rapid transportation, engineering has provided the means for both cultural and economic improvement of humanity.

Science is the foundation upon which the engineer builds toward the advancement of mankind. With the continued development of science and the worldwide application of engineering, the general standard of living may be expected to improve and further increase the demand for those things that contribute to people's love for the comfortable and beautiful. The fact that these human wants may be expected increasingly to engage the attention of engineers is, in part, the basis for the incorporation of humanistic and social considerations in engineering curricula. An understanding of these fields is essential as engineers seek solutions to the complex sociotechnological problems of today.

1.2 THE BI-ENVIRONMENTAL NATURE OF ENGINEERING

Engineers are confronted with two important interconnected environments, the *physical* and the *economic.* Their success in altering the physical environment to produce products and services depends upon a knowledge of physical laws. However, the worth of these products and services lies in their utility measured in economic terms. There are numerous examples of structures, machines, processes, and systems that exhibit excellent physical design but have little economic merit.

Want satisfaction in the economic environment and engineering proposals in the physical environment are linked by the production or the construction process. Figure 1.1 illustrates the relationship between engineering proposals, production or construction, and want satisfaction.

In dealing with the physical environment engineers have a body of physical laws upon which to base their reasoning. Such laws as Boyle's law, Ohm's law, and Newton's laws of motion were developed primarily by collecting and

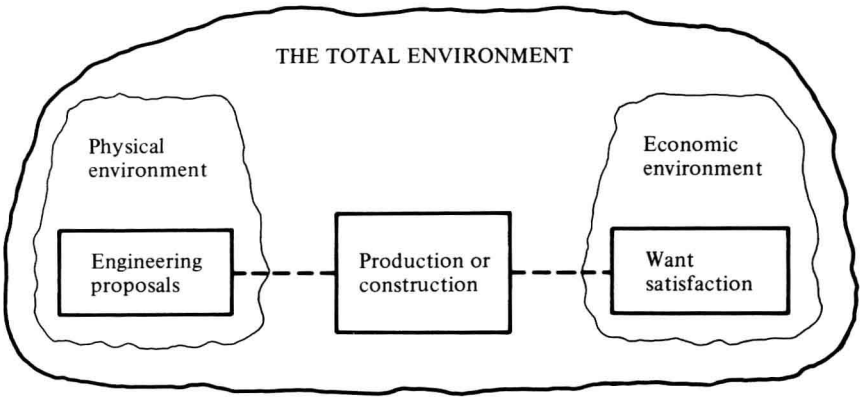

FIGURE 1.1. The physical and economic environments.

comparing numerous similar instances and by the use of an inductive process. These laws may then be applied by deduction to specific instances. They are supplemented by many formulas and known facts, all of which enable the engineer to come to conclusions that match the facts of the physical environment within narrow limits. Much is known with certainty about the physical environment.

Much less, particularly of a quantitative nature, is known about the economic environment. Since economics is involved with the actions of people, it is apparent that economic laws must be based upon their behavior. Economic laws can be no more exact than the description of the behavior of people acting singly and collectively.

The usual function of engineering is to manipulate the elements of one environment, the physical, to create value in a second environment, the economic. However, engineers sometimes have a tendency to disregard economic feasibility and are often appalled in practice by the necessity for meeting situations in which action must be based on estimates and judgment. Yet today's engineering graduates are increasingly finding themselves in positions in which their responsibility is extended to include economic considerations.

There are those, and some are engineers, who feel that engineers should restrict themselves to the consideration of physical factors and leave the economic and humanistic aspects of engineering to others; some would not even consider these aspects as coming under engineering. The reason may be that those who take pleasure in discovering and applying the well-ordered certainties of the physical environment find it difficult to adjust their thinking to consider the complexities of the economic environment.

Engineers can readily extend their inherent ability of analysis to become proficient in the analysis of the economic aspects of engineering application. Furthermore, the engineer who aspires to a creative position in engineering will find proficiency in economic analysis helpful. The large percentage of engineers who will eventually be engaged in managerial activities will find such proficiency a necessity.

Initiative for the use of engineering rests, for the most part, upon those who will concern themselves with social and economic consequences. To main-