

Second Edition

Project Economics and Decision Analysis

Volume 1: Deterministic Models

M.A. Mian

 PennWell®

Contents

Preface	xi
Acknowledgments	xvii
1. Introduction	1
Profit Planning	2
Typical oil company objectives	3
The role of management in planning	4
Planning of capital expenditures	4
Some Basic Principles of Economics	6
Demand, supply, and equilibrium price	7
Crude oil price volatility	15
Energy independence	20
Inflation	22
Consumer price index	26
Uncertainty and Risk	30
Questions and Problems	32
2. The Time Value of Money	35
The Concept of Interest	37
Simple and compound interest	39
Nominal and effective interest rate	42
Cash Flow Diagram	45
The Time Value of Money	46
Present value of future sum	49
Future value of present sum	54
Present value of an annuity	57
Future value of an annuity	59
Present value of deferred annuity	62
Annuity from present value	64
Annuity from future value	67
Present value of uniform gradient series	68
Present value of shifted gradient series	70
Calculation of unknown interest rate	72
Loan Amortization Schedule	73
Funds Flow and Compounding/Discounting	81
Spreadsheet Applications	83
The Time Zero Dilemma	95
Questions and Problems	96

3. Before-Tax Cash Flow Models	111
Cash Flow Model	113
Data Required for Project Evaluation	116
Forecasting Product Stream	117
Volumetric calculations	119
Decline curve analysis	121
Gas reservoir material balance	142
Production forecast by analogy	146
Product Pricing	149
Capital Expenditures (CAPEX)	154
Geological and geophysical (G&G) costs	155
Estimating drilling costs	155
Facility costs	158
Operating Expenditure (OPEX)	162
Abandonment costs and sunk costs	166
Opportunity costs	167
Types of Cost Estimates	168
Order of magnitude estimate	168
Optimization study estimate	169
Budget estimate	169
Control estimate	170
Variations in Actual Project Costs	170
Cost overrun	170
The accuracy of the estimates	171
Contingencies and allowances	172
Transfer Pricing	174
Transfer price at cost	176
General formula for computing transfer price	177
Transfer at market price	177
Aspects of Leasing	178
System of land ownership identification	179
Ownership interest computation	181
Severance and Ad Valorem Taxes	185
Cash Flow Estimation Bias	190
Cash Flow Analysis of Foreign Investments	191
Cash Flow Analysis and Inflation	192
The Cost of Capital	193
The Cash Flow Spreadsheet	195
Questions and Problems	198

4. After-Tax Cash Flow Model	207
Depreciation	213
Tangible property	213
Intangible property	213
Modified accelerated cost recovery system	214
Accelerated cost recovery system	218
Straight-line depreciation	219
Declining balance depreciation	220
Sum-of-years'-digits depreciation	221
Units of production depreciation	223
Amortization and Depletion	223
Amortization	224
Depletion	224
Intangible Drilling Costs (IDCs)	228
Spreadsheet Application	235
Questions and Problems	243
5. International Petroleum Economics	245
Types of Contract Arrangements	247
The concessionary system	249
Sample concessionary system cash flow spreadsheet	251
The production sharing system	254
Sample PSC cash flow spreadsheet	259
Basic elements of production sharing and royalty tax systems	263
Contract initiation and award	270
Government and contractor take	271
Risk service contracts	273
Rate of return (ROR) contracts	274
Effects of Various Fiscal Terms	274
Efficient fiscal regime	275
The effect of cost recovery ceiling	277
Designing fiscal systems	280
Questions and Problems	294
6. Capital Budgeting Techniques	301
Accounting Approaches	306
Payback period	306
Average return on investment (AROI)	310
Discounted Cash Flow Approaches	311
Discounted payback period	312

Net present value (NPV)	313
Internal rate of return (IRR)	316
Profitability index (PI)	328
Unit technical cost (UTC) or long-run marginal cost (LRMC)	331
Netback value (NBV) and indexed pricing	337
Growth rate of return (GRR)	350
Adjusted net present value (ANPV)	353
Effect of Discounting Frequency	355
Treatment of Financing Mix	360
Pattern of project debt repayment schedule	362
After-tax weighted average cost of capital method	366
Equity residual method— NPV_{ER}	369
Arditti-Levy method— NPV_{AL}	371
Adjusted net present value— NPV_A	372
Comparison of the four methods	373
Questions and Problems	375
Further Reading	385
7. Investment Selection Decision Making	387
Service-Producing Investments	389
Equivalent cost analysis	390
Rate of return analysis	392
Present value ratio or PI analysis	394
Service life breakeven analysis	394
Unequal life service-producing alternatives	395
Lease versus Buy Decision Analysis	398
Income-Producing Investments	403
Project screening economics	403
Mutually exclusive investment analysis	406
Non-mutually exclusive investment analysis	415
Questions and Problems	420
Appendix A. Interest Factors for Annual Interest Compounding	433
Appendix B. Overview of Spreadsheets on CD-ROM that Accompany Volume 2	441
Answers to Selected End-of-Chapter Problems	445
Index	453

Preface

Welcome to the second edition of *Project Economics and Decision Analysis*. As mentioned in the previous edition, the international oil and gas industry remains one of the most important, highly capital-intensive, and risky industries at global, regional, and local levels. The Global E&P expenditure reached \$324 billion in 2007 (*World Oil* magazine, February 2008, Vol. 229, No. 2). Our profit margins are under real pressure from many factors, including the higher costs of developing new reserves, less oil found per foot drilled, rising inflationary costs of doing business, oversupply of crude, crude oil price volatility, competition for oil company investments, competition for acreage/concessions, competition for funds, and overall business risk and uncertainty.

Therefore, it is crucial to carry out prudent economic evaluations of any capital investments before resources are committed. This, of course, requires a thorough understanding of the techniques available and their application by all those involved in decision-making. To assist in achieving this goal, the industry deserves a comprehensive guide to provide all the necessary concepts of capital investment evaluation, capital budgeting, and decision analysis. This book, *Project Economics and Decision Analysis*, in its second edition, will hopefully meet this requirement.

Objective

One goal in writing this book has been to provide students, practicing engineers, geologists, economists, planners, and managers with a solid foundation in the dynamic and growing field of capital investment evaluation with emphasis on the uncertainty aspect. It describes how investment decisions are currently made under different stages of uncertainty and prescribes techniques for making rational decisions.

This two-volume set describes the philosophy, process, and methods of capital investment evaluation and decision analysis. In summary, the main objectives of the book are to:

- Explain the ever-expanding role of economics in prudent capital investment decision-making.
- Assist readers in developing a knowledgeable vocabulary of the terms associated with economic analysis.
- Review the procedures used in preparing capital investment evaluations and decision analysis.
- Relate the new vocabulary and knowledge to some specific problems.

- Present ways of interpreting estimates that include uncertainty (i.e., converting probabilistic description into a measure of profitability).
- Provide solid hands-on experience with capital investment evaluation and decision analysis.

The subject of project economics and decisions analysis is not difficult. It does not require you to remember your differential equations, nuclear physics, or atomic theory. However, it does require the use of a good deal of logic and common sense, and the rest is just number crunching. The analyst doing economic evaluations needs to think imaginatively to identify a problem, to weigh the various factors that will affect these variables, to evolve alternatives, to take a position, and finally to be prepared to defend his or her position.

I urge students and practitioners to have a helicopter view of the entire process and develop an eye for details in order to be able to resolve problems as opposed to completing a series of cookbook computations. This is what *Project Economics and Decision Analysis* is all about. While I have retained most of the features that have made these books so popular, I have further enhanced the coverage to make it more relevant and more accessible to students of varying backgrounds.

This edition is further improved in order to address audiences who are not sophisticated in the subject. An attempt has been made to present the subject matter clearly and simply so that the reader will be in a position, whether in the classroom or in practice, to move immediately to higher levels of sophistication in understanding and application.

Changes in the Second Edition

This edition continues the basic philosophy of the first edition, which is to provide users with coverage of all-important areas of project economics and decision analysis, while providing flexibility in the use of materials. This objective of flexibility has warranted the addition of some new material.

Those who will be using these books either as a college text, a learning guide, or as a reference in day-to-day economic decision making may be interested to know what is different about the second edition. Apart from polishing the material and making the concepts easier to understand, I have made the following changes:

1. All materials that have a time aspect have been updated.
2. Throughout the book I have added new, real-world examples to round out the coverage of concepts and to provide appropriate emphasis on areas of central importance.

3. Although most youngsters these days are becoming increasingly proficient in their MS Excel skills, many still need to be aware of the power and limitations of this valuable software—especially when it comes to economic evaluation of projects. In my five-day courses on the subject, I note that the participants really struggle with using Excel's full potential. Therefore, I have expanded the spreadsheet applications sections to elaborate on the capabilities of Excel and highlight the areas where analysts have misused it.
4. The section on the weighted average cost of capital (WACC) concept is expanded to make the concept easy to comprehend so that the analysts can easily recognize the weakness of this concept in practice.
5. A new section on netback pricing and indexed netback pricing is included.
6. The concept of unit technical cost, also referred to as long-run marginal cost (LRMC) is expanded to make it easier to calculate and apply.
7. The section on international economics (fiscal systems) is rewritten and expanded.
8. A new chapter on exploration economics is added to volume 2.
9. Many problems in volume 2 were solved using the previous versions of the Palisade DecisionTools suite. These problems are updated using the latest version of the DecisionTools suite.
10. After using the books for six years, with significant feedback from the participants in my five-day courses on the subject and some of the professors who are using these books in their courses, I found that there was room for improvement in adding clarity to some of the topics. Therefore, I have provided additional examples or reworked the existing examples.
11. For professors who are using these books, a test bank of approximately 300 multiple-choice and true-false questions was developed. In addition, a comprehensive set of some 300 MS PowerPoint slides is made available.

Emphasis and Style

The book presents a balanced blend of theoretical concepts and their practical utility. I prefer to focus less on extensive theoretical discussions than

might be found in other books. Theory, I feel, distracts the reader from the most important concepts and their practical application. Moreover, theory can seem sterile and pointless unless its usefulness is made clear. Therefore, I have focused more on practical application. The underlying concepts are stressed and made concrete with liberal use of illustrations, many of them taken from actual real-life capital investment evaluations. Algebraic formulations and spreadsheets are used side-by-side to help readers develop conceptual thinking skills. Emphasis is placed on model formulation and interpretation rather than algorithms.

The technical materials have been developed with considerable patience—assuming very little foreknowledge and proceeding in a step-by-step manner to minimize the possibility of the reader getting lost along the way. Moreover, I have resorted to a greater degree of informality in the presentation in the belief that readability should be an overriding consideration. Toward the same goal, intuitive and economic explanations are frequently provided to clarify the why of a particular concept/technique.

This book is primarily intended for use by economists, earth scientists, engineers, and students. It is also intended to serve as a refresher and perhaps as a self-study textbook. The problem-solving approach is instructive in nature, but the foundational principles show the practical application of the material. Its chief purpose is two-fold: (1) to render a systematic exposition of certain basic deterministic investment evaluation methods, and (2) to relate these to the decision analysis in such a way that the mutual relevance of the two is clearly brought out.

Therefore, the book is divided into two separate, yet complementary, volumes. This book, volume 1, is essentially introductory and deals with the deterministic evaluation tools used for capital investment evaluations. These concepts are seldom covered as broadly or from the same viewpoints in economics and other courses, yet they are fundamental to the proper understanding of all evaluation work.

Volume 2 in this series deals with the concepts of decision analysis (i.e., incorporating risk and uncertainty as applied to capital investments). Generally, each topic is introduced by a brief practical or conceptual overview, followed by a brief discussion related to its application in practice and a solved example. For optimum benefit, it is recommended that readers explore both volumes and benefit from their integrated instruction.

Examples and Assignment Problems

Being gratified by the success of the first edition, I have maintained the example-driven approach to the subject matter. I believe that the best way to learn any subject is by working through examples and completing plenty

of problems—the problems however have to represent reality, not textbook examples or problems. Although this active learning approach is not new, I believe these books have more fully developed this approach than any other book on the subject. This example-driven approach is further reinforced by imparting valuable modeling skills that students can appreciate and take with them into their careers.

Included in this second edition are additional solved real-life examples (100+) and end-of-chapter assignment material (300+ questions and problems). Examples help reinforce the learning process. Each solved example is straightforward, fully explained, and avoids sudden leaps to conclusions that might confuse the reader. The assignment material is divided into questions and problems. The questions primarily address key concepts and terms in the chapter. The problems either consolidate a number of chapter topics or focus on a comprehensive analysis of a single topic.

The wide variety of assignment material offers practical knowledge since the assignments include various combinations of breadth and depth, theory and procedures, simplicity and complexity. For maximum benefit, the reader should work out as many of these problems as possible, if indeed not all.

Spreadsheet Applications

During my five-day courses that I teach on this subject, I notice that most of the participants struggle a lot with the use of financial functions provided in MS Excel. Today, most of us are using spreadsheet programs to build models of the decision problems we face as a regular part of our daily work activities. Spreadsheets also capture users' interest and add a new relevance to investment evaluation and decision analysis. Since we extensively use Excel for our economic modeling, it is essential that those who are interested in working in this area be fully conversant with Excel.

In this second edition, I have repeatedly highlighted the mistakes committed by very senior analysts in modeling problems using MS Excel; such mistakes are unnecessary and avoidable. I stress again and again that the use of software is to organize and expedite our calculations rather than solve the problems for us. We should use software only if we know, given sufficient time, how to solve a given problem by hand.

A unique feature of this book is embedded application of computers in solving investment evaluation and decision analysis problems. I have tried to give both aspects of the required calculations—problem solving by hand and by using Excel. For those who build economic models, they also need to debug these models. So, how would one find bugs in any spreadsheet or economic model if one does not know how to solve the problems by hand?

Examples are provided to show how computers can be used to help make better evaluations and, hence, better decisions. The Microsoft Excel spreadsheet is making it increasingly easy and practical to do sensitivity and scenario analysis. Its use has gained acceptance in the industry and makes it feasible to do a variety of analyses with a multitude of problems. The latest version of DecisionTools Suite (an Excel add-on) by Palisade Corp. includes the award-winning @RISK and PrecisionTree applications, which are used where applicable. Screen captures of the various menus of DecisionTools Suite are used.

Reviewers' Comments

Many useful comments were received from PennWell's technical reviewers. These are incorporated wherever possible. Some reviewers noted that perhaps I may overkill some of the basic concepts, such as the Time Value of Money, etc. That may be true, but this is how I learned these concepts more than 30 years ago when I took a course from Dr. Franklin J. Stermole at Colorado School of Mines. It is very ironic that it is these simple concepts where very experienced analysts make mistakes or misinterpret the limitation of the concepts applied. I have specifically brought these mistakes to your attention so that they can be avoided. These basic concepts have been of considerable help to me over the years, enabling me to visualize the investment problems and their time horizons. Therefore, I have decided to leave them as they are. Similarly, the use of interest tables (in this modern age of computers) might be considered orthodox. The tables may not be used in practice, but they definitely add to understanding the concepts. I feel strongly that readers will benefit, so I have included them here.

Request for Suggestions

It should be noted that one cannot always add new material and never delete some of the existing material. Some examples and materials become dated and become natural candidates for deletion. In addition, some material needs to be enhanced by rewriting or restructuring in order to improve readability and understanding.

A considerable amount of dedication and investment (time and capital) goes into writing and publishing such a book. I have made every effort to introduce this two-volume set as a comprehensive desk reference. I sincerely welcome your thoughts as an end-user to help us further improve the contents, presentation, and utility of this book so as to make it a standard for the new generation of petroleum industry personnel. I will always be very grateful for your comments, suggestions, or corrections sent to me directly (asifmian55@yahoo.com) or through PennWell Publishing.

commodity. The market demand curve is the sum of the demand curves of *all* individuals in the market for a commodity.

As shown in figure 1–1, the demand curve is a downward sloping (negative slope) curve. This means that when the product price increases, the demand for the product (to a certain extent) will decrease, and vice versa. This is called the *law of demand*. The extent of change, of course, will depend on the elasticity of demand for the product (discussed later in the section). The demand curve in figure 1–1 shows that at price P1 (\$30/unit) the demand Q1 is only 10 units. As the price is reduced to P2 (\$15/unit), the demand Q2 for the product increases to about 17 units.

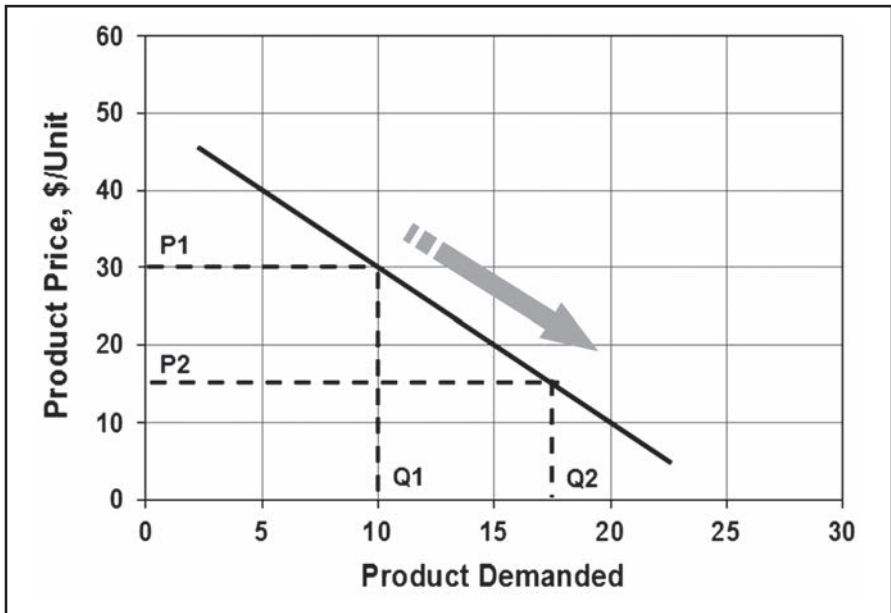


Fig. 1–1 The demand curve

As shown above, demand is a function of many factors. If any of these factors (other than the price) change, the entire demand curve for the product may shift upward or downward depending on the particular situation and the factor. If the income level of consumers increases and/or the population increases, there will be an upward shift in the demand curve as shown in figure 1–2. Because of the upward shift in the demand curve, the demand at P1 is now 20 units as compared to the 10 units with the original demand curve. Similarly, if there is a downward shift in the demand curve, then the units demanded at P1 will be 5 rather than 10 or 20 units.

annually. As shown in figure 1–11, the CPI usually shows a very smooth and consistent trend over the years, but the inflation rate shows wild fluctuations over time. The following calculations show the inflation rate for 2008.

Average CPI for 2008	215.30
Average CPI for 2007	207.34
Index Point Change7.96
Divide Index Point Change by 2007 CPI.	0.0384 or 3.84%

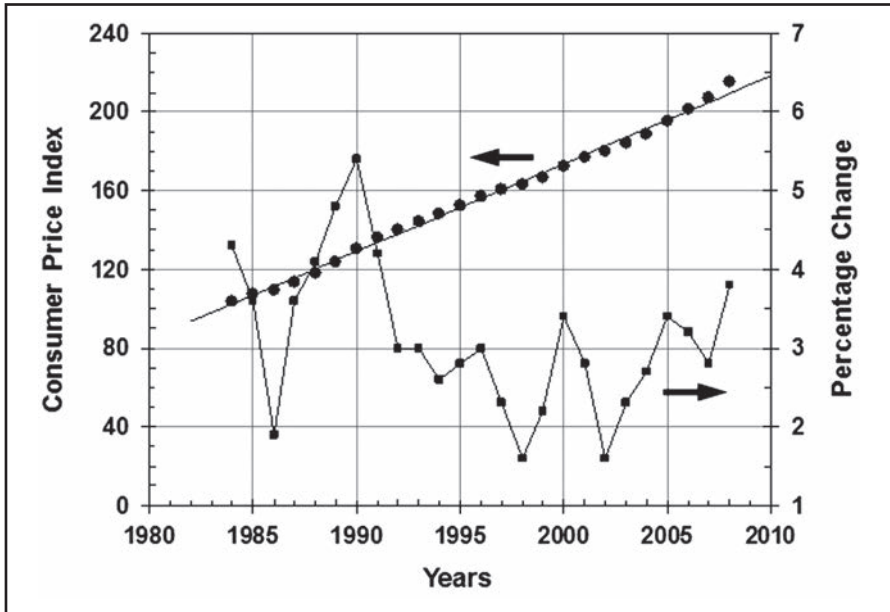


Fig. 1–11. U.S. Consumer Price Index, All Urban Consumers (CPI-U)

As shown above, to arrive at a percentage change over an entire year it is recommended to use CPIs based on 12-month averages. This should not be confused with over-the-year change in the CPI, such as December 2007 to December 2008. This may not always give the right inflation figure because there will be wide fluctuations in the monthly CPIs as shown in figure 1–12. The calculations below show the difference in the inflation rate calculated by using the December 2007 and December 2008 CPIs, versus the annual averages as shown in the calculations above. The difference could be significant; the over-the-year percent change may be misleading and not very useful.

Example 2–11

Using the royalty payments in example 2–7, calculate the future value of these payments at 8% effective interest.

Solution: The cash flow diagram for example 2–11 is shown in figure 2–8. Using equation (2.13),

$$\begin{aligned}
 F_v &= \$2,000(1+0.08)^4 + \$2,200(1+0.08)^3 + \$1,900(1+0.08)^2 \\
 &\quad + \$2,500(1+0.08)^1 + \$1,500(1+0.08)^0 \\
 &= \$2,000(1.3605) + \$2,200(1.2597) + \$1,900(1.1664) \\
 &\quad + \$2,500(1.08) + \$1,500 \\
 &= \$11,908.50
 \end{aligned}$$

The present value of this amount is calculated by treating it as a single future sum,

$$\begin{aligned}
 P_v &= \$11,908.50 \frac{1}{(1+0.08)^5} \\
 &= \$8,104.73
 \end{aligned}$$

which is the same value as calculated in example 2–7. Similarly, the future value of \$8,104.73 (obtained in example 2–7) could have been calculated by treating it as a single payment present sum.

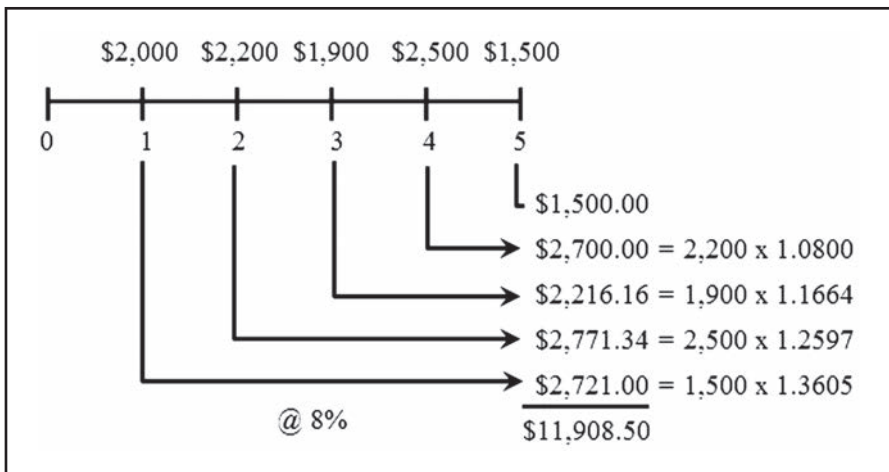


Fig. 2–8. Cash flow diagram for example 2–11, showing future value of periodic receipts

2.9 Your current salary is \$60,000/year, your salary is increased every year by 5% per year, and the inflation rate is 3% per year. Your inflation adjusted income after five years will be

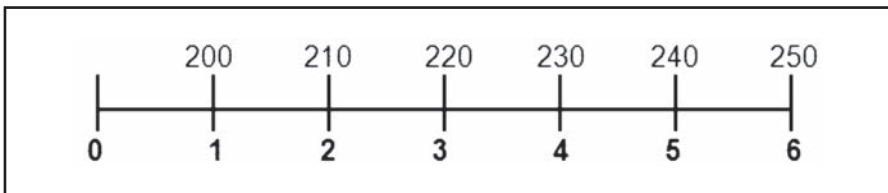
- a. \$76,577
- b. \$85,245
- c. \$66,245
- d. \$70,650

2.10 Conditions for ordinary annuity are:

- a. The periodic payments or disbursements are of equal amount.
- b. The interest rate is constant throughout the annuity period under consideration.
- c. The time intervals between each payment are of same length.
- d. The interest rate is compounded at the end of each time period.
 - I. Only A and C are true.
 - II. Only B and D are true.
 - III. All four conditions are true.
 - IV. None of the above conditions are true.

2.11 The following time diagram shows

- a. Ordinary annuity
- b. Annuity due
- c. Deferred annuity
- d. None of the above



Problem 2.11 diagram