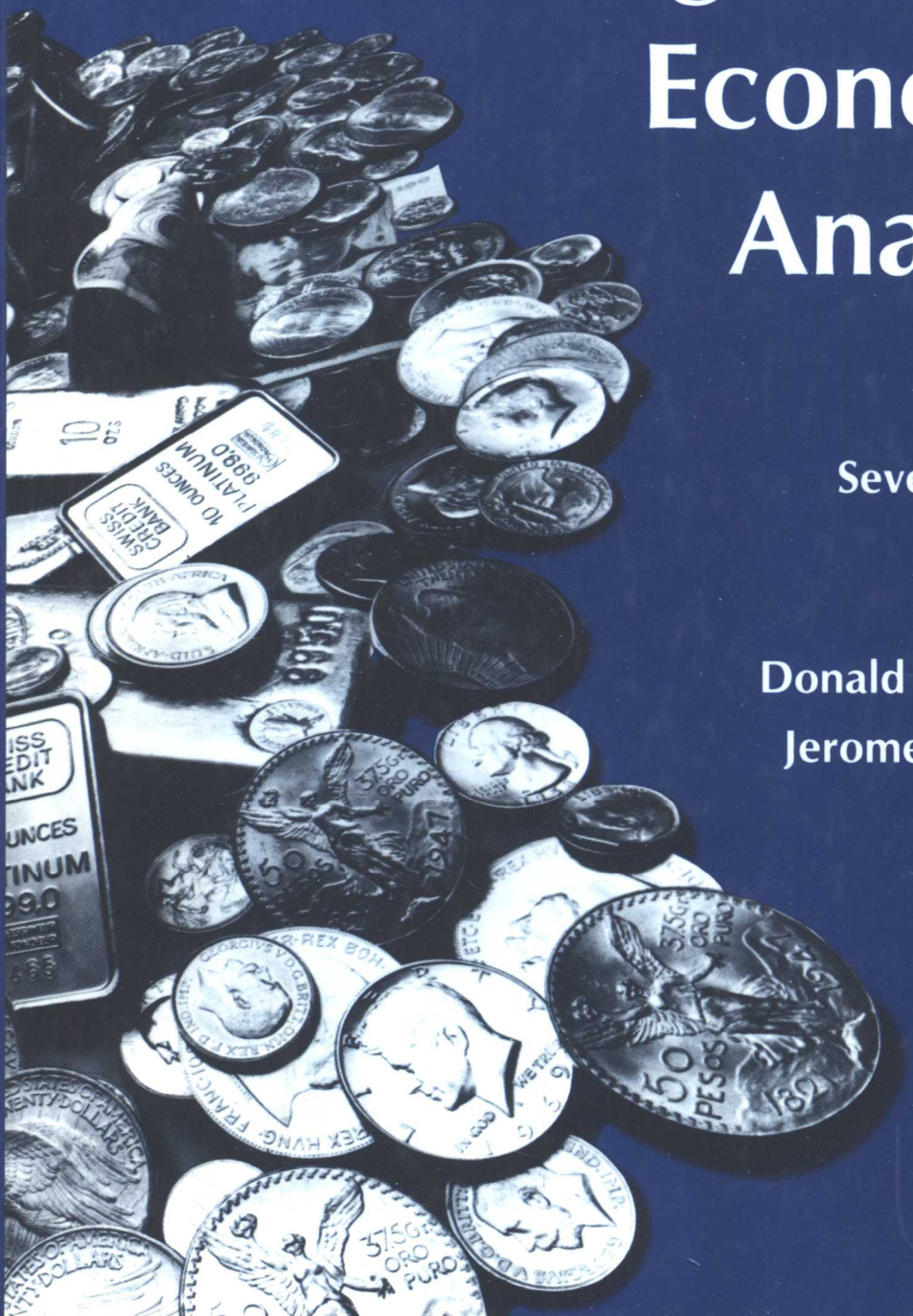
Engineering Economic Analysis



Seventh Edition

Donald G. Newnan
Jerome P. Lavelle

Engineering Economic Analysis

Seventh Edition

Donald G. Newnan
Jerome P. Lavelle

Engineering Press

Austin, Texas

Student Pak I 0-910554-97-8 Contains Engineering Economic Analysis 7th edition, Student's Quick Study Guide, and Windows Diskette

Student Pak II 0-910554-96-X Contains Student's Quick Study Guide, and Windows Diskette

The items are shrink wrapped together and sold as a set. The textbook is not sold separately.

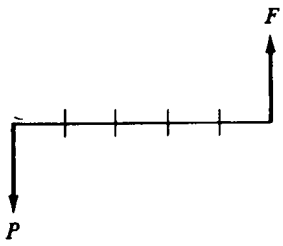
Cover illustration courtesy of Monex International Ltd.

Printed in the United States of America 5 4 3 2

Engineering Press
P.O. Box 200129
Austin, Texas 78720

Editor: bdnewnan@aol.com
Website:www.engrpress.com

Single Payment



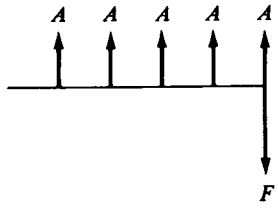
Compound Amount:

To Find F Given P $\quad (F/P,i,n) \quad F = P(1 + i)^n$

Present Worth:

To Find P Given F $\quad (P/F,i,n) \quad P = F(1 + i)^{-n}$

Uniform Series

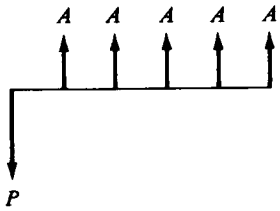


Series Compound Amount:

To Find F Given A $\quad (F/A,i,n) \quad F = A\left[\dfrac{(1 + i)^n - 1}{i}\right]$

Sinking Fund:

To Find A Given F $\quad (A/F,i,n) \quad A = F\left[\dfrac{i}{(1 + i)^n - 1}\right]$



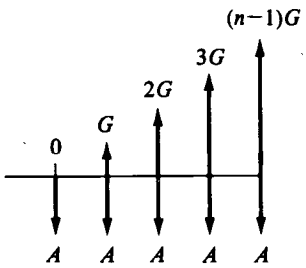
Capital Recovery:

To Find A Given P $\quad (A/P,i,n) \quad A = P\left[\dfrac{i(1 + i)^n}{(1 + i)^n - 1}\right]$

Series Present Worth:

To Find P Given A $\quad (P/A,i,n) \quad P = A\left[\dfrac{(1 + i)^n - 1}{i(1 + i)^n}\right]$

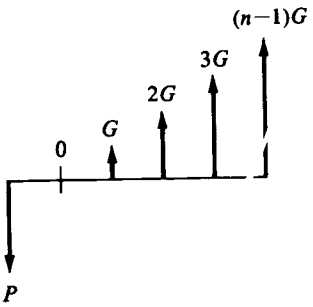
Arithmetic Gradient



Arithmetic Gradient Uniform Series:

To Find A Given G $\quad (A/G,i,n) \quad A = G\left[\dfrac{(1+i)^n - in - 1}{i(1+i)^n - i}\right]$

or $\quad A = G\left[\dfrac{1}{i} - \dfrac{n}{(1+i)^n - 1}\right]$



Arithmetic Gradient Present Worth:

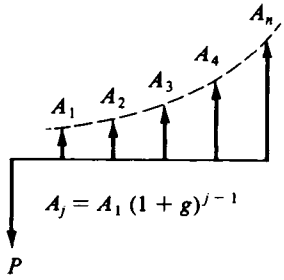
To Find P Given G $\quad (P/G,i,n) \quad P = G\left[\dfrac{(1 + i)^n - in - 1}{i^2(1 + i)^n}\right]$

Geometric Gradient

Geometric Series Present Worth:

To Find P Given A_1, g — $(P/A,g,i,n)$ When $i = g$ — $P = A_1[n(1 + i)^{-1}]$

To Find P Given A_1, g — $(P/A,g,i,n)$ When $i \neq g$ — $P = A_1\left[\dfrac{1 - (1 + g)^n(1 + i)^{-n}}{i - g}\right]$



Continuous Compounding at Nominal Rate r

Single Payment: $F = P[e^{rn}]$ $\quad P = F[e^{-rn}]$

Uniform Series: $A = F\left[\dfrac{e^r - 1}{e^{rn} - 1}\right]$ $\quad A = P\left[\dfrac{e^{rn}(e^r - 1)}{e^{rn} - 1}\right]$

$F = A\left[\dfrac{e^{rn} - 1}{e^r - 1}\right]$ $\quad P = A\left[\dfrac{e^{rn} - 1}{e^{rn}(e^r - 1)}\right]$

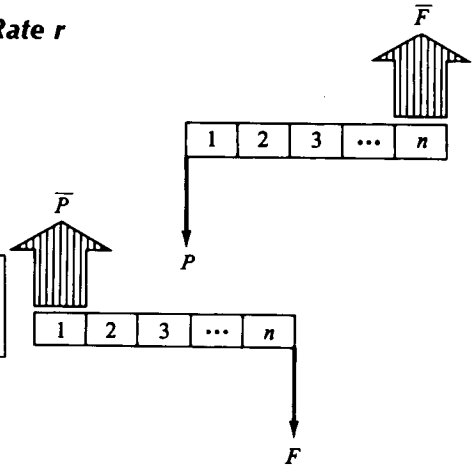
Continuous, Uniform Cash Flow (One Period) With Continuous Compounding at Nominal Rate r

Present Worth:

To Find P Given $\overline{F}$ — $\left[P/\overline{F},r,n\right]$ — $P = \overline{F}\left[\dfrac{e^r - 1}{re^m}\right]$

Compound Amount:

To Find F Given $\overline{P}$ — $\left[F/\overline{P},r,n\right]$ — $F = \overline{P}\left[\dfrac{(e^r - 1)(e^m)}{re^r}\right]$



Compound Interest

i = Interest rate per interest period*.

n = Number of interest periods.

P = A present sum of money.

F = A future sum of money. The future sum F is an amount, n interest periods from the present, that is equivalent to P with interest rate i.

A = An end-of-period cash receipt or disbursement in a uniform series continuing for n periods, the entire series equivalent to P or F at interest rate i.

G = Uniform period-by-period increase or decrease in cash receipts or disbursements; the arithmetic gradient.

g = Uniform *rate* of cash flow increase or decrease from period to period; the geometric gradient.

r = Nominal interest rate per interest period*.

m = Number of compounding subperiods per period*.

$\overline{P}$, $\overline{F}$ = Amount of money flowing continuously and uniformly during one given period.

*Normally the interest period is one year, but it could be something else.

Preface

In the first edition of this book we said:

> This book is designed to teach the fundamental concepts of engineering economy to engineers. By limiting the intended audience to engineers it is possible to provide an expanded presentation of engineering economic analysis and do it more concisely than if the book were written for a wider audience.

We felt then that authors of competing books were making a mistake in trying to make their books something for everyone. Unfortunately, authors of current books continue to write for other people. One set of authors suggests their book is also for upper-division students in management and economics. Another author mentions courses in financial management, capital budgeting, and the like. Our view has not changed. We have written exclusively for engineering students.

Our goal was, and still is, to provide an up-to-date presentation of engineering economic analysis in a way that students can understand and relate to. That means the book must provide a style of writing that never forgets that everything done must be to promote the reader's understanding of the topic. We are most humble to find that our approach has been well received by engineering professors - and more importantly - by engineering students through the prior six editions of the book.

The emphasis of the changes in this edition has been to promote computer and spreadsheet solution of engineering economic analysis problems. The computer programs, described in chapter 19 and included on the diskette in the student pak, have been revised for Windows. This makes them much easier to use. And for the first time there is an Apple/Macintosh version of the diskette available from the publisher. Professor Bruce Johnson at the US Naval Academy prepared the two spreadsheet chapters for the fifth edition and has modified them for this edition to make the content easier to understand and the spreadsheet workbooks on the diskette easier to use.

A variety of changes have been made in this edition. Chapter 11(Income Taxes) has been changed to reflect the 1997 tax legislation and 1997 tax rates. Chapters 12 (Replacement Analysis), 13 (Inflation and Price Change), and 16 (Economic Analysis in Government) have been rewritten to provide a more detailed discussion of the topics. Chapter 19 (Personal Computer Programs) has been redone for the Windows environment. As computer-based spreadsheets, along with word processing programs

and e-mail, have become commonplace in business and industry, we have placed emphasis on the use of spreadsheets throughout this edition. Beginning as a supplement to chapter 2 and continuing through chapter 12 are spreadsheet tutorials with examples appropriate for the core economic analysis discussion. The previous chapters 20 and 21 spreadsheet presentations have been condensed into a single new chapter.

In addition to the specific changes to the various chapters described, over 120 new homework problems have been added at the end of the chapters. Also, many less noticeable changes have been made throughout the book to improve its content and readability.

As in the past, the textbook is part of a three part set. In addition to the textbook there is the 296 page *Student's Quick Study Guide: Engineering Economic Analysis* with an abstract of engineering economic analysis plus 386 solved problems, and a diskette of computer programs and spreadsheet workbooks. These are shrink wrapped together in a complete three-part student pak at less than the cost of competing single textbooks.

For instructors there is now an expanded set of supplemental materials.

1. **Instructor Lecture Notes**
These detailed instructor lecture notes have been prepared for the first 17 chapters of the book. They are distributed on a 3½" HD disk for easy viewing and printing.

2. **Overhead Transparencies**
For those who use an overhead projector or slides, there are many illustrations from chapters 1-12. Many of these masters are in color and can be driven directly by a laptop to a LCD display.

3. **Compound Interest Tables**
A separate 32-page pamphlet contains the compound interest tables from the textbook. Classroom quantities are free to adopting professors.

4. **Engineering Economic Analysis Solution Manual**
All end-of-chapter problems are fully solved in the Solution Manual available only to Instructors.

5. **Student's Quick Study Guide: Engineering Economic Analysis**
Instructors receive a copy of this component of the student pak.

6. **Diskette of Computer Programs and Spreadsheet Workbooks**
These have been updated, now for Windows and Apple/Macintosh. The student pak contains the standard Windows version. For MAC users, we exchange the diskette when it is sent to us.

Many people have directly or indirectly contributed to the content of the book in its seven editions. We have been influenced by our Stanford and North Carolina State University educations, our university colleagues, and students. We are particularly grateful to Professors:

Dick Bernhard, North Carolina State University
Charles Burford, Texas Tech University
Jeff Douthwaite, University of Washington
Utpal Dutta, University of Detroit, Mercy
Lou Freund, San Jose State University
Vernon Hillsman, Purdue University
Oscar Lopez, Florida International University
Nic Nigro, Cogswell College North
Ben Nwokolo, Grambling State University
Cecil Peterson, GMI Engineering & Management Institute
Bruce Reichert, Kansas State University
Robert Seaman, New England College
R. Meenakshi Sundaram, Tennessee Tech University
Roscoe Ward, Miami University
Jan Wolski, New Mexico Institute of Mining and Technology

and particularly Bruce Johnson, US Naval Academy.

We would appreciate being informed of errors, or receiving other comments about the book. Please write us at the Engineering Press address or email to editor: bdnewnan@aol.com.

Contents

Compound Interest Equations	**inside front cover**
Economic Criteria	**inside back cover**
PC Diskette	**See Student PAK**
Preface	**xi**
1 Introduction	**1**
People Are Surrounded By A Sea Of Problems	1
The Role Of Engineering Economic Analysis	4
Problems	5
2 The Decision-Making Process	**9**
Rational Decision Making	10
Decision-Process System	19
Engineering Decision Making	21
When Is A Decision Made?	24
Summary	25
Problems	27
An Introduction To Spreadsheet Analysis	39
3 Interest and Equivalence	**43**
Computing Cash Flows	43
Time Value Of Money	45
Simple Interest	46
Equivalence	49
Single Payment Compound Interest	55
Summary	63
Problems	64
4 More Interest Formulas	**67**
Uniform Series Compound Interest Formulas	67
Relationships Between Compound Interest Factors	78
Arithmetic Gradient	80
Geometric Gradient	88
Nominal And Effective Interest	92
Continuous Compounding	99

Summary 106
Problems 110
Financial Spreadsheets 133

5 Present Worth Analysis 147
Economic Criteria 147
Applying Present Worth Techniques 148
Assumptions In Solving Economic Analysis Problems 163
Summary 166
Problems 167
Spreadsheet Applications 185

6 Annual Cash Flow Analysis 189
Annual Cash Flow Calculations 189
Annual Cash Flow Analysis 194
Analysis Period 197
Summary 203
Problems 204
Spreadsheet Applications 217

7 Rate Of Return Analysis 219
Internal Rate Of Return 219
Calculating Rate Of Return 221
Rate Of Return Analysis 228
Summary 237
Problems 238
Spreadsheet Applications 251

7A Difficulties Solving For An Interest Rate 255
Cash Flow Rule Of Signs 258
External Interest Rate 263
Summary 266
Problems 267

8 Incremental Analysis 275
Graphical Solutions 275
Incremental Rate Of Return Analysis 284
Elements In Incremental Rate Of Return Analysis 289
Present Worth Analysis With Benefit-Cost Graphs 292
Choosing An Analysis Method 293

Summary 294
Problems 295

9 Other Analysis Techniques 307

Future Worth Analysis 308
Benefit-Cost Ratio Analysis 310
Payback Period 317
Sensitivity And Break-even Analysis 322
Summary 327
Problems 328
Spreadsheet Applications 341

10 Depreciation 347

Basic Aspects Of Depreciation 347
Straight Line Depreciation 350
Sum-Of-Years Digits Depreciation 352
Declining Balance Depreciation 354
Declining Balance Depreciation
With Conversion To Straight Line Depreciation 362
Unit-Of-Production Depreciation 368
Modified Accelerated Cost Recovery System Depreciation 370
Depletion 375
Summary 378
Problems 379
Spreadsheet Applications 387

11 Income Taxes 393

A Partner In The Business 393
Calculation Of Taxable Income 394
Income Tax Rates 397
Economic Analysis Taking Income Taxes Into Account 402
Capital Gains And Losses 406
Estimating The After-Tax Rate Of Return 407
Summary 407
Problems 408
Spreadsheet Applications 424

12 Replacement Analysis 431

The Replacement Problem 432
Replacement Analysis Decision Map 433
What Is The Basic Comparison 434
After-Tax Replacernent Analysis 455
Summary 464

Problems 466
Spreadsheet Applications 474

13 Inflation And Price Change 479

Meaning And Effect Of Inflation 479
Constant Dollar Versus Then-Current Dollar Analysis 488
Price Change With Indexes 490
Cash Flows That Inflate At Different Rates 496
Different Inflation Rates Per Period 498
Inflation Effect On After-Tax Considerations 500
Summary 502
Problems 504

14 Estimation Of Future Events 513

Precise Estimates 513
A Range Of Estimates 516
Probability And Risk 518
Expected Value 520
Distribution Of Outcomes 525
Simulation 536
Summary 541
Problems 542

15 Selection Of A Minimum Attractive Rate Of Return 549

Sources Of Capital 549
Cost Of Funds 550
Investment Opportunities 552
Selecting A Minimum Attractive Rate Of Return 555
Adjusting MARR To Account For Risk And Uncertainty 556
Representative Values Of MARR Used In Industry 559
Summary 560
Problems 561

16 Economic Analysis In The Public Sector 563

Investment Objective 564
Viewpoint For Analysis 565
Selecting An Interest Rate 567
The Benefit-Cost Ratio 569
Incremental Benefit-Cost Analysis 573
Other Effects Of Public Projects 580
Summary 585
Problems 586

17 Rationing Capital Among Competing Projects **593**
Capital Expenditure Project Proposals 594
Rationing Capital By Rate Of Return 598
Rationing Capital By Present Worth Methods 600
Ranking Project Proposals 607
Summary 609
Problems 611

18 A Further Look At Rate Of Return **619**
Cash Flow Situations 620
Analysis Of A Cash Flow As An Investment Situation 621
Summary 637
Problems 638

19 Personal Computer Programs **641**
Economic Programs For Windows and MAC 641
Program For Engineering Economic Analysis 644
Program For Uniform Series Calculations 651
Program For Rate Of Return 655
Program For After-Tax Cost Analysis 658
Program For Capital Expenditure Analysis By Simulation 666
Problems 683

20 Advanced Topics In Spreadsheet Analysis **685**
Designing Efficient And Easy-To-Use Spreadsheet Notebooks For Engineering Economic Analysis 686
Commercial Spreadsheet Commonality Constraints: File Formats, Macros And Built-in Financial And Logic Functions 687
Multiple Alternative Equal Life Analysis: 5ALTEL 688
Required Freight Rate Analysis (Equal Lives): DRFREL 692
Sensitivity And Break-even Analysis Using Multi-Variable Solver Tools 695
Unequal Life Analysis: 3ALTUL 697
After-Tax Cash Flow Analysis In Leveraging Situations 701
ATAX F I N 703
ATAX4ALT 708
Problems 712

References 715
Index 717
Compound Interest Tables **725**
Discrete End-Of-Period Compounding 725
Values Of Interest Factors When N Equals Infinity 725

CHAPTER 1

Introduction

This book is about making decisions. ***Decision making***, however, is quite a broad topic, for it is a major aspect of everyday human existence. This book will isolate those problems that are commonly faced by engineers and develop the tools to properly grasp, analyze, and solve them. Even very complex situations can be broken down into components from which sensible solutions are produced. If one understands the decision-making process and has tools for obtaining realistic comparisons between alternatives, one can expect to make better decisions.

Although we will focus on solving problems that confront firms in the marketplace, many techniques we will use may be applied to the problems one faces in daily life, as will be evident in the problems at the end of each chapter. Since problem solving (which is possibly a less glamorous name for decision making) is our objective, let us start by looking at some problems.

People Are Surrounded By A Sea Of Problems

A careful look at the world around us clearly demonstrates that we are surrounded by a sea of problems. Just in a single day, problems begin with the sound of an alarm clock:

> Should Joe shut off the alarm? Yes, by all means, the darn thing is far too noisy to let it ring on. Wow! Awake for three seconds and there's the first decision of the day. Should Joe get up and go to work today? That's really two more questions which require, at least, two more decisions; for early-morning decision making, it might be better to split the questions and take them one at a time: Shall Joe get up? It's obvious that unless Joe plans to just lie there forever, the answer at some point in

time has to be "yes." Shall Joe go to work? This all depends on what day of the week it is and–assuming Joe *has* a job–whether he's needed at work, if he needs the income, and whether he wants to keep his job or not!

About thirty or forty decisions later, Joe finds himself dressed and at the breakfast table. A question is posed: Would Joe like toast with the rest of his breakfast? That kind of decision making is pretty straightforward. And even if Joe later decides he made the wrong decision, the consequences are not of much importance. But there are harder decisions to come.

A look at the morning newspaper poses more serious questions. There is a lengthy article concerning world disarmament. That doesn't look easy to solve, so Joe had better turn to another page. The financial pages offer possibly 2000 different stocks and bonds in which he can invest his money. Some of these are bound to be excellent. In fact, it wouldn't take more than a couple of hundred dollars and two or three years to become a millionaire–if only Joe could make the right decisions. But those kinds of decisions are not very easy to make at all.

It has been a decision-a-minute situation for Joe so far, and it probably will remain that way for the rest of the day. One could ask, however, "Did he or did he not make a decision to shut off the alarm clock?" Although Joe might point out that he did not make a *conscious* decision to shut off the alarm–he *always* shuts it off–the answer actually depends on whether or not he had an alternative. Did he? Yes, of course he did: he could have let the alarm clock keep ringing. If it were a spring-wound clock, it would eventually run down, or an electric clock might just ring for hours.

It is clear, then, that Joe *did* have an alternative but he didn't even consider it. As a result of not recognizing that there was an alternative (and therefore not considering its merits), Joe thought he was taking the *only* course of action. By ignoring alternatives, Joe slipped onto the well-worn path that he was accustomed to taking each workday morning. There is a second, equally important, fact about Joe's morning. Although he may not actually recognize it, he is surrounded by a great variety of ***problems***, or events that call for ***decisions***. Some are relatively easy problems to solve, but many are of increasing complexity and have far-ranging consequences to Joe's life.

Yet, despite the similarity of Joe's situation to all of ours, there does not seem to be any exact way of classifying problems, simply because problems are so diverse in complexity and "personality." One approach to classification would be to arrange problems by their *difficulty*. A simple problem could be, "Shall I have toast for breakfast?" or, "Shall we replace a burned-out motor?" or even, "Shall I stop smoking?" An example of an intermediate problem might be, "Should a manual or semi-automatic machine be purchased for the factory?" or, "Shall I buy or lease my next car?" A complex problem might be, "How should the U.S. Government budget its money?" or, "Should a firm build an assembly plant in a foreign country?" Problems appear to group themselves into three broad categories.

Simple Problems

On the lower end of our classification of problems are less difficult situations. While deciding on the components of your breakfast may not be *easy*, the problem does not seem of great importance. In fact, when compared to complex problems, it may not be much of a problem at all. However, it is not clear that *all* apparently straightforward decisions are truly *simple*. After all, consider how many people smoke cigarettes even though they fully realize that smoking may be harmful to health. That problem, while seemingly simple, has all sorts of social and psychological complexities.

Intermediate Problems

At this level of complexity we find problems that are primarily ***economic***. The selection between a manual or a semi-automatic machine is an instance in which the economics of the situation will be the primary basis of decision making. (There will, of course, be other aspects as well.) A semi-automatic machine implies that less labor would be needed than if the manual machine were selected. Moreover, in this kind of problem, whether or not an extra machine-tender would need to be hired is still more an economic consideration than, say, a social one.

Complex Problems

On the upper end of our classification system, we discover problems that are indeed complex. They represent a mixture of ***economic, political,*** *and* ***humanistic***–that is, lively but unpredictable–elements.

For example, the preparation of the annual budget of the United States is *economic* in that it attempts to allocate available money to all the various federal agencies so that the best possible use is made of the money. But the allocation of money clearly has *political* consequences (for example, to the President, the Congress, and individual members of Congress). The closing of a large military installation in a particular congressional district may create unemployment and, consequently, dissatisfaction among the people with their representatives. No member of Congress wants to create such an unfavorable climate in his district; thus, he can be expected to oppose government actions that are *economically* sound but that create political problems.

Meanwhile, what might be a truly economic level of defense spending? Economics, in fact, may have little or nothing to do with this problem! Rather, defense spending appears to be based primarily on certain critical decisions made by the President as part of a complex world strategy. Other problems at the upper end of the classification scale are *humanistic* and involve relationships between people with economics playing a subordinate role.