

PRINCIPLES OF ENGINEERING ECONOMY

GRANT • IRESON

FOURTH EDITION

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Preface

This is a book about a particular type of decision making. It explains the principles and techniques needed for making decisions about the acquisition and retirement of capital goods by industry and government. Normally, such decisions should be made on grounds of long-run economy. Because engineers make many such decisions and make recommendations for many others, the body of principles and techniques relating to them has been called "engineering economy."

The same concepts and methods that are helpful in guiding decisions about investments in capital goods are useful in certain kinds of decisions between alternative types of financing (for example, ownership versus leasing) and in many personal decisions. Applications to these other areas of decision making are also discussed in this book.

The book can be used in two ways. First, it can serve as a college textbook. The material covered is appropriate not only for engineering students but also for students of economics, accounting, finance, and management. Second, it can serve as a working manual for engineers, management personnel, government officials, and others whose duties require them to make decisions about investments in capital goods.

The underlying philosophy regarding comparisons of alternatives is the same as in previous editions. As before, continued emphasis throughout the book is placed on the following two important points:

1. It is prospective *differences* between alternatives that are relevant in their comparison.
2. The fundamental question regarding a proposed investment in capital goods is whether the investment is likely to be recovered plus a return commensurate with the risk and with the return obtainable from other opportunities for the investment of limited funds. The purpose of calculations that involve the time value of money should be to answer this question.

Although its underlying philosophy remains the same, the book has been almost completely rewritten for this Fourth Edition. As in the nearly complete rewritings for the second and third editions, the changes have been aimed in part at the introduction of new material and in part at improved presentation of fundamental principles. Some changes that will be of interest to users of the previous editions are as follows:

1. An increased emphasis on the concept of cash flow helps to clarify such matters as the income tax aspects of decision making, comparisons of alternative financing methods, replacement economy, and increment costs and sunk costs. Moreover, an emphasis on the expression of the differences between alternatives in terms of cash flow makes possible a clearer exposition of an important topic—the calculation of unknown rates of return by correct compound interest methods. (In recent literature, such correct methods are referred to by various names, including “discounted cash flow method” and “investors’ method.”)

2. Greater stress is placed on the concept of capital rationing and on the use of prospective rate of return as a guide to decision making.

3. Greater stress is placed on methods of analysis that are based on the mathematics of compound interest. Certain approximate methods previously covered in the main body of the text are now discussed in appendixes.

4. Diagrams and mnemonic symbols have been introduced to clarify certain aspects of compound interest.

5. A number of useful new interest tables have been added. These include tables to convert a uniform gradient to an equivalent uniform annual series and to a present worth. They also include present worth tables based on effective interest rates and assuming continuous compounding and the uniform flow of funds throughout stated time periods.

6. One of the appendixes deals with economy studies that assume continuous compounding and the uniform flow of funds. The end-of-year convention is still used throughout the main body of the book.

7. The importance of income tax considerations is stressed early in this edition. As an experiment in their classes, the authors introduced calculations of prospective disbursements for income taxes concurrently with the study of annual costs, present worths, and rates of return. They concluded that better results are obtained if the first examples and problems in the course are based on stipulated

minimum attractive rates of return *before* income taxes and if calculations of the effects of decisions on income taxes are introduced later. However, it seemed desirable in this edition to introduce after-tax studies a little earlier than in the Third Edition—prior to the topics of replacement economy and the comparison of alternative methods of financing.

8. Additional stress is laid on the extent to which after-tax rates of return are influenced by different methods of writing off cost for tax purposes. Depreciation methods authorized under recent tax laws in the United States are explained.

9. Reasons for avoiding certain unsound criteria for evaluating investment proposals are stressed. Particular emphasis is laid on reasons why the primary criteria for investment decisions should not be payoff periods (discussed in Chapter 19) or so-called rates of return by original book or average book methods (discussed in Chapter 10).

10. In the discussion of economy studies for public works, a fuller exposition has been given of the relationship between the benefit-cost ratio as a criterion for investment decisions and the more conventional criteria based on annual costs or prospective rates of return on investment.

11. In order to clarify the presentation of certain topics, several phrases and concepts employed by writers on operations research have been introduced. An extremely useful concept is that of sensitivity. Some useful phrases are suboptimization, system viewpoint, and mathematical model.

In order to make room for the foregoing, certain more specialized topics covered in the Third Edition have been omitted.

The arrangement of the chapters recognizes the fact that some introductory courses in engineering economy are too short to permit a full coverage of the subject. Most of the material in Chapters 1 to 16 is fundamental and should be included in any presentation of basic principles. The subject matter of Chapters 17 to 19 is appropriate for an elementary course if time permits but might also be deferred till an advanced course. Appendixes A to D cover topics that might be omitted in elementary college courses but should be included in advanced courses and in any presentation to persons in industry.

The authors wish to thank Professors Robert Oakford and David Heebink, both of Stanford University, for the programming of the calculation of new tables, and Paul T. Norton, Jr., of St. Petersburg, Florida, for many helpful comments on our manuscript.

We are grateful also to our colleagues on the Stanford industrial engineering faculty for suggesting a number of our new problems and examples.

EUGENE L. GRANT
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Palo Alto, California
January, 1960

In this Revised Printing Chapter 15 has been completely re-written so that the examples and the discussion reflect income tax rates, laws, and regulations applicable to 1965 taxable income in the United States. The most important new topic introduced has been the investment tax credit as modified by the 1964 Internal Revenue Code.

E. L. G.
W. G. I.

November, 1964

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PART I
PLANNING ECONOMY STUDIES FOR
DECISION MAKING

I

"Hunch" Decisions Are Dangerous

The question "Will it pay?" is always present in engineering decisions. It may be broken down into several subsidiary questions.

The late General John J. Carty, as chief engineer of the New York Telephone Company, had three such questions that he applied to every engineering proposal that came before him for review:

1. Why do this at all?
2. Why do it now?
3. Why do it this way?

Why do this at all? Will a proposed new enterprise be profitable? Shall an existing enterprise be expanded? Shall existing operating procedures be modified?

Why do it now? Are market conditions favorable to a present development? Shall we build now with excess capacity in advance of demand, or with only sufficient capacity to satisfy the demand immediately in prospect? Are interest rates and business conditions favorable to a present development?

Why do it this way? This choice between alternative ways of doing the same thing is common to all types of engineering activity.

This book deals with certain principles underlying any rational answers to questions of this type. The central problem discussed in the book is how we may judge whether any proposed course of action will prove to be economical in the long run, as compared to other possible alternatives. Such judgment should not be based on an unsupported "hunch"; it requires an economy study. An economy study may be defined as a comparison between alternatives in which the differences between the alternatives are expressed so far as practicable in money terms. Where technical considerations are somehow involved, such a comparison may be called an engineering economy study.

Economy in Everyday Life. Although this book deals primarily with engineering economy studies, the principles and techniques herein presented are general in their nature and are applicable to many everyday personal problems. These techniques of analysis are just as useful in many personal decisions as they are in engineering situations. In fact, many examples used in this book deal with economy studies for individuals or families even though the majority deal with studies for business or government. Many decisions between personal alternatives can be made more sensibly if the differences between the alternatives are expressed as far as practicable in terms of prospective money receipts and disbursements and if these money figures are analyzed along the lines developed in this book.

For instance, in a choice between home ownership and renting, it is obvious that many aspects of the matter should be estimated in terms of money as a guide to intelligent decision making. Nevertheless, matters of personal taste that cannot be expressed in money terms often carry much weight in personal decisions. Thus the pride of home ownership may be of great importance to one family and a matter of complete indifference to another.

Economy in Business Enterprise. The problems of economy in business enterprise are considerably less subjective than problems of personal economy. A competitive business enterprise cannot survive unless it makes a profit. It follows that sensible decisions between alternatives must consider the effects of the alternatives on the prospective profits of the enterprise. Alternatives should be judged so far as practicable in terms of prospective receipts and disbursements; they are made commensurable by being expressed in money units.

An Example of a "Hunch" Decision. Many business decisions are made on the basis of guesswork, with very little attempt to consider the various possible alternatives and to judge the differences between them that are measurable in money terms.

For instance, a schoolteacher invested her small savings in a down payment on a rental property. She made this investment without consideration of the relationship between the price of the property, on the one hand, and the prospective receipts from rentals and the disbursements for operation, maintenance, and debt interest and repayment, on the other hand. As a matter of fact, the particular property was greatly overpriced in relation to its prospective earnings and expenses. She finally sold the property several years later at a substantial loss. If she had substituted for her guess

that all rental properties were profitable, specific estimates of receipts and disbursements for this particular property, and if she had given consideration to alternative possible investments, she would doubtless have reached the correct conclusion that this rental property was an unwise investment.

The practice of making business decisions on the basis of a "hunch" that a proposal will or will not pay is not confined to persons without business experience. Such a method of solving problems by "going into a trance and coming out with the answer," as one engineer described it, is a method that sometimes appeals to executives responsible for decisions as making minimum demands on their time and effort. The limitations of decisions made in this way are obvious.

Comparing Engineering Alternatives. These limitations are most likely to be apparent when the decisions to be made deal with matters of technology. The businessman who is not technically trained must rely on the engineer's advice as to the probable differences between engineering alternatives. The engineer, on the other hand, needs to translate these differences into money terms in order to make them clear to the businessman. In fact, he must translate them into money terms in order to make commensurable the many different kinds of physical differences that are so frequently involved in a choice between alternative plans.

A "Hunch" Decision in an Industrial Situation. An industrial concern owned its own steam plant, which had been operated for many years to furnish steam for heating, for operation of steam-driven pumps, steam-driven air compressors, and for generation of the electricity needed in the plant for lighting and for the operation of small motors. An increase in the concern's volume of business finally increased the demands for compressed air and for electric energy above the capacity of the existing plant.

Without any engineering survey of the situation, the general manager of the plant contracted to purchase from the local electric light and power company the excess of his needs for electric energy above the amount that could be generated in his existing plant. To meet the increased needs for compressed air, he bought a large electrically driven air compressor.

His decision proved to be an expensive one. The air compressor purchased was a single large unit; it turned out that it was operated most of the time at a very small fraction of its capacity and at a correspondingly very low efficiency. The amount of energy purchased from the power company was insufficient to bring the unit

rate into the lower blocks of the company's rate schedule. Occasional breakdowns of one or another of the old steam engines in the company's power plant made the peak load of power purchased very high in proportion to the average purchased; the rate structure was such that this poor "load factor" was reflected in a high rate for the purchased power. No reduction in labor cost for operation of boilers, engines, compressors, and pumps, or in the costs for fuel and maintenance of the old and inefficient prime movers, was possible under the plan adopted by the manager.

An Economy Study To Correct a "Hunch" Decision. Finally an engineer was called in to survey the situation and to make recommendations. He recognized that there were a number of alternatives that had not been considered by the general manager; several of them appeared likely to be more economical than the plan that had been adopted. Thus, it would be possible to increase steam capacity by the addition of new boilers; generating capacity might be increased by the purchase of a steam turbine and generator that because of its greater efficiency would produce more kilowatt-hours of electric energy from the same amount of steam now being used to operate the steam engines; a diesel engine and generator might be purchased for the production of electric energy; the engines might be shut down and all of the electric energy requirements be purchased from the power company, permitting all the steam generated to be used for operation of steam-driven compressors and pumps, and for heating; the compressors and pumps might be electrified, and all electric energy requirements then purchased, with boilers operated for steam heat only in those months in which heating is necessary.

The engineer examined the factory's past requirements for the services that had been provided by the steam plant—heat, pumping, compressed air, and electric energy—and, after consideration of the trend of growth of production and of some changes in production methods that seemed to be in prospect, made a forecast of the needs for these services for several years to come. With this forecast as a basis, he then made preliminary designs for meeting the expected needs by each of the possible alternatives that he had recognized. For each alternative, he then made approximate estimates of the immediate investment required, and of the annual expenditures necessary in the future. With these estimates, he was able to make a preliminary comparison of the long-run economy of the several alternative plans (including as one plan a continuance of the existing scheme), and to select those that seemed to justify detailed study.

Of all of the alternatives given preliminary study, two appeared to be much more economical than any of the others. One was the plan to modernize the power plant by the purchase of one or more steam turbines; the other was the plan for the electrification of the compressors and pumps and the purchase of all power. Each of these plans was given detailed study with complete designs, and with careful estimates of investment costs and operation and maintenance costs.

As is characteristic of all economy studies to determine general policy, each of these designs involved numerous subsidiary alternatives, and each selection between subsidiary alternatives called for a subsidiary economy study. For example, in the first alternative what type and size of turbines should be selected? How many should there be? What boiler pressures should be used? Should the power generation be combined with other steam requirements by selecting turbines that exhaust at pressures that permit the use of their exhaust steam for other purposes? In the second alternative, several different possible power rates were offered by the power company. “Primary” power could be taken at 23,000 volts, requiring the customer to install his own transformers for stepping down the voltage, and, of course, to take the transformer losses involved; a variation of this was an “off-peak” rate with severe restrictions on the maximum power that could be used in certain specified hours of certain months. Two other different rates were available under which the company supplied power at the voltages at which it was to be used. The electrification of compressors and pumps involved several possible alternative designs.

Translating an Engineering Economy Study into a Business Decision. The engineer’s estimate showed the alternative involving the steam turbine to require a considerably higher immediate investment than was required by the plan to purchase power; on the other hand, once the investment was made, the turbine plan involved lower prospective annual disbursements. Since the choice between these alternatives would have no influence one way or the other on the factory’s revenues, the problem was merely one of comparing future expenditures. The real question was whether the additional investment in the steam turbine plan was justified by the prospective saving in operating costs. Or—stated a little differently—the question was whether it seemed likely that the extra investment would be recovered, plus a return that was attractive in the light of the risk and in the light of the cost of money and of other opportunities for the investment of available funds. In order to answer this question, the expenditures involved in each plan were