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A BIBLIOGRAPHY OF ECONOMIC AND COST ANALYSIS

MARCH 1972

DEPARTMENT OF THE ARMY

Prepared by

Comptroller of the Army

Directorate of Cost Analysis

Washington, D. C.

A

BIBLIOGRAPHY

OF

ECONOMIC AND COST ANALYSIS

Prepared by: Department of the Army
Comptroller of the Army
Directorate of Cost Analysis
Washington, DC 20310

March 1972

User's Guide

This bibliography has been prepared to serve as a quick reference source for materials available in the areas of economic and cost analysis. Entries are arranged in alphabetical order by title. Additions will be inserted in order and page indicators assigned alphabetically (for example: 9, 9a, 9b, 10). This will allow additions to be made as more materials are published. Entries are organized in the following format:

title (and subtitle)
author(s)

place of publication, publisher, year of publication, number of pages
reference numbers

abstract, summary, or brief description

breakdown by chapters or divisions

The reference numbers include, wherever possible, the AD number, to facilitate ordering the document from the Defense Documentation Center. The breakdown by chapters was used to allow quick referencing of the topics covered in the work. Indexes are indicated to allow a more detailed search for specific items of interest.

The index at the end of the bibliography gives entries, by page number, of some of the most frequently referenced topics.

Instructions for Ordering Publications

When available, the Office of the Director of Cost Analysis makes an initial distribution of new Economic and Cost Analysis publications which are sponsored by the Office of the Assistant Secretary of Defense or Department of the Army. The Director of Cost Analysis does not stock extra copies of these publications after the initial distribution has been completed. Many of the publications described in the attached Bibliography may be ordered from the Defense Documentation Center (DDC), Cameron Station, Alexandria, Virginia 22314. When ordering from DDC, cite appropriate AD number if available, and include appropriate payment. The service charge for most of the current publications stocked at DDC is $3.00.

This Bibliography was prepared primarily for reference purposes and it is not intended or implied that every Economic and Cost Analysis Office should have access to all of the publications listed. The following publications are endorsed by the Director of Cost Analysis, Office of the Comptroller of the Army:

Cost Considerations in Systems Analysis
Fisher, Gene H. (Rand Corporation) (Page 27) (Note 1)

Costing Methodology Handbook
Directorate of Cost Analysis, Comptroller of the Army
(Page 43) (Note 2)

Guidebook for Systems Analysis/Cost Effectiveness
ARINC Research Corporation (Page 90) (Note 3)

An Introduction to Equipment Cost Estimating
Batchelder, C.A.; H.E. Boren; H.G. Campbell; J.A. Del Rossi; J.P. Large (Rand Corporation) (Page 99) (Note 4)

Note 1: Initial distribution has been completed. Publication is not available at DDC. Authorized Government Agencies may obtain publication from RAND Corporation. Textbook may also be purchased from the American Elsevier Publishing Company, Inc, 52 Vanderbilt Ave, New York, N.Y. 10017.

Note 2: Initial distribution has been completed. Publication is available at DDC.

Note 3: Publication is available at DDC. Publication is also available as AMC Pamphlet AMCP 706-191, entitled: "Engineering Design Handbook - System Analysis and Cost-Effectiveness", April 1971.

Note 4: Available from RAND Corporation or from DDC. It is planned to update this document and republish it in loose-leaf form. Initial distribution will be made when it is received.

Analysis for Financial Decisions
Beranek, William

Homewood, Richard D. Irwin, 1963, 480 p.

The objective of this book is to provide the student with a basic framework for the systematic analysis of financial problems. To this end, we seek (a) to set forth the central issues involved in the fundamental problem areas of financial administration, and (b) to develop tools, techniques, and insights which are relevant and useful for solving these problems.

I. Introduction.
II. Goals, Decisions, and Models.
III. Rationing of Resources: Single-Period, Single-Product Projects.
IV. Rationing of Resources: Two-Product Projects.
V. Rationing of Resources: Multiple Periods.
VI. Multiple Period Projects: Risk and Uncertainty.
VII. Supply of Resources.
VIII. Long-Term Financing and Maximizing the Market Value of Common Stock.
IX. Capital Structure and Risk.
X. Receivables and Credit Policy.
XI. The Cash Balance.
XII. Simulation.
XIII. Linear Programming and the Simplex Method.
XIV. Multiperiod Analysis and Linear Programming.
Appendix A. Cumulative Normal Distribution.
Appendix B. Table of Random Numbers.
Index.

Analysis for Military Decisions
Quade, E.S. Editor

Santa Monica, The Rand Corporation, 1964, 382 p.
Rand No. R-387-PR. AD 453 867.

A report prepared for United States Air Force Project Rand; Concerned with the origin and development of the systems analysis approach and its relation to national security planning, the elements and methods common to all systems analyses, and special aspects. Part 1: orientation (chapters 1-3); Part 2: elements and methods (chapters 4-8); Part 3: special aspects (chapters 9-16); Part 4: summary (chapter 17).

I. Introduction (E.S. Quade).
II. Analysis for Air Force Decisions (C. J. Hitch).
III. The Selection and Use of Strategic Air Bases: A Case History (E. S. Quade).
IV. The Why and How of Model Building (R. D. Specht): relevant factors; quantifiable factors; aggregation; quantifying relations between elements; model building and the real world; human judgment.
V. Criteria (R.N. McKean).
VI. The Relevance of Costs (Malcolm W. Hoag).
VII. Analysis and Design of Conflicting Systems (Albert Wohlstetter).
VIII. Methods and Procedures (E.S. Quade): formulation; search; explanation; interpretation.
IX. Technological Considerations (R. Schanberg): performance parameter; state-of-the-art parameters; scaling laws; optima and constraints; reliability considerations.
X. Assumptions about Enemy Behavior (T.C. Schelling).
XI. Gaming Methods and Applications (H.G. Weiner).
XII. Strategies for Development (W.H. Meckling).
XIII. Mathematics and Systems Analysis (E.S. Quade): linear programming; Monte Carlo; theory of games; the computer; the role of mathematics.
XIV. The Use of Computers (Paul Armer).
XV. Costing Methods (G.H. Fisher and the Staff of the Rand Cost Analysis Department): individual systems; investment cost; operating cost; R&D cost; total force structure; incremental costing and long-term programming; mission and other levels; sensitivity, timeliness, and clarity; cost categories; cost-sensitivity analysis; presentation of results.
XVI. Pitfalls in Systems Analysis (E.S. Quade): formulation; search; explanation; interpretation.
XVII. Recapitulation (E.S. Quade).
Appendix A. An Introduction to the Lunar Base Problem (E.W. Paxson).
Appendix B. A Missile Comparison (E.S. Quade).
Bibliography.
Index.

An Analytical Estimation of System Cost Uncertainty
Schlenker, George

Rock Island, US Army Weapons Command (Weapons Operations Research Office), 1967, 28 p.
Technical Note 67-3.

Abstract: "The method proposed for producing a probability distribution of system cost requires that the system cost be a sum of component costs each of which is uncertain. These uncertain inputs are assumed fit by beta distributions. The statistical moments of the distribution of system cost are obtained from the moments of the input distributions by a recursive procedure. Finally, the system cost distribution is synthesized from its moments using orthogonal polynomials. This method is quite efficient for computer operation and avoids lengthy Monte Carlo runs. An example is given. The FORTRAN program is given."

Abstract.
Glossary.
An Analytical Estimation of System Cost Uncertainty.
Types of Beta Distribution Used in Costing.
An Example.
References.
Computer Programs.

Annotated Bibliography of Cost Analysis Research Documents Prepared by the Economic and Costing Department

Research Analysis Corporation
McLean, Research Analysis Corporation, 1967, 13 p.

Introduction.
Cost Estimating Relations.
Models.
Applications.
Orientation and Guidelines.
Review of Army Practice.

Annotated Bibliography on Systems Cost Analysis
DonVito, P.A.

Santa Monica, The Rand Corporation, 1967, 80 p.
Rand Memorandum RM-4848-PR. AD 810 910.

The bibliography includes books, pamphlets, articles, papers, and technical and research memoranda. Written materials carrying security classification have not been included. A brief description of the nature and content of each work is presented. Works are listed by author, alphabetically, under major areas of interest.

Preface.
I. Cost Analysis for Purposes of Systems Analysis.
II. Cost Estimating in Military Planning.
III. Program Budgeting.
IV. System Definition.
V. Cost Categories.
VI. Cost Elements.
VII. Cost Estimating Relationships and Methodology.
VIII. Data Requirements.
IX. Individual System Analysis.
X. Total Force Structure and Program Analysis.
XI. Models.
XII. Uncertainty and Special Problems.

An Annotated Cost Analysis Bibliography
Cost Analysis Division

Fort Monmouth, US Army Electronics Command, 1967, 216 p.

"The purpose of this publication is to make available to management and cost-oriented analysts, information about documents catalogued in the Cost Analysis Division, Comptroller and Director of Programs, on the concepts and techniques of cost analysis. To expedite this objective, brief summaries have been provided for each document. Listed documents are available to all members of this command for research and reference purposes."

I. Indexes: numerical listing; alphabetical listing; subject listing (guidelines and orientation, cost estimating relationships, systems analysis and cost effectiveness, mathematical models and applications, tables and cost data).
II. Synopses.
III. Bibliography.

An Application of Dynamic Programming to Cost-Effectiveness Studies
Sacco, William; Palmer Schlegel; John Wortman

Aberdeen Proving Ground, Ballistic Research Laboratories, 1963, 16 p.
BRL Report No. 1217. AD 425 743.

Abstract: "A mathematical model has been developed for use in conducting cost-effectiveness studies, wherein the objective of the study is to determine alternative families of fire support weapons which will provide a given level of effectiveness for minimum weight and cost."

Introduction.
Statement of the Problem.
Dynamic Programming Formulation of the Problem.
An Illustrative Example.
Discussion.

Applied Dynamic Programming
Bellman, Richard E. and Stuart E. Dreyfus

Princeton, Princeton University Press, 1962, 363 p.
Rand No. R-352-PR.

Summary and Introduction.

I. One-Dimensional Allocation Processes: introduction; verbal description of the allocation process; construction of a mathematical model; discussion; calculus; difficulties; conclusion; sensitivity analysis; dynamic programing; functional equations; the principle of optimality; a direct derivation; discussion; computational scheme; nonuniqueness of maximum; dynamic programming versus direct enumeration; what difficulties have we overcome; flow chart for general allocation process; numerical results; a useful device; stability; a cargo-loading process; mathematical formulation; discussion; recurrence relations; discussion of computational procedure; reliability of multicomponent devices; reliability via component duplication; a mathematical model; parallel operations; conclusion.

II. Multidimensional allocation processes: introduction; allocation processes involving two types of resources; recurrence relations; allocation processes two types of constraints; recurrence relations; computational aspects; the flyaway-kite problem; stochastic aspects; dynamic programming approach; computational procedure; the Lagrange multiplier; geometric origin; reduction in dimensionality; equivalence of variational problems; pyramided problems; multidimensional policy space; reliability problem; transportation process; difficult crossing problems.

III. One Dimensional Smoothing and Scheduling Processes: mathematical formulation; functional equations; the caterer problem; inventory problems.

IV. Optimal Search Techniques; unimodal function; Fibonacci numbers; golden mean, zeroes of functions; functional equations; defective coin problem; two coin problem.

V. Dynamic Programing and the Calculus of Variations: isoperimetric problems; necessary, natural boundary, Legendre; Weierstrass, transversality, Erdmann corner conditions; basic nonlinear partial differential, Euler, and Hamilton-Jacobi equations.

VI. Optimal Trajectories.

VII. Multistage Production Processes Utilizing Complexes of Industries.

VIII. Feedback Control Processes.

IX. Computational Results for Feedback Control Processes.

X. Linear Equations and Quadratic Criteria: smoothing problems; deterministic and stochastic cases; adaptive prediction theory.

XI. Markovian Decision Processes: analytic formulation; computational aspects; solution; simulation technique; connection with linear programing.

XII. Numerical Analysis: polynomial approximations; orthogonal polynomials, gaussian quadrature; stability; problems; extensions.
Appendix I. On a Transcendental Curve (O. Gross): the number of inflection points; a necessary condition for convexity.
Appendix II. A New Approach to the Duality Theory of Mathematical Programming (S. Dreyfus and M. Freimer).
Appendix III. A Computational Technique Based on Successive Approximations in Policy Space (S. Dreyfus).
Appendix IV. On a New Functional Transform in Analysis: the Maximum Transform (R. Bellman and W. Karush).
Appendix V. The Rand Johnniac Computer (S. Dreyfus).
Name Index.
Subject Index.

An Appreciation of Systems Analysis
Hitch, Charles

Santa Monica, The Rand Corporation, 1955, Revised, 25 p.
Rand No. P-699.

A condensation of lectures prepared for Air Force audiences and presented to the Operations Research Society of America at the Los Angeles meeting, 15 August 1955.

Introduction.
The Development of Military Systems Analysis: force composition and development decisions; variables; explicit treatment of uncertainty; explicit treatment of uncertainty; explicit treatment of enemy reactions; explicit treatment of time phasing; broadening of criteria.

The Difficulties are in the Problems.

The Positive Side: systems versus nonsystems; analysis versus intuition.

Conclusion.

Army Force Planning Cost Handbook
Directorate of Cost Analysis

Washington, Department of the Army, 1971, 289 p.

"The purpose of the handbook is to provide type forecast unit building block data and a methodology for force costing."

I. Explanatory Notes: introduction; assumptions and limitations; glossary.
II. Basic Planning and Cost Factors: initial investment; annual operating; descriptive data; tables.
III. Force Unit Summary Costs: division force equivalent summary peacetime costs; force unit summary peacetime costs; SRC composition of divisions.
IV. Force Unit Building Block Data.

Aspects of Cost and Utility Analysis in Planning
Bryk, Oliver

McLean, Research Analysis Corporation (Economics and Costing Division), 1965, 9 p.
RAC Paper RAC P-8. AD 622 114.

"In this paper, some aspects of planning in preparation for resource-allocation decisions among alternatives, which are generally made under uncertainty, will be discussed from the pragmatic viewpoint of a practicing analyst. No new theory will be expounded. We will be concerned only with that area of economic analysis in which the inputs are not commensurable with the outputs."

Introduction.
Input-Output Relations.
Quantification
Models and Structure.
Discounted and Time-Phased Costs.
Marginal Utility and Cost.
Marginal Substitution.

Background, Development, and Extension of the Revised Simplex Method, Orchard-Hays, William

Santa Monica, The Rand Corporation, 1954, 61 p.
Rand Memorandum RM-1433.

This paper is a short but comprehensive discussion of the development of the present form of the simplex method.

Foreward.

1. Definitions and Convex Sets: introduction; convex cones as intersections of half-spaces; convex cones as the sum of half-lines; polyhedral cones (equivalence of the definitions); further properties and relationships; simplices and optimality problems.
II. The Simplex Method: prefatory remarks; notation; statement of the linear programming problem; the original simplex method; the development of the simplex method (the revised simplex method, the generalized simplex method, illustrative example, a remark on cycling, the product form of the inverse).
III. Some Results of Computational Experience: introductory remarks; pre-selecting a feasible or near optimal basis; introducing legitimate unit vectors during construction of a model; introducing some (but not all) artificial unit vectors; synthesizing unit vectors from given activities; generalized use of elementary (row) transformations.
IV. Parametric Variations and Post-Optimality Problems: parametric variations; the dual problem; altering the right hand side of a system; altering the cost row; changes within the matrix; the complete dualized system.

References.

A Beginning to Cost-Effectiveness Analysis
Visco, Eugene P.

McLean, Research Analysis Corporation, 1963, 11 p.
Technical Paper RAC-TP-100. AD 422 374.

Abstract: "This short paper describes a method of cost-effectiveness analysis developed to evaluate specific items of Army equipment in mathematical terms as part of the larger problems of optimum allocation of resources. The medium (now "main") battle tank was selected as the leading item on a list of Army equipment chosen for "critically in combat". A linear programming model for the Univac Scientific 1103A computer was set up to solve the problem of maximum combat effectiveness subject to dollar constraints and minimum cost subject to maintaining selected levels of combat effectiveness. Comparative combat effectiveness of US and enemy forces was considered to be the product of ratios of rates of fire, probabilities of hit, and probabilities of kill, given hit. Later, weighting procedures allowed consideration of other factors. The area that gave the greatest difficulty (and that requires the most future research) is that of measures of effectiveness. That difficulty, plus the application of a simplified programming model, qualifies the study's product as illustrative rather than factual."

Foreward.
Abstract.
Introduction.
Effectiveness.
Cost and Effectiveness Relations.
General Considerations.
Figures.

Bibliographical Reference of Accuracy of Cost Information for Decision-Making, Onsi, Mohammed

Syracuse, Syracuse University, 1969, 39 p.
NASA No. N70-21107.

"This bibliography examines the literature related to the accuracy of cost information for decision-making. Listings are alphabetically by author."

I. Introduction.
II. Periodical References.
III. Government Contracts.
IV. Selected NASA Publications.
V. Author Index.

Bibliography on Cost-Benefit Analysis and Planning-Programming-Budgeting Pearman, Elizabeth H.

McLean, Research Analysis Corporation, 1966, 44 p.
AD 650 904.

The citations are arranged by broad subject categories and alphabetically by author within these classifications.

Preface.
Cost-Benefit Analysis: general; defense; health, education, and welfare; public investments; resource development; transportation; urban development.
Planning-Programming-Budgeting.
Sources.

Building a New Force Structure Cost Analysis Model
Bradley, B.D.

Santa Monica, The Rand Corporation, 1965, 20 p.
Rand Memorandum RM-4764-PR. AD 627 611.

Abstract: "A description of a new force structure cost analysis model being developed to advance the concept of force structure analysis and to facilitate its use in Air Force planning studies. The model is designed to incorporate non-weapon support activities and provide means for explicit analysis of their resource requirements. The concepts of the model and their use in the analytical process are discussed, as well as the definitional framework devised for it. This framework provides a two-dimensional description of the Air Force. The method by which the model will accommodate both planner and analyst is considered."

Preface.
Summary.
Text: General; concepts; framework of the model (cost elements, program elements, using the framework); computational structure of the model; a look to the future.

Bureau of the Budget Bulletin to the Heads of Executive Departments and Establishments: Planning-Programming-Budgeting (PPB)
Bureau of the Budget

Washington, Bureau of the Budget (Executive Office of the President), 18 July 1967, 26 p.
BOB Bulletin 68-2.

Guidelines for implementation of the planning-programming-budgeting system to be used by government agencies in establishing priorities and reviewing program alternatives.

1. Purpose.
2. Application of Instructions.
3. Principal Objectives of PPB.
4. Elements of the System: program memoranda; program and financial plan; special studies.
5. Program Structure.
6. Program Memorandum.
7. Multi-Year Program and Financial Plan: presentation of future year data; outputs; costs; reconciliation of program costs to appropriations.
8. Special Studies.
9. Timing for Production of Documents.
10. Illustrative Annual Cycle.
11. Responsibility, Staffing and Training.

Attachment: Program Categories.

The Complete Strategist: Being a Primer on the Theory of Games
Williams, John Davis

New York, McGraw-Hill, 1966, 268 p.

I. Introduction.
II. Two-Strategy Games.
III. Three-Strategy Games.
IV. Four-Strategy Games and Larger Ones.
V. Miscellany.
VI. General Methods of Solving Games.
Appendix. Table of Random Digits. Solutions to Exercises.
Index.

A Computerized Technique to Express Uncertainty in Advance System Cost Estimates Sobel, S.

Bedford, The Mitre Corporation, 1965, 102 p.
Technical Report No. ESD-TR-65-79. AD 624 894.

Abstract: "The technique described presents a method to express uncertainty quantitatively in advanced system cost estimates. In particular, the techniques suggest the employment of subjective probability distributions, which describe the uncertainty in each system element, to determine an approximate distribution for total system cost. A 7090 program has been written to perform the computational operations."

Glossary.
Preface.
I. Introduction: purpose; sources of uncertainty; expressing cost uncertainty; a few early approaches to describe category II uncertainties.
II. Description of the Proposed Technique: general, limitations, inputs provided by the cost analyst; determining uncertainty in total costs; utilization of moments to generate distribution of total costs.
III. Computer Program: introduction; programs I, II, and III.
IV. Usefulness of the Results.
V. Validity of the Results.
VI. Areas of Future Work.
Appendix 1. Dependence among Variables.
Appendix 2. Product of Random Variables.
Appendix 3. Moments for the Sums and Products of Independent Variables.
Appendix 4. Determination of the Parameters for the Approximating Linearly Scaled Beta.
Appendix 5. Illustrative Examples.
Appendix 6. Description of Three 7090 FORTRAN Programs.
Appendix 7. Details of FORTRAN Subroutines.
References.

Concepts and Procedures of Cost Analysis
Large, J.P.

Santa Monica, The Rand Corporation, 1963, 402 p.
Rand Memorandum RM-3589-PR. AD 411 554.

Summary: "This Memorandum presents the basic concepts of cost analysis as well as certain specialized procedures for estimating the cost of particular types of equipment. It is intended to be useful both as a primer for persons unfamiliar with cost-analysis and as a handbook for those already in the field. Thus the various chapters differ considerably in their level of generality. One chapter, for example, explains what an estimating relationship is, while the following one presents a step-by-step illustration of the use of statistical regression analysis to derive an estimating relationship. Similarly, primary mission equipment is treated in a general way in one chapter, and then detailed methods for estimating the cost of certain kinds of primary mission equipment (aircraft and missiles) are presented. Other subjects discussed at some length include total force structure cost analysis, the problems of uncertainty, estimating research and development costs of large launch vehicles, and determining personnel requirements."

Preface.
Summary.
I. Introduction: system definition; use of dollar costs; time phasing; cost categories; an example; total force structure.
II. Total Force Structure Cost Analysis (G. H. Fisher): definition; total force structure cost analysis; use of a cost model; relation to individual system.
III. Cost Analysis of Individual Systems (David Novick & R.L. Petruschell): data requirements (PME and AGE descriptive data, operational and organizational data, manning policy data, in-commission rate data, maintenance concept data, training data); weapon system description - an example; cost categories (R&D, investment, annual operating); investment (installation, equipment, stocks, initial training, miscellaneous); annual operating costs (equipment and installation replacement; maintenace; training; pay and allowances; fuels, lubricants, and propellants; services and miscellaneous); non-direct costs.
IV. An Introduction to Estimating Relationships (R.L. Petruschell): data accumulation; display forms; benefits of ERs; derivation procedure; example.
V. Use of Statistical Regression Analysis in Deriving Estimating Relationships (G.H. Fisher): introduction; statement of the problem; a linear normal regression analysis; a curvilinear analysis: logarithmic regression; a curvilinear analysis:

second degree equation; a multiple regression analysis; appendix A (derivation of the normal equations for a linear normal regression); appendices B, C, D (student problems).

VI. The Probability of Uncertainty (G.H. Fisher): requirements uncertainty; cost estimating uncertainty; proposals for treatment of uncertainty; use of adjustment factors; the summers magic formula; cost sensitivity analysis.

VII. Estimating Research and Development Costs of Large Launch Vehicles (J.W. Noah).

VIII. Estimation of the Requirements for Primary Mission Equipment (R. L. Petruschell): demand for primary mission equipment; time phasing; use of cost-quantity relationships; an example; calculation procedure.

IX. Aircraft Airframe Cost Estimating Techniques (J.M. Carrier & R.W. Smith): introduction; examples.

X. Missle Airframe Cost Estimating Techniques (H.G. Campbell).

XI. Installations (H.F. Harris): estimating methods; example.

XII. Total System Personnel Estimating (R.L. Petruschell): prerequisite; general procedures; breakdown of jobs; personnel estimating relationships; an example; calculation procedure; personnel data sources.

Concepts and Techniques for Summarizing Defense System Costs
Noah, J.W.

Washington, Center for Naval Analyses, 49 p.
SEG RC #1. AD 624 447.

Abstract: "Some techniques used to summarize total costs employed in systems analyses are classified, described, and compared. Their respective advantages and disadvantages are given, and some implications of each are brought out. Five cost-summarizing techniques are selected and distinctions between them are based on common usage. The procedures are termed: five-year system cost, period outlay, net cost, present cost, annual cost. Necessary to their discussion is an understanding of the major types and general content of defense system cost analyses, the concept of remaining value, and the principle that money has time value. A brief section on each of these subjects with appropriate references precedes the discussion of the methods for summarizing costs."

Summary.
Major Types and General Content of Cost Analyses.
Remaining Value.
Time Value.
System Cost Summarizing Techniques.
Some Implications.
References.
Appendix A. Tables: interest table, single payment compound amount factors $(1 + i)^n$; interest table, single payment present cost factor $(1 + i)^{-n}$; declining balance factors, $(1 - i)^n$.
Appendix B. Comparison of Alternative Cost Streams.

Correlation and Regression Techniques
McClosky, John W.

Fort Belvoir, US Army Management School (Operations Research/Systems Analysis Executive Course), 1967, 29 p.
AD 661 836.

"In regression the variable which is being predicted is often referred to as the dependent variable, and the variables used in the predicting are referred to as the independent variables. The initial step in an investigation requires that observations be made on both the dependent and independent variables. Using this data a relationship is established which best describes the trend of the observations between the dependent and independent variables to make a reliable prediction as to what the value of the dependent variable would be if observed."

I. Introduction.
II. Regression in Two Variables.
III. Correlation in Two Variables.
IV. Describing the Data.
V. Spearman's Rank Correlation Coefficient.
VI. Multiple Linear Regression.
VII. The Correlation Matrix.
VIII. Multiple Correlation Coefficients.
IX. Geometrical Considerations.
X. Partial Correlation Coefficients.
Bibliography.

Cost: Analysis and Methodology, Operations Research Series, Volume I. A Report Bibliography

Washington, Defense Documentation Center, 1967, 291 p.
AD 808 900.

"This bibliography was prepared to satisfy recurring requests for searches for cost analysis materials. It represents a comprehensive compilation of unclassified references in the DDC collection that have been catalogued since 1955. References in this collection are concerned with identifying and estimating research and development costs and their associated problems and possible solutions. This broad comprehensive compilation favors cost analysis of systems and yet provides adequate references concerning component, computer programming, and planning costs, along with their associated mathematical concepts and treatments. This is volume 1 of a series, the other parts of which will be as follows:

Vol. III AD 808 901 Cost Effectiveness Analysis

Vol. V AD 808 902 Parametric Identification for Cost Analysis

Preface.
Abstract.
AD Bibliographic References.
Corporate Author/Monitoring Agency Index.
Subject Index.
Personal Author Index.
Contract Index.
Report Number Index.

Cost Analysis for Planning-Programming-Budgeting Cost Benefit Studies
McCullough, J.D.

Arlington, Institute for Defense Analysis, 1967, 31 p.
AD 643 472.

Adapted from a paper prepared for the Financial Management and Planning-Programming-Budgeting Training Center.

I. The Role of Cost-Benefit Analysis.
II. The Role of Cost in Cost-Benefit Analysis.
III. Features of Systems Cost Analysis: end-product orientation; extended time horizon; incremental costing; life cycle costs; dollars as the measure of resources; analytical approach and statistical techniques.
IV. Steps of Cost Analysis: defining the problem; obtaining a specific systems description; collecting data; converting information to a statement of resource requirements; translating to costs (catalog price, specific analog, estimating relationship, expert opinion; learning curve); presenting cost estimates; documenting the analysis.
V. Total Program Cost Analysis: inter-systems analysis; intra-systems analysis; major program studies; total agency studies (incremental costs; total program costs; annual costs; base case; use of program and program element; computer model); time phasing.
Concluding Remarks.
References.

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Cost Analysis Handbook
AMC

Washington, Consultec, 1968, 169 p.
AD 682 069.

"The purpose of this handbook is to provide guidance and instruction for AMC Cost Analysis personnel who have modest experience with the subject of cost analysis and cost estimating and/or who may be unfamiliar with the operations of the Army Materiel Command. To this end, it provides a definitional framework for cost analysis and cost estimating and a description of the organizational framework within which costs are utilized. It is expected that the users of the handbook will be primarily involved in the Administrative-Decision Making Function within AMC, supplying cost analyses and cost estimates for decisions related to organization, equipment, maintenance, and deployment of Army forces."

List of Exhibits.
Foreward.

I. Introduction: purpose and scope; cost analysis and cost estimating; the cost estimating sequence and perspective.
II. AMC Cost Estimating Framework: administrative-decision making function; resource administration function; AMC organizational function; coding structure interfaces.
III. Procedures for Cost Analysis: cost information definition acquisition of cost information; validation procedure; consolidating and structuring information; cost analysis; cost estimating relationships; cost analysis documentation and presentation; cost analysis quality control checklist.
IV. Cost Estimating Techniques: cost estimating relationships; purpose of the estimate; conditioned estimate; translation of estimates into time-phased relationships; validation of cost estimating techniques; specific application of cost estimating in cost analysis.
V. Cost Estimating Procedure: level of estimate detail; cost estimating schedule; sources of cost information; cost sensitivity analysis; validation of estimate; cost estimate change reports; estimate documentation and presentation; summary report.
VI. Organizational Implications: cost analysis responsibilities; basic organizational theory; AMC staff interfaces; conclusion relative to the cost analysis function role in AMC.

Appendix A. Learning curves.
Appendix B. Derivation of Cost Estimating Relationships.
Appendix C. Extract from Interim Report.
Appendix D. Basic Organization Theory.
Appendix E. Glossary.
Appendix F. Abbreviations.
Bibliography.
Index.

Cost Analysis Program
Headquarters, Department of the Army

Washington, Department of the Army, 1970, 6 p.
AR 11-18.

This regulation establishes objectives and assigns responsibilities governing Army-wide cost analyses.

I. Purpose.
II. References.
III. Objectives.
IV. Policy.
V. Definitions and Functions; cost analysis; cost/benefit analysis; cost information system; economic analysis; force structure cost analysis; incremental cost; life cycle cost analysis; sensitivity analysis; validated cost data; weapon system cost analysis.
VI. Responsibilities of the Army Staff.
VII. Responsibilities of Army Commands.
VIII. Responsibilities of Agencies and Services.
IX. Coordination Instructions.

Cost Considerations in Systems Analysis
Fisher, Gene H. (Rand Corporation)

New York, American Elsevier, 1971, 336 p.
Rand Report R-490-ASD.

A report prepared for the Office of the Assistant Secretary of Defense (Systems Analysis) on cost analysis aspects of systems analysis. "A text for the teaching of force planning cost analysis . . . as a subset of systems analysis." The main concern: "major resource allocation decisions in the long-range planning context." A listing of supplementary readings follows each chapter.

I. Introduction.
II. What is Systems Analysis?: definition; analytical process, models; uncertainty (sensitivity, contingency, & a fortiori analyses); time; validity; qualitative supplements; pitfalls; examples of past applications.
III. Concepts of Economic Cost: definition; identification, measure, evaluation; past and future; relevant and irrelevant; external and internal; minimizing and maximizing; comparing alternatives; discounting; macro-cost and micro-cost analysis.
IV. Introduction to Military Cost Analysis: (the output side) major characteristics (emphasis on output-oriented packages of capability; accuracy requirements and possibilities; systematic collection of data and derivation of estimating relationships); fixed budget and fixed effectiveness approaches; examples (intra- and inter-command systems comparisons, force mixes, total force structure cost analysis).
V. The Input Side: types of input; input structures; examples.
VI. Estimating Relationships: types (simple linear forms, step functions, multivariate functions); data problem (format, integration, categories, temporal factors, comparability) and approaches (ad hoc sample surveys, experiments, adjustments to raw data base); derivations and uses; examples.
VII. Cost Models: types (resource requirements submodels, individual system, mission area force mix, total force); examples.
VIII. Special Topics: treatment of uncertainty (supplemental discounting, adjustment factors, special studies, cost sensitivity analysis); time (military context, undiscounted costs, supplemental discount rate, residual value); wartime costs.
IX. Systems Analysis Examples.
X. Summary and Concluding Remarks.
Appendix A: The Opportunity Cost Concept, an Example from the Microeconomic Theory of the Firm.
Appendix B: The Concept of Comparative Advantage.
Appendix C: The Theory of Maximizing Behavior, an Example from the Theory of the Firm.
Author Index.
Subject Index.

Cost-Effectiveness: An Appreciation
Quade, E.S.

Santa Monica, The Rand Corporation, 1965, 6 p.
Rand No. P-3248. AD 623 105.

"This paper attempts to clarify the nature and scope of cost-effectiveness analysis and to point out its proper role as an aid to decision-making. It discusses, in the context of national security problems, the reliability and limitations of such analyses and ways to improve its quality."

Introduction.
Definitions.
The Essence of the Method.
The Limitations.
Analysis is Necessarily Incomplete.
Measures of Effectiveness are Approximate.
No Satisfactory Way to Forecast the Future Exists.
The Virtues.
The Future.
Concluding Remarks.
Bibliography.
Graph; the Structure of Analysis.

Cost-Effectiveness: Estimating Systems Costs
McCullough, J.D.

Bethesda, The Rand Corporation, 1965, 26 p.
Rand No. P-3229. AD 622 023.

The objective is "to discuss the significant features and general procedures involved in systems analysis, directed particularly to the users of cost estimates - either study directors who must direct a team of systems analysts and cost analysts, or systems analysts who must work with cost analysts."

Introduction.
Features of Cost Analysis: end-product orientation; extended time horizon; incremental costing; life cycle costs; dollars as a measure of resources; the analytical approach and the use of statistical techniques.
Steps of Cost Analysis: defining the problem; collecting data; deriving the estimate; presenting the estimate; documenting the analysis.
Concluding Remarks.
Bibliography.

Cost-Effectiveness: Some Trends in Analysis
Quade, E.S.

Santa Monica, The Rand Corporation, 1967, 18 p.
Rand No. P-3529. AD 650-129.

New approaches to cost-effectiveness analysis are being proposed constantly. Most are primarily mathematical in nature, but a few are "directed toward a better treatment of those aspects of its problems that cannot be handled by purely quantitative methods." This paper notes three trends involving, respectively: computers, mathematics, and the direct use of expertise. The last is described in some detail, especially the Delphi technique and its extensions.

Cost-Effectiveness Analyses
O'Neill, Daniel D.

Aberdeen Proving Ground, US Army Ballistic Research Laboratories, 1966, 48 p., BRL Report No. 1315. AD 635 168.

Abstract: "Methods for the conduct of cost-effectiveness studies and formats for the presentation of results are presented."

I. Introduction
II. Discussion: general; threat; target acquisition; effectiveness; attrition; weapon-target allocations.
III. Summary.
References.
Appendix. Cost Effectiveness Analysis - An Outline.

Cost-Effectiveness Analysis: New Approaches in Decision-Making
Goldman, Thomas A., Editor

New York, Frederick A. Praeger, 1967, 231 p.

A collection of essays sponsored by the Washington Operations Council and one of the series in the Praeger Studies in US Economic and Social Development. The papers included are those given at a symposium in Washington.

I. Introduction and Overview (Edward S. Quade): definitions; the essence of the method; the virtues; the limitations; the present; the future; notes.
II. Measures of Effectiveness (William A. Niskanen): choosing measures of effectiveness; the relation of defense objectives to national objectives; defense objectives by area and level of conflict; measures of effectiveness for defense objectives; notes.
III. The Choice of Analytic Techniques (Alfred Blumstein): kinds of models; relationship of models to defense systems; uses of the model; considerations in model selection.
IV. The Use of Cost Estimates (Harry P. Hatry): types of cost-effectiveness analysis; the basic input data; future system cost estimating (CERs); treatment of cost uncertainty; problems of cost analyst-system analyst coordination; documentation; the choice of the cost measure; selected bibliography.
V. Estimating Systems Costs (James D. McCullough): features of cost analysis; steps of cost analysis; selected bibliography.
VI. Armed Forces' Use of Cost-Effectiveness Analysis (LTC R.S. Berg): the operational requirement; technical trade-offs; system costs; analysis of design characteristics; intersystem comparisons.
VII. Defense Contractor Use of Cost-Effectiveness Analysis (Eugene R. Brussell).
VIII. An Analysis of Tactical Air Systems (Murray Kamrass and Joseph A. Navarro).
IX. Cost-Effectiveness Analysis for Government Domestic Programs (William M. Capron).
X. Cost-Effectiveness Analysis for the "War on Poverty" (Stanley M. Besen, Alan E. Fechter, and Anthony C. Fisher).
XI. An Analysis of Metropolitan Transportation Systems (John F. Kain)
XII. The Structure of Incentive Contracts (Collim W. Scarborough).
XIII. The Structure of Military Industrial Funds (Martin J. Bailey).

Cost-Effectiveness Optimization (Summary, Conclusions, Recommendations) Task Group IV

Andrews Air Force Base, Headquarters Air Force Systems Command, 1965, Volume I, 18 p.
AFSC-TR-65-4. AD 458 595.

Abstract: "The underlying principles associated with cost-effectiveness analysis are discussed. The rationale, purpose, methodology required, and nature of the results that can be obtained by means of the analysis are presented in summary form. Illustrations of the type of input data required and the logic associated with its applications are provided."

Foreword.
Abstract.
I. Introduction.
II. Considerations in Cost-Effectiveness Analysis.
III. Conclusions and Recommendations.

Cost-Effectiveness Optimization (Tasks and Analysis Methodology) Task Group IV.

Andrews Air Force Base, Headquarters Air Force Systems Command, 1965, Volume II, 160 p.
AFSC-TR-65-4. AD 462 398.

Abstract: "This report discusses the philosophy of cost-effectiveness and techniques for trade-off and optimization studies. It lists and discusses twelve tasks necessary to perform a cost-effectiveness analysis. A methodology is outlined for identifying and standardizing cost and effectiveness factors. Descriptive analytical models for cost-effectiveness are provided, including discussion of their sensitivity and validity. One section defines and discusses risk and uncertainty and their effect on the decision making process. Included is an extensive bibliography on cost effectiveness."

I. Introduction: general concepts; levels of cost-effectiveness analyses.
II. Discussion of Tasks and Factors in Cost-Effectiveness Analysis.
III. Inputs and Relationships: define program objectives, mission, and constraints; criteria selection; identify and synthesize alternatives; identify variables.
IV. Cost-Effectiveness Models, Concepts, Validation and Sensitivity: mathematical formulation of effectiveness and costs; statement of the optimization problem; some possible models; model validity and sensitivity; conclusions.
V. Development of Cost Inputs to Cost Effectiveness Models: objectives; theory and practice; a general cost methodology; cost estimating relationships; developing CERs; AFSC format for recording CERs; the future development of costing.
VI. Effectiveness Factors for Cost Effectiveness Models: introduction; effectiveness factors; availability; survivability; reliability; penetrability; lethality; other considerations.
VII. Risk and Uncertainty in Cost Effectiveness: risk, uncertainty; use of risk and uncertainty; examples of risk and uncertainty considerations; summary.
VIII. Evaluation of Alternatives and Optimization: evaluation of individual improvement alternatives; ranking of alternatives; determination of optimum point; model outputs for decision support.
IX. Interpretation of Results, Sensitivity, and Limitations.
X. Conclusions and Recommendations: discussion of accomplishments and implementation; conclusions; recommendations.
Appendix I. Compilation of Abstracts from Examples of Volume III of Task Group IV Final Report.
Appendix II. Example of Cost Effectiveness Analysis for the Definition Phase.
References.
Bibliography.

Cost Estimates as Predictors of Actual Weapon Costs: A Study of Major Hardware Articles
Summers, Robert

Santa Monica, The Rand Corporation, 1965, 72 p.
Rand Memorandum RM-3061-PR (Abridged). AD 612 723.

Summary: "This is a statistical study of military cost estimates aimed at decreasing the uncertainties about their interpretation and use. Based on a sample of 68 cost estimates of major hardware articles in 22 systems, it assesses their accuracy as predictors of actual cost. Section 1 describes the aims and scope of the study and presents a detailed summary of methods and results. Section 2 presents the statistical analysis of estimating errors, and Section 3 shows quantitatively that the observed errors can significantly affect the choice between alternative systems."

Preface.
Summary.
I. Introduction: aims and scope of the study; outline of methods and results.
II. An Analysis of Cost-Estimate Chronologies: errors in nonmilitary cost-estimating; model of the development process; preliminary description of the data; raw measure of accuracy of estimates; adjusted measure of accuracy of estimates; model of the development process; bivariate analysis of $\underline{t}$ and $\underline{A}$; the variables; regression results; hypothesis testing; data problems (errors in measurement, randomness); estimation of independent variables; conclusions about learning during development; cost changes of major article components; the "changing-configuration" hypothesis; conscious underbidding of contractors.
III. The Consequences of Cost-Estimate Inaccuracies: cost inaccuracies versus other uncertainties; system choice and inaccurate cost estimates: bias; variance; implications for cost-effectiveness studies; implications for force-structure projections.
Appendix. Examination of Three Cost-Effectiveness Studies.

Cost Factoring System for Force Readiness Projection (COFACTS)
Wilbourn, C.R.; R.M. Burbridge; D. Cohen; K.L. Lehmann; M.L. Patterson; J.D.H. Sidley.

Washington, Planning Research Corporation, 1968, 180 p.
PRC R-1145. AD 860 253.

Abstract: "This report describes the analyses and development of the Cost Factoring System for Force Readiness Projection (COFACTS). Three mathematical models were developed: a force readiness measurement model, which has the unique feature of utilizing cost as a criterion of readiness capability; a budget model, which computes force related costs by budget program; and a cost impact model which calculates cost implications of increasing or decreasing force readiness levels. The computer system, which incorporates these models, the resultant reports, and their applications to the various levels of the force planning process are also presented."

Summary: introduction; system applications; measurement of projected force readiness; budget model; cost impact of readiness changes; COFACTS computer system; conclusions and recommendations.

I. Introduction: the problem; status of the problem's solution; background orientation; the COFACTS system; beyond COFACTS; organization of the report.

II. Systems Application: introduction; the COFACTS resource readiness summary; the COFACTS force budget outputs; cost impact outputs; annex outputs.

III. Measurement of Projected Force Readiness: general; major assumptions; general methodology systems flow; selection of readiness measurement categories; general readiness cost ratios; individual subcategory cost factor development; aggregate readiness level determination.

IV. Budget Model: recurring costs; replacement training; initial costs; the reserve/national guard model.

V. Cost Impact of Readiness Changes: introduction; methodology.

VI. COFACTS Computer System: general; the preprocessor; SACS; PAMSIM; P20A/224T; the COFFIN file; the model; implementation procedure; current implementation status.

VII. Conclusions and Recommendations.

Appendix A. Example of Total Cost Implication of a PEMA Budget Cut.

Appendix B. Cost Models.

Appendix C. Glossary.

Appendix D. Previous Studies of Army Force and Force/Budget Readiness.

A Cost Model for Use in Cost-Effectiveness Analyses of Dissimilar Weapon Systems Westerman, ean F. and Ronald F. Mathias

Aberdeen Proving Ground, Army Materiel Command (Ballistic Research Laboratories), 1964, 24 p.
BRL MR 1602. AD 453 842.

Abstract: "A model is presented for the determination of system costs in cost-effectiveness studies of dissimilar weapon systems. The assumptions employed are listed so that an adaptation of the model may be made to fulfill individual study requirements."

I. Introduction.
II. General Discussion and Assumptions.
III. Cost Model.
IV. Annex, Terms, and Definitions.

Cost Performance Report
Office of the Assistant Secretary of Defense (Comptroller)

Washington, Department of Defense, 1970, 13 p.
DODI 7000.8.

References.
I. Purpose.
II. Applicability.
III. Scope.
IV. Objective.
V. Responsibilities.
VI. Implementation and Effective Date.
Enclosure 1. DD Form 1664, Data Description Item.
Attachment 1. CPR - Work Breakdown Structure.
Attachment 2. CPR - Functional Categories.
Attachment 3. CPR - Manpower Loading.
Attachment 4. CPR - Problem Analysis.

Cost-Quantity Calculator
Noah, J.W. and R.W. Smith

Santa Monica, The Rand Corporation, 1962, 27 p.
Rand Memorandum RM-2786. AD 279 346.

Summary: "The Cost-Quantity Calculator at the back of the book is designed to provide cost analysts with a tool for construction and interpretation of those cost-quantity relationships usually referred to as learning, progress, or improvement curves. The two most common of these curves are treated here: the Log-linear cumulative average curve and the log-linear individual unit curve. A definition of these curves is given in the text, along with an explanation of their differences and interactions. For practical application of these relationships, tables of slope-quantity factors are provided."

Preface.
Summary.
I. Introduction.
II. The Log-Linear Cumulative Average Curve.
III. The Log-Linear Individual Unit Curve.
IV. Slope.
V. Asymptotes.
VI. Examples Illustrating Use of Tables.
The Calculator.

Cost Research Symposium (1967)
Proceedings of the Second Annual DOD Cost Research Symposium

Washington, Directorate of Budget, Department of the Air Force, 1967, Vol. 1, 300 p.
AD 820 274.

Volume II contains documents classified through confidential, while Volume III contains the one report classified Secret.

Introductory Remarks (LGEN Jack G. Merrell, Hon. Norman S. Paul, Dr. Alain Enthoven).
Comparison of Four Approaches in Developing Estimating Relationships for POL Consumption (Irwin L. Seidel and Jeffrey Williams).
The Measurement of Army Aircraft Flying Hour Costs (MAJ Paul P. Mehler).
Cost of Aircraft Depot Maintenance: the F-4 Case (Dr. Seymour Fiekowsky and Arnold Schwartz).
Prediction of Life-Time Equipment-Related Repair Parts Support Cost for Naval Ships (C.L. Karr, Jr.).
An Expansion of the Improvement Curve to Allow Its Use with a Common/Peculiar Production Mix (William W. Baker and Jules Silver).
Estimating Aircraft Flyaway Costs by Adjusting the Conventional Learning Curve (William W. Vardeman and Culbert Laney).
Estimating Weapon System Development Costs (Richard J. Trainor).
The Army Divisional Cost Model (T. Arthur Smith).
Off-Loading Military Supplies from Cargo Ships in Unimproved Port Areas (A.S. Childers).
Aircraft Systems Cost and Force Structure Automated Model (Ronald S. Feldman).
A Cost/Effectiveness Formula for Man/Machine Function Allocations (Dr. Joe E. Willis and Marilee N. Connelly).
Variable Costs of Army Equipment Operation (John O'Flaherty and R. O'Rorke).
Cost Uncertainty Analysis (William Leathwood and Frank J. Husic).
Closing Remarks (Saul Hoch, Dr. Harold Asher).
Attendees.

Cost Research Symposium (1968)
Proceedings of the Third Annual DOD Cost Research Symposium

Washington, Office of the Comptroller of the Army, 1968, Vol. 1, 230 p.
AD 833 207.

Volume 2 contains classified papers through Secret.

Introductory Remarks: LTG Frank J. Sackton, Hon. Eugene M. Becker, Hon. Alain Enthoven.

A. Estimates of Aircraft Characteristics with Some Implications for Cost Analysis (Donald M. Fisk).
B. The Development and Use of a Computer-Implemented Time-Phased Model (CPT Charles H. Wells).
C. A System Concept for Determining Navy Stock Fund Budgeting Requirements (Charles E. Emberger).
D. Aircraft Maintenance Cost Research, KC-135 (Jean Mullery).
E. Measuring the Impact of Reliability and Maintainability on Combat O&M Costs (Robert Byer).
F. Personnel Cost Research for Early Man/Machine Design Trade-Offs (Marilee Connelly).
G. Missile-Automated Resources Management Operating Technique (MARMOT) (CPT Robert G. Smith).
H. System Cost and Operational Resource Evaluater (SCORE) (Solomon Getz).
I. Development of Automated Methodologies for Weapon System Life Cycle Costing (Frederick M. Chakour).
J. Mathematical Method for Pricing Learning Curve Changes (Paul M. James).
K. The Maintenance Aspects of the Life Cycle Cost of Electronic Systems (Hugh W. McNeil).
L. System Effectiveness and Life Cycle Costing Analysis for the Fast Deployment Logistic Ship (CPT B. D. Lamar).
M. Life Cycle Costing in System Acquisition (Perkins C. Pedrick).
N. An Inventory Model for Reparable Spares: the F-4 Case (Marshall Rose).
O. Closing Remarks: Dr. Donald B. Rice.
P. Closing Remarks: Robert C. K. Valtz.
Q. Attendees.

Cost Research Symposium (1969)
Proceedings of the Fourth Annual DOD Cost Research Symposium

Washington, Office of the Comptroller of the Navy, 1969, 358 p.
AD 854 663.

Welcome to the Symposium (RADM Eli T. Reich).
Introductory Remarks (VADM Jackson D. Arnold).
Keynote Address (Hon. Charles A. Bowsher).
OSD Welcome (Hon. Ivan Selin).
Air Force Welcome (Hon. Thomas H. Nielson).
Army Welcome (LTG Frank J. Sackton).
Concluding Remarks (Dr. Donald B. Rice).

Historical Simulation (Charles A. Graver).
A Three Dimensional Cost Model for Analyzing or Estimating Director Labor Requirements (MAJ Gordon J. Johnson).
The Marine Corps Cost Model (DRS. Richard A. Jenner & Joseph H. Augusta).
Cost Estimating Methodology for Ground Combat Surveillance Equipment (Steve Klein).
An Example of Relationships Between the Uses and the Development of CERs (John E. Buchanan & Ronald A. Chiodo.
First Order Approximation of Cost Variance and its Value (George T. Patton).
An Approach to Quantitative Measurement of Advances in State-of-the-Art. (Dr. Edward N. Dodson).
The Cost Implications of New Technology (J.D.S. Gibson).
Study of Trends and Escalation of Costs (MAJ Horace Schow, II).
Cost Analysis in Support of Contract Negotiations (T. Arthur Smith).
An Approach to Estimating Costs of Maintenance Material and Personnel for Naval Airborne Weapon System (Paul Casuk).
Pilot Training Study (W.E. Moos).
Selecting the Proper Cost Variables for a Cost-Effectiveness Study (Seymour Horowitz).
Missile Cost Model (John Johnson).
SAMSO Unmanned Spacecraft Cost Model (G.B. Guarino).
Airmobile and Infantry Division Operating Costs in Vietnam (Robert Calderone).
Use of ADP Sources in Collecting Operating Costs (LTC Errol Hayes).
Attendees.

Cost Research Symposium (1970)
Proceedings of the Fifth Annual DOD Cost Research Symposium

Washington, Office of the Assistant Secretary of Defense (Systems Analysis), 1970, Volume 1, 320 p. and Volume 2, 266 p.
AD 875 742.

National Bureau of Standards Welcome (Dr. Lewis W. Branscomb).
Keynote Address (Hon. Gardiner L. Tucker).
Army Welcome (Hon. Eugene M. Becker).
Navy Welcome (Hon. Charles A. Bowsher).
Air Force Welcome (Hon. Spencer J. Schedler).
Discussion of New PPBS Procedures (C.G. Nuckols).

A. Selected Acquisition Reports: Role of the Selected Acquisition Report in Management and Cost Analysis (T. Arthur Smith).
B. Operations Costs:
   An Analysis of Base Operating Support Costs (CPT Robert C. Owens).
   Depot Maintenance Cost Estimating Relationships for Fighter Aircraft (Robert Boulais).
   Operating Costs Associated with REDCON Improvement - An Historical Example (LT Edward B. Doherty).
   Methodology for Determining Aviation Spare Costs per Flying Hours (V. Badia).
   An Analysis of Operating Costs for Selected Missle Units in USAREUR FY 1968 (LTC Everett L. Alvey).
C. Analysis of Investment Alternatives:
   Economic Replacement Analysis and Cost Uncertainty (LTC John Knubal).
   The Impact of Discounting, Inflation, and Residual Value on Life Cycle Costs of Weapon System Acquisition (MAJ John D. Johnston).
   Measuring Price and Productivity Change in the Aircraft Industry (J.A. DeRossi).
D. Cost Analysis Education Programs: Presentation on course sponsored by Dr. David Ameen.
E. Logistics Costs:
   Force Costing and Support Planning (Dr. Bernard Rostker).
   Aircraft Rework Cost-Benefit Model (Dr. Marshall Rose).
   Project ABLE - Acquisitions Based on Considerations of Logistics Effects (Irving Katz).
F. Weapon System Acquisition Process:
   Estimating Learning Curve Cost Factors (Walter C. Hartung).
   Time-Cost-Risk Trade-Offs in Development Programs (Edward Dodson).
   Ridge Analysis: An Improved Procedure for Developing Cost Estimating Relationships (Henry Eskew).
G. Role of Force Costing in Force Planning:
   Force Planning Cost Information System (Peter Salomone).

Force Cost Assessor (J.E. Koletar, Jr.).
Time-Sharing - Breakthrough in Military Staff Procedures (MAJ John R. Alexander, Jr.).
The Electrical FYDP (Dr. Christopher Snyder).

H. Equipment Costing:
The FAMECE Study, Costing the Phase-in of a Family of Military Engineer Construction Equipment (MAJ M.F. Higgins).
A Cost Model for Semiactive Radar Guidance and Control Sections of Air Defense Missiles (Dr. C.D. Billings).
Methodological Problems in Estimating Costs of Shipbuilding Programs and Some Proposed Selections (Prof. Henry Solomon).
Ship Cost Estimating (G.H. Main and J.A. Fetchtio).

J. Manpower Costing:
Personnel/Manpower Life Cycle Built Cost Models (CDR Thomas J. Sullivan).
Empirically Estimating Pilot Training Cost Functions (CPT G.M. Kipnis).
A Mathematical Approach to Estimating Training Requirements (George Travers).
Development and Application of a Total Ship Simulation Model (M.A. Schwartz).

Symposium Wrap-Up (Milton A. Margolis and Dr. Donald B. Rice).

Costing Methodology Handbook
Directorate of Cost Analysis, Comptroller of the Army

Washington, Department of the Army, 1971, 179 p.
AD 884 835L.

Published (in conjunction with a revised AR 37-18) in response to a need expressed in the Weapon System Acquisition Improvement Program to provide a vehicle for developing a standard cost methodology. Objectives: (a) to provide a better understanding of the cost estimating/analysis process, (b) to promote standardization in cost analyses, (c) to contribute to a better cost analysis capability in the Army, consistent with the objectives of the Army Cost Analysis Program (Cf. AR 11-18). Part 1: the process of cost estimating (chapters 1-7); Part 2: other considerations (chapters 8-10).

I. The Life Cycle and Decision Points: concept formulation; contract definition; development and production; operations and disposal.
II. Preliminary Guidance.
III. System Description and Information Search: Five Year Defense Program; Army Materiel Plan; Army Force Planning Cost Handbook; selected acquisition reports; contractor reports and financial records; Weapon System Cost Data Handbook; Development Concept Paper; Area Coordination Paper; Materiel Need; prior studies.
IV. Techniques of Costing: parametric cost estimating (cost/parameter relationships, scatter diagrams, regression models, least-squares estimating, measuring errors, correlation analyses, other regression techniques, learning curves); estimating by analogy; industrial engineering approach; expert judgment; program stretchouts.
V. Measures of Estimate Validity: uncertainty and risk (techniques, examples); sensitivity analysis.
VI. Economic Considerations: economic analyses; time-phasing; inflation; constant dollars; current year dollars; present value; annex 1 (general instructions for inclusion of price escalation in certain cost estimates for research and development, procurement, and construction); annex 2 (instructions for calculations of price escalation in the selected acquisition report).
VII. Presentation of the Estimate: general format and instructions for use; US Army Management School Operations Research/Systems Analysis Executive Course - Check List, Briefing Techniques.
VIII. Cost Growth: definition, categories.
IX. Cost Effectiveness.
X. A New Technique to Analyze R&D Estimates: STECPLOT: problem, technique, explanation, example, qualifications and extensions.
Appendix A. Modeling and Simulation: types (iconic, analog, symbolic); principle types of cost models; design and use of weapon system cost model.
Appendix B. References.
Appendix C. Glossary.

Costs and Benefits in Mathematical Programming
Manne, A.S.

Santa Monica, The Rand Corporation, 1956, 14 p.
Rand Memorandum RM-1785.

Summary: "In cooperation with members of the US Military Air Transport Service (MATS), the author recently engaged in an attempt to determine whether MATS airlift planning could be improved by the substitution of linear programing methods for trial-and-error rule-of-thumb methods. The experiment, described in some detail in the paper, was not successful, for the following reasons. The gains were not spectacular, being on the order of two or three percent in terms of the potential increase in useful airlift from the existing resources, and on the order of one day in fourteen in terms of reduction of the length of the planning cycle. The costs promised to be rather high, because to realize the potential gains it would be necessary to have a guarantee of immediate access at unpredictable times to an expensive electronic computing machine. Above all, the lack of mathematical training among the middle management group makes it far easier for an organization such as MATS to accommodate itself to trial-and-error methods rather than to linear programming models."

I. Introduction.
II. Background of the Study.
III. The Linear Programming Model.
IV. Variants upon the Standard Linear Programming Model.
V. Conclusions from One Experiment.

Costs of Operation and Maintenance Activities (Army): Techniques for Analysis and Estimation
Phillips, John G.

McLean, Research Analysis Corporation, 1967, 77 p.
Technical Paper RAC-TP-242. AD 811 500.

The research in this paper develops "a method for determining the cost impact of proposed force changes on the operation and maintenance, Army (OMA) appropriation activities. A study of the Army's financial accounting system structure and budget data has been made to form a method that will determine those OMA activities that depend on force changes. For these activities illustrative cost-estimating relations (CERs) are developed."

Foreward.
Summary: Problem; facts; discussion; conclusions.
Abbreviations.
I. Introduction: purpose; limitations of the study.
II. Method for the Determination of Force-Dependent OMA Activities and Their Cost: the classification process; cost estimating relations.
III. Cost Estimation and the Development of OMA CERs: introduction; summary of force-dependent CERs; operating forces, BP 2000; training activities, BP 2100; central supply activities, BP 2200; major overhaul and maintenance of materiel, BP 2300; medical activities, BP 2400; Army-wide activities, BP 2500; operation and maintenance of facilities, BP 9000.
Appendix A. Supporting Data for Development of CERs.
Appendix B. Reference Data, by Budget Program.
References.
Abstract.

Curves: a Five-Function Curve-Fitting Computer Program
Boren, H.E.

Santa, Monica, The Rand Corporation, 1968, 83 p.
Rand Memorandum RM-5762-PR. AD 680-762.

Summary: "This Memorandum describes a FORTRAN-IV curve-fitting computer program that has been developed within the Rand Cost Analysis Department. The program makes least-squares determinations of the parameters of any of five mathematical functions selected by the user, given a set of observations on the dependent and independent variables of interest. The functions available in the program are the line, parabola, power, asymptotic-power, and exponential. Up to three independent variables may be used for the line and power functions. Also, the Y-intercept may be specified for the line, parabola, or asymptotic-power function. A discussion of the characteristics of the functions is presented in Section I, including an examination of those nonlinear functions that require special methods for solution. Also included is a brief discussion of the statistics used in the program. Specific details on the operation of the program are presented in Section II. This section also treats the options available to the user. Program outputs are discussed in Section III. For the benefit of the reader, sample outputs from two runs are shown."

Preface.
Summary.
List of Figures.
List of Tables.
1. Introduction: program description; function types; function characteristics; nonlinear-least-squares solutions; statistical considerations.
II. Input Procedures: title card; order card; format card; scale card; data cards; blank card; end card; summary.
III. Program Outputs.
Appendix A. Nonlinear-Least-Squares Considerations.
Appendix B. Least-Squares Solution for Asymptotic-Power Function.
Appendix C. Listing of Curves FORTRAN-IV Computer Program.

Decision Analysis: Introductory Lectures on Choices Under Uncertainty
Raiffa, Howard

Reading, Addison-Wesley, 1970, 310 p.

This approach prescribes how an individual who is faced with a problem of choice under uncertainty should go about choosing a course of action that is consistent with his personal basic judgments and preferences.

Introduction.
I. Your Basic Problem: statement; variations.
II. Analysis of Your Basic Problem: data; expected monetary value; analysis of the no-experiment alternatives; the decision flow diagram; probability assessments at chance forks; averaging out and folding back; expected value of perfect information and opportunity loss.
III. Uncertain Payoff and Biased Measurements: sampling costs; value of information.
IV. Utility Theory: use of CMEs in analysis; lotteries; substitutability; the indifference function for money; transitivity; the maximization of expected utility; decreasing risk aversion; risk control.
V. Use of Judgmental Probability: objective vagueness; calibration of subjective vagueness; a consistency property for judgmental probability; the additivity of judgmental P*-measure; the analysis of the e_0-branch; the reduction of a general lottery; the revision of judgmental probabilities.
VI. The Normal Form of Analysis: strategies; randomized strategies; choice; modification of a nonEMV'er; indifference curve analysis; the principle of substitution for strategies; choice of weights.
VII. More on the Economics of Sampling.
VIII. Risk Sharing and Group Decisions.
IX. The Art of Implementation and General Critique: the multi-attribute problem; assessments of several uncertain quantities.
X. Further Perspectives and a Guide to the Literature.
Index.
The Data of Your Basic Problem.

Decisionmaking Among Multiple-Attribute Alternatives: a Survey and Consolidated Approach
MacCrimmon, K.R.

Santa Monica, The Rand Corporation, 1968, 63 p.
Rand Memorandum RM-4823-ARPA. AD 681 005.

Summary: "Various methods have been proposed to help the decision-maker with multiple-attribute decisionmaking. These range from techniques which consider all attributes at once to those which consider just single attributes, or proceed sequentially over single attributes. This memorandum critically reviews the assumptions underlying each approach and examines its information requirements. In addition, each method is described both in a general way and using a formal, abstract mathematical representation. Two examples, the choice of a weapon system and of a space suit, are used to illustrate the discussion."

Preface.
Summary.
I. Introduction: the decisionmaking process (goals, complexity, choosing among alternatives with many attributes); scope and organization of the memorandum.
II. Multiple-Attribute Decisions: attributes, goals, criteria, and dimensions; a military systems example; symbolic representation.
III. Existing Approaches to Multiple-Attribute Decisionmaking: full dimensionality (dominance, satisfying); single dimensionality (maximin, maximax, lexicography, additive weighting, effectiveness index, utility theory); intermediate dimensionality (trade-offs, non-metric scaling, summary of procedures).
IV. Extensions and Combinations of Procedures for Multiple-Attribute Decision-Making: uncertainty in attribute values; a subsystems example; eclectic approaches to the multiple-attribute problem (combinations of approaches, current uses of multiple-attribute methods).
Bibliography.

Decision-Making for Defense
Hitch, Charles J.

Berkley, University of California, 1965, 83 p.

"The first series of Garther lectures. The first lectures trace the evolution of the defense problem; the second describes the purpose and function of the 'programming' system installed in 1961. The third describes the efforts to apply the techniques of operations research or systems analysis to the problem of defense decision-making, particularly with regard to the choice of weapon systems and the allocation of resources among alternative forces and programs. The final lecture attempts to evaluate these innovations, to discuss the unresolved problems in their application, and to assess their place in the future."

I. 1789-1960
II. Planning-Programming-Budgeting
III. Cost-Effectiveness
IV. Retrospect and Prospect
Notes.

Defense Management
Enke, Stephen

Englewood Cliffs, Prentice-Hall, 1967, 385 p.

This book appraises and describes various aspects of cost-benefit analysis of the kind now widely practiced within the Department of Defense. Part 1: Pentagon decision making (chapters 1-5); Part 2: cost effectiveness applications (chapters 6-14); Part 3: special defense problems (chapters 15-20).

I. The Defense Resource Allocation Process (William A. Niskanen).
II. The Annual Cycle: Planning-Programming-Budgeting (Robert N. Grosse and Arnold Proschan).
III. Costing of Systems (Norman V. Breckner and Joseph W. Noah).
IV. Remaining Difficulties in Program Budgeting (Roland N. McKean).
V. Cost Effectiveness of Cost Effectiveness (Armen A. Alchian).
VI. The Changing Environment for Systems Analysis (James R. Schlesinger).
VII. Central War Alternatives (R.H. McMahan, Jr. and D.H. Taylor).
VIII. New Perspective in Civil Defense (Herman Kahn and Anthony J. Weiner).
IX. Mobility-Airlift, Sealift, and Prepositioning (Richard B. Rainey, Jr.).
X. Maintenance (John J. McCall).
XI. Procurement and Management of Spares (Harrison S. Campbell).
XII. Incentive Contracts (Frederick T. Moore).
XIII. Land Utilization for Defense (Jora R. Minasian).
XIV. Military Manpower Utilization (Harry J. Gilman).
XV. Research and Development (T.K. Glennan, Jr.).
XVI. Defense Impacts on International Payments (Rolf Piekarz).
XVII. Defense Expenditures and the Domestic Economy (Murray L. Weidenbaum).
XVIII. Defense Decentralization Through Internal Prices (Martin J. Bailey).
XIX. NATO Defense Planning: the Political and Bureaucratic Constraints (A.W. Marshall).
XX. Military Assistance Programs (Charles Wolf, Jr.).

Defense Planning and Organization
Enthoven, Alain and Henry Rowen

Santa Monica, The Rand Corporation, 1959, 78 p.
Rand No. P-1640.

This is an exploratory essay on the organization of the Department of Defense, written expressly for an audience of professional economists (and using, therefore, the technical language of formal economic theory). The paper covers three topics: (1) the shortcomings of the present organization, (2) the general question of intelligibility of defense allocation problems, and (3) some implications of the principles discussed and a few practical suggestions.

Prefatory Note.
I. Introduction.
II. The Defense Economy: some views on defense allocation; conflict over budget level and the efficiency of allocation; budget structure; organization structure and decentralization; the lack of permanent staff.
III. Some Theoretical Aspects of Defense Organization: Which criteria? Whose criteria?; the multiplicity of criteria; interactions; the significance of game aspects; the power and limits of analysis.
IV. Some Suggestions for Improving Defense Organization: the role of the Secretary of Defense; budgeting for missions and weapon systems; decentralization through the use of budgets and prices; the defense reorganization of 1958.
Footnotes.

Definitions of Expenses and Investment Costs
Office of the Assistant Secretary of Defense (Comptroller)

Washington, Department of Defense, 1966, 10 p.
DODI 7040.5.

This instruction sets forth criteria and definitions to be used in (a) specifying the financial contents of the program elements in the Five Year Defense Program, (b) defining the financial contents of those accounts that make up the Defense budget, and (c) defining the financial contents of the accounts that comprise the Department of Defense management accounting system.

I. Purpose.
II. Applicability.
III. Basic Distinction Between Expenses and Investment Costs.
IV. Expenses.
V. Investment Costs.
VI. Conditional Cases.
VII. Implementation and Effective Date.
Enclosure 1. Investment Cost Decision Diagram.
Enclosure 2. Special Guidance Concerning Real Property.

Derivation of Estimating Relationships: an Illustrative Example
Fisher, G.H.

Santa Monica, The Rand Corporation, 1962, 83 p.
Rand Memorandum, RM-3366-PR.

This memorandum was prepared for a course in military systems cost analysis concepts and techniques, offered by the Air Force Systems Command. It presents illustrative examples of how statistical regression analysis may be used to derive estimating relationships from historical data. Examples of simple linear regression, logarithmic linear regression, second degree regression, and multiple linear regression analyses are presented and discussed.

Preface.
Summary.
I. Introduction.
II. Statement of the Problem.
III. Linear Normal Regression Analysis of Initial Tooling Cost as a Function of Airframe Weight.
IV. A Curvilinear Analysis: Logarithmic Regression.
V. A Curvilinear Analysis: Second Degree Equation.
VI. A Multiple Regression Analysis.
Appendix A. Derivation of the Normal Equations for a Linear Normal Regression.
Appendix B. Student Problem in Simple Linear Regression Analysis.
Appendix C. Student Problem in Curvilinear Regression Analysis.
Appendix D. Student Problem in Multiple Regression Analysis.

The Development and Application of a Procedure for Estimating the Economic Life of Weapons Systems
Eastman, Samuel Ewer and William K. Scheirer

Washington, Department of the Army (Directorate of Cost Analysis, Comptroller of the Army), 1970, 38 p. AD 711 115.

"The research work herein was undertaken to assist in the implementation of Army Regulation No. 37-13, 'Financial Administration, Economic Analysis of Proposed Army Investments.' . . . The approach to the development and application of a procedure for estimating the economic life of weapons systems has been threefold. Our first task [illegible] what was good practice in determining economic [illegible] the economic life of [illegible] Army equipment using a [illegible] data.

I. Summary and Conclusions.
II. Introduction.
III. Determination of Useful Life by the US Treasury. Applicability to military weapons systems; the economic life of military weapons systems determined from technical change.
IV. Definitions of Economic Life from Economic Theory.
V. Applications of the Cost Minimization (with Replacement).
Technical Appendix: Cost Minimization Model; Parts Cost Functions and Odometer Settings; Expected Depot Overhaul Costs.
References.

Best Available Copy

Development Cost Estimating Survey
Task 3

Cambridge, Management Systems Corporation, 1963, 124 p.
AD 408 987.

This report documents a survey of development cost estimating techniques and sources of pertinent data on past weapon systems. It catalogues and codifies most of the valuable information on this subject and outlines the sources of appropriate historical data. In addition, the survey provides a basis for defining the analytical and data collection program to follow.

I. Summary: objectives, results.
II. Conclusions and Recommendations.
III. Discussion: general; historical data sources; cost-estimating techniques; cost estimating relationships; approach to future data analysis.
Appendix 1. Bibliography.
Appendix 2. Selected Report Abstracts.
Appendix 3. Sources Contacted, Sept. 27 to Dec. 14, 1962.
Appendix 4. Summary of Cost Estimating Relationships.
Appendix 5. Data Collection Formats.
Appendix 6. Task Statement.

Differential Games: A Mathematical Theory with Applications to Warfare and Pursuit, Control and Optimisation
Isaacs, Rufus

New York, John Wiley and Sons, 1965, 384 p.

"This work covers the nature and scope of differential games, discrete models, formal mathematical mold, and detailed explanations of the solutions. The primary emphasis is on military applications."

I. An Introduction: the theory of games; the state and control variables; battle games; games with moving craft; pursuit games; games of kind and games of degree; strategies; dogfights, firing games, programming, and athletics; a perspective on precision; a perspective on progress.
II. Definitions, Formulation, and Assumptions: the kinematic situation; the realistic and reduced space; termination of the game; the payoff; games of kind and games of degree; strategies; canonization on circular vectograms; a lemma on circular vectograms.
III. Discrete Differential Games: the general discrete game; battles of extinction; quasi-discrete games.
IV. The Basic Mathematics and the Solution Technique in the Small: the nature of a solution; the main equation; semipermeable surfaces and a second derivation of the main equation; the verification theorem; the path equations; the retrogression principle; the initial conditions.
V. Examples.
VI. Efferent or Dispersal Surfaces: singular surfaces; dispersal surfaces; the question of the perpetuated dilemma; the geometric method for simple pursuit games of kind; the existence of the perpetuated dilemma.
VII. Afferent or Universal Surfaces: with null integr[illegible]; with linear vectograms; the analytic necessary condition for a linear vectogram type universal service; the workable condition when n=3; the calculus of variations viewpoint; all strategies optimal; the workable criterion when n=4; a test for a void; test for a transition surface; relation to Euler equation; restoration of the totality of control variables; semiuniversal surfaces.
VIII. Games of Kind: the barrier concept; the construction of semi-permeable surfaces; termination of barriers; construction of the barrier; fusion of games of kind and degree.
IX. Examples of Games of Kind.
X. Equivocal Surfaces and the Homicidal Chauffeur Game: geometric solution; primary solution; the universal curve and its tributaries; equivocal surfaces; appendix.
XI. The application to Warfare: game theory and war; the available techniques; types of applications; problems of formulation; some pitfalls.

XII. Toward a Theory with Incomplete Information: search games with immobile hiders; with mobile hiders; the improtance of approximations; the chancifying method; appendices.

References.

Index.

The Discount Rate in the Non-Market Context
Franks, Francis John

Monterey, Naval Postgraduate School, 1968, 47 p.
AD 832 903.

Abstract: "Systems Analysis uses many disciplines and sophisticated techniques to determine the relative effectiveness of alternate systems. This relationship can then be reversed by an arbitrary choice of a discount rate. In the private sector, the discount rate is determined by the cost of capital. In the public sector, the cost of acquiring the capital is not clearly defined. The following proposals for the interest rate in the public sector are considered: (1) the government bond rate; (2) the rate of growth of the national product; and (3) a rate derived from the average rate of return in the private sector. It is concluded that the interest rate in the private sector lies between 4.75 and 10 percent. The circumstances which generate uncertainty and the means of handling this uncertainty are also discussed. A procedure is recommended which modifies the difference between expected costs to make them equally significant. Particular attention is focused on uncertainty occasioned by changing technology and the probablity of war. It is concluded that a unique estimate of the risk component is indeterminate and that uncertainty should be considered in the context of the specific systems under consideration."

I. Introduction.
II. Opportunity Costs: the interest rate; the bond rate; growth rate of the national product; the rate of return in the private sector.
III. Uncertainty: factors generating uncertainty; means of handling uncertainty; statistical analysis.
IV. Summary.
Bibliography.
Appendix A. Average Rates of Return in the Private and Public Sectors.
Appendix B. Sensitivity Analysis.

Discount Rates and Procedures to be Used in Evaluating Deferred Costs and Benefits
Bureau of the Budget

Washington, Executive Office of the President, 1969, 7 p.
BOB Circular A-94.

This circular prescribes standard discount rates and procedures to be used in evaluating the measurable cost, benefits, or outputs of programs or projects when these costs, benefits, or outputs occur over time and when they can be estimated.

I. Purpose.
II. Scope.
III. Agency Coverage.
IV. Preparation and Presentation: expected yearly cost; expected yearly benefit; expected yearly output; discount rate; discount factor; present value cost; present value benefit; present value output; present value net benefit; benefit-cost ratio; output-cost ratio; internal rate of return.
V. Discount Rate Policy.
VI. Uncertainty and Risk.
VII. Interpretation.
VIII. Effective Date.
Attachment A. Sample Format for Discounting Deferred Costs and Benefits.
Attachment B. Discount Factors.

Discounting in Military Cost-Effectiveness Studies
Stone, Donald R.

Monterey, Naval Postgraduate School, 1965, 42 p.
AD 475 334.

Thesis abstract: "Discounting is a means of assigning different weights to costs expected to be incurred in different future time periods. Such costs are a vital element of cost-effectiveness studies, which under present DOD policy provide the primary basis for military procurement and force structure decision making. The discounting process is reviewed, and an attempt is made to identify qualitatively the factors which should determine the discount rate to be used by DOD cost-effectiveness studies. These factors are separated into two groups: those which apply to cost-effectiveness studies of all types of weapons systems, and those which depend upon the type of system being considered. Finally the manner of presenting the results of the discounting process to the decision maker is discussed."

I. Introduction.
II. Cost-Effectiveness Studies.
III. The Discounting Process.
IV. The Normative Component.
V. The Risk Component.
VI. Presentation of Results.

"Discounting in Systems Cost Analysis"
Cownie, John

Washington, DC, Office of the Assistant Secretary of Defense (SA) Economics, 19 September 1967, 15 p.

"The purpose of this paper is to specify the costs which are relevant in the comparison of defense systems; in particular, it will be stressed that if cost streams which are spread over time are to be compared, some sort of discounting procedure must be used."

Introduction.
The Costs of Defense.
Systems Costs and Discounting.
Discounting in Business Decisions.
Discounting Defense Expenditures.
Present Values and Future Values.
The Significance of Discounting.

(Not Used)

This page is reserved to describe the DOD Handbook for Economic Analysis at such time as it is published.

Dynamic Programming
Bellman, Richard

Princeton, Princeton University Press, 1956, 342 p., Rand No. R-295.

"The purpose of this work is to provide an introduction to the mathematical theory of multi-stage decision processes." Bibliographies follow each chapter.

Preface.

I. A Multi-Stage Allocation Process: functional equation approach; a multi-dimensional maximization problem; a smoothing problem; infinite stage approximation; existence and uniqueness theorems; approximation in policy space; convexity, concavity; time-dependent processes; multi-activity processes; multi-dimensional structure theorems; continuity and memory; stochastic allocation processes; functional equations; Stieltjes integrals.

II. A Stochastic Multi-Stage Decision Process: stochastic gold mining; enumerative treatment; infinite stage approximation; existence and uniqueness; a finite number of stages; a three-choice problem; a stability theorem.

III. The Structure of Dynamic Programming Processes: the principle of optimality; discrete deterministic, stochastic, and continuous deterministic processes; causality and optimality; approximation in policy space.

IV. Existence and Uniqueness Theorems: equations of type one, two, and three; monotone convergence; stability theorems; an optimal inventory equation.

V. The Optimal Inventory Equation.

VI. Bottleneck Problems in Multi-Stage Production Processes.

VII. Bottleneck Problems: Examples.

VIII. A Continuous Stochastic Decision Process; continuous versions; derivation of the differential equations; the variational procedure; solution for finite total time; mixed policies; solution for infinite time; nonlinear utility.

IX. A New Formalism in the Calculus of Variations.

X. Multi-Stage Games: single-stage discrete game; min-max theory; continuous games; finite resources; games of survival; pursuit games; a basic lemma; existence and uniqueness; proof of results; non-zero-sum games.

XI. Markovian Decision Processes: a lemma; existence and uniqueness; Riccati equation; approximation in policy space; discrete versions; recurrence relation; min-max; generalization of a VonNeumann resul

Index of Applications.

Name and Subject Index.

Dynamic Programming: a Bibliography of Theory and Application
Bellman, Richard and Rebecca Karush

Santa Monica, The Rand Corporation, 1964, 140 p.
Rand Memorandum RM-3951-PR.

Preface.
Bibliography of Papers, 1946-1963 (alphabetically by author).
Bibliography of Books, 1950-1963 (alphabetically by author).
Author Index (Books).
Author Index (Papers).
Subject Index: allocation processes; calculus of variations; communications and information theory; control processes; equipment replacement and inventory theory; game theory; maximization and minimization; multistage production and scheduling theory; optimal routing and trajectory theory; mathematical physics; reliability; search processes; sequential analysis; transportation processes; stochastic variational processes; adaptive processes; analytic results; computational aspects; surveys.
Abbreviations.

Dynamic Programming and the Calculus of Variations
Dreyfus, Stuart E.

Santa Monica, The Rand Corporation, 1965, 511 p.
Rand No. R-441-PR. AD 468 205 and AD 470 877.

Abstract: "A demonstration of the relationships between the calculus of variations, a mathematical discipline concerning certain problems of optimization theory, and dynamic programming, a newer mathematical approach to optimization problems. In addition to explaining and contrasting the two approaches, the report shows that many results of the calculus of variations become simple and intuitively apparent when examined from the dynamic programming viewpoint. In emphasizing the geometrical and physical insight afforded by this approach, the study shows how these techniques can be applied, for instance to stochastic and adaptive variational problems. It can be used in the study of dynamic programming and other new mathematical formalisms; in optimal control problems, such as the determination of rocket trajectories, the correction of launch errors and inflight disturbances of spacecraft; and in the problems of optimal control found in economics, biology, and the social sciences."

Preface.
Summary.
I. Discrete Dynamic Programming.
II. The Classical Variational Theory.
III. The Simplest Problem.
IV. The Problem of Mayer.
V. Inequality Constraints.
VI. Problems with Special Linear Structures.
VII. Stochastic and Adaptive Optimization Problems.
Bibliography.
Index.

Dynamic Programming, System Identification, and Suboptimization
Bellman, Richard

Santa Monica, The Rand Corporation, 1965, 13 p.
Rand Memorandum RM-4593-PR. AD 616 780.

Abstract: "A discussion of the mathematical technique of dynamic programming to obtain a best-fit approximation to a function that is defined over some given interval. The author describes the use of this method as an approach to the handling of a particular type of pattern-recognition problem and to the approximation of optimal control policies."

Preface.
Summary.
I. Introduction.
II. Adaptive Curve Fitting.
III. Discussion.
IV. Identification of Systems.
V. Suboptimization.
VI. Reduction of Dimensionality.
References.

Economic Analysis
Working Paper

Norfolk, Armed Forces Staff College, 1971, 523 p.

This draft volume is a working paper and is being developed as a first source reference in support of Department of Defense Instruction 7041.3. The additional references and bibliography are not included in the draft, but will be included in the final hard copy.

I. Economic Analysis: definitions; discussion; techniques; DODI 7041.3; article from Armed Forces Management.
II. Accounting, Financial Management: roles of financial executive; primary functions; secondary functions; organizational processes; managerial accounting; analysis of funds; budgeting; financial management in government and business; the profit motive.
III. Analog Method of Cost Estimation.
IV. Benefit-Cost Analysis: problem; background; tradeoffs.
V. Correlation Analysis.
VI. Cost-Effectiveness Analysis: definitions; background; marginal utility of weapon systems; contributions by analysts.
VII. Cost-Estimating Relations.
VIII. Critical Path Method: military planning; wide application; basic procedures; compress schedule; complicating elements.
IX. Delphi Method.
X. Engineering Method of Cost Estimation.
XI. Discounting: planning capital acquisitions; general framework of analysis; estimating the variables; other methods; reference problems.
XII. Gaming.
XIII. Linear Programming: preliminary remarks; graphical solution; linear programming.
XIV. Marginal Analysis: theory of production and marginal products; demands for factors (derived, interdependent); the production function; marginal products (defined, as solution to distribution); maximizing profit; graphical depiction; law of diminishing marginal physical product; least cost.
XV. Modeling: nature; design and use; types; evaluation; advantages.
XVI. Monte Carlo Techniques.
XVII. Operations Research: origin; basic concepts; methods; future; examples.
XVIII. PERT: principles and applications; techniques.
XIX. Probability Theory.
XX. Quantitative Analysis: systems approach; scientific method; uncertainty; objectives; alternatives; costs; models; criteria; readings.
XXI. Queuing.

XXII. Regression Analysis.
XXIII. Sensitivity Analysis.
XXIV. Simulation.
XXV. Statistical Inference.
XXVI. Systems Analysis: background; principles and procedures.
XXVII. Productivity Accounting.

Economic Analysis and Military Resource Allocation
Smith, T. Arthur, ed.

Washington, Department of the Army (Office, Comptroller of the Army), 1968, 182 p., AD 841 253.

"This volume considers the decision process in the Department of Defense and its impact on Army plans. The role of Army plans is then addressed in terms of the economic decisions that must be made and the form and types of economic analysis used to support these decisions. Where methodology is developed, general models are described and their implications discussed. This is the case in the development of resource impact models for use in force planning and the development of resource projects for hardware systems. In other instances, such as logistics areas, maintenance and reliability considerations, and the broader aspects of life cycle costing, model development has not reached that general state. In these cases, the discussion centers on the impact of policy on resource acquisition and utilization and available methodological techniques. In all instances, the cost side of the cost-effectiveness equation is stressed. This emphasis is a reflection of the primary intent of the series, the improvement of training and the development of communications within the cost analysis community."

Introduction (T. Arthur Smith).
Economic Analysis and Military Resource Allocation (T. Arthur Smith).
Economic Analysis of the Army Logistics System (Rex Brugh).
Peacetime and Wartime Costs in Cost Effectiveness Analysis (John McClelland).
Army Force Cost Models - An Example (T. Arthur Smith).
Whither Life-Cycle Cost? (Arnold F. Klick).
A Method for Relating Combat Vehicle Operating and Maintenance Costs to Reliability and Maintainability Goals (R.J. Byer, C.F. Blozan, W.T. Towles).
Management and the Systems Analysis Mystique (Paul L. Peck, Jr.).
Cost Estimations for Conceptual Systems (David O. Cochran).
Vehicle Cost Model (John L. Hamilton).
Cost Analysis Methodology for T53 and T55 Turbine Engines (John L. Hamilton & James T. Wormley .

Economic Analysis for Engineering and Managerial Decision-Making
Barish, Norman N.

New York, McGraw-Hill, 1962, 729 p.

"This book is directed to persons who are concerned with economic analyses and aims to present the basic reasoning and methodology of various disciplines which are important in decision-making. It is designed to be practical rather than theoretical. It is technique-oriented. Mathematical symbolism is kept as simple as possible and derivations or proofs are presented only if they are simple and will illustrate the subject matter." Part 1: engineering and business decision-making (chapters 1,2); Part 2: costs (chapters 3-8); Part 3: methods for tangible evaluation of alternatives (chapters 9-12); Part 4: capital management (chapters 13-17); Part 5: determinations of minimum cost and maximum profit (chapters 18, 19); Part 6: risk, uncertainty, and intangibles (chapters 20-27); Part 7: elements of economic measurement, analysis, and forecasting (chapters 28-35).

I. Introduction.
II. Objectives and Criteria for Engineering and Business Decisions.
III. The Cost of Operating an Enterprise.
IV. Cost Concepts for Decision-Making.
V. Interest and Time Value of Money.
VI. Depreciation.
VII. Profits, Interest, and Return on Investments.
VIII. Income Taxes.
IX. Annual-Cost Comparisons.
X. Present-Worth and Premium-Worth Comparisons.
XI. Determination of Rate of Return.
XII. Determinations of Equal Cost and Payout.
XIII. Capital Investment and Theory of Planning.
XIV. The Enterprise's Assets and Sources of Funds.
XV. Sources of Future Capital Funds.
XVI. Capital Planning and Budgeting.
XVII. The Economy of Replacement and Retirement (Economic Life).
XVIII. Minimum-Cost Functional Relationships.
XIX. Programming for Minimum Cost of Maximum Profit.
XX. Risk, Uncertainty, and Intangibles.
XXI. Descriptive Statistics, Probability, and Expected Costs.
XXII. Probability Distributions.
XXIII. Sampling and Confidence Limits.
XXIV. Model Building and Simulation.
XXV. Simulating Risk (Monte Carlo Technique).
XXVI. Waiting-time (Queuing) Evaluations.
XXVII. Evaluating Intangibles.
XXVIII. Economics of the Firm.
XXIX. Measures of Economic Activity.
XXX. Time-series Analyses.
XXXI. Regression and Correlation Analysis.

XXXII. Econometric Models, Demand Analysis, and Sales Forecasting.
XXXIII. Short-run Cost Relationships.
XXIV. Break-even Analysis for Profit Planning.
XXXV. Long-run Cost Variations (Scale of Operations).

Appendix:
Tables: ½% interest factors; 1% interest factors; 2% interest factors; 3% interest factors; 4% interest factors; 5% interest factors; 6% interest factors; 8% interest factors; 10% interest factors; 12% interest factors; 15% interest factors; 20% interest factors; 25% interest factors; 30% interest factors; 40% interest factors; 50% interest factors; uniform-gradient conversion factors (values of factors to convert a uniform gradient, G, to an equivalent uniform payment, R); areas under the normal curve; student's t distribution; random digits; random normal numbers (Gaussian deviates).
Charts: single-payment compound-amount factors for various interest rates from ½% to 50%; single-payment present-worth factors for various interest rates from ½% to 50%; uniform-series compound-amount factors for various interest rates from ½% to 50%; sinking-fund payment factors for various interest rates from ½% to 50%; capital-recovery factors for various interest rates from ½% to 50%; uniform-series present-worth factors for various interest rates from ½% to 50%; curves for determining probability of observing d or less Poisson occurrences in a sample selected from a population having an average of c occurences per unit of space or time.
Selected Bibliography.

Index.

Economic Analysis of the Integrated Facilities System (IFS)
Noah, Joseph W.; Robert P. Caldarone; Carl R. Wilbourn

Washington, Planning Research Corporation, 1969, 101 p.
PRC R-1209, Volume IX, AD 872 133L.

Summary: "The economic analysis of the IFS addresses the total resource requirements and benefits associated with the development, implementation, and operation of a CONUS-wide system. The study results provide information to assess the impact of IFS on Army resources, and to indicate the magnitude of benefits that will accrue to the Army from IFS. The economic analysis should be viewed as a tentative effort."

I. Introduction: purpose; summary; report organization.
II. Methodology: cost-benefit analysis; limitations.
III. Development of Resource Implications of IFS: functional resource implications; ADP resource implications; total costs.
IV. Potential Benefits: general; benefits measured; benefits not measured.
V. Cost-Benefit Comparison: general; conclusions.

Economic Analysis of Proposed Army Investments
Headquarters, Department of the Army

Washington, Department of the Army, 1969, 23 p.
AR 37-13.

I. General Policies for Proposed Investments: general (purpose, scope and applicability, explanation of terms, objectives, policies, responsibilities, references); concepts (time period covered by an economic analysis, present value, discount rate, uncertainty, adjustment for inflationary trends).
II. Investment Proposals for Weapon Systems and Research Projects: general; application to weapon system application to research projects; exceptions.
III. Administrative Instructions: general; preparation of Format A; preparation of Format A-1; Preparation of Format B.
Appendix. Definition of Terms.

Economic Analysis of Proposed AWC Investments and Other Resource Management Programs
Headquarters, Army Weapons Command

Washington, Army Weapons Command, 1970, 11 p.
AWCR 11-20.

This regulation implements AR 37-13 and AMCR 11-36 and prescribes supplemental policy, responsibilities, and procedures to be employed in applying economic analysis to the US Army Weapons Command decision process.

I. Purpose.
II. Scope.
III. General.
IV. Objectives.
V. Policy.
VI. Responsibilities.
VII. Procedures.
VIII. References.

Economic Analysis of Proposed Department of Defense Investments
Headquarters, Department of the Air Force

Washington, Department of the Air Force, 1969, 44 p.
AFR 172-2.

This regulation is applicable to all commands and separate operating agencies. It implements the attached DOD Instruction 7041.3 and requires the preparation and evaluation of economic analyses on proposed Air Force investments meeting certain criteria. It encourages the submission of an economic analysis when it has significant impact on budget justification. It prescribes the necessary policy, procedures and assignment of responsibilities necessary for the evaluation of economic aspects of proposed investments.

I. Background.
II. Purposes.
III. Applicability and Scope.
IV. Explanation of Terms.
V. Policy on the Use of Economic Analysis in Investment Decisions.
VI. Procedures for Preparing and Submitting Economic Analyses.
VII. Responsibilities of HQ USAF Directorate of Budget.
VIII. Other HQ USAF Office Responsibilities.
IX. Command Operating Agency Responsibilities.
Attachment 1. References and Related Directives.
Attachment 2. DOD Instruction 7041.3, 26 February 1969, and Change 1, 26 March 1969.

Economic Analysis of Proposed Department of Defense Investments
Office of the Assistant Secretary of Defense (Comptroller)

Washington, Department of Defense, 1969, 40 p.
DODI 7041.3.

This instruction establishes policy and procedures for consistent application of economic analysis to proposed Department of Defense investment projects.

I. Purpose and Objectives.
II. Policy.
III. Applicability and Scope.
IV. Definitions.
V. Procedures: general (equal benefits, equal cost, both unequal); time periods covered; present value; discount rate; uncertainty; adjustments for inflation; criteria for recommending and selecting investments; preparation and submission of investment proposals.
VI. Effective Date and Implementation.
Enclosure 1. References.
Enclosure 2. Definitions.
Enclosure 3. Instructions for Preparing Formats A, A-1, and B - Summary of Project Costs and Benefits: general; format A; format A-1; format B; project year discount factors.
Enclosure 4. Techniques of Economic Analysis: general; use of the present value (discounting) technique.

Economic Analysis of Proposed Department of the Navy Investments
Office of the Secretary of the Navy

Washington, Department of the Navy, 1970, 40 p.
SECNAVINST 7000.14.

This instruction implements DOD Instruction on Economic Analysis of Proposed DOD Investments, and establishes policy and procedure for consistent application of economic analysis.

References.
I. Purpose.
II. Cancellation.
III. Objectives.
IV. Policy.
V. Applicability and Scope.
VI. Definitions.
VII. Procedures.
Enclosure 1. Definitions.
Enclosure 2. Instructions for Preparing Formats A, A-1, and B - Summary of Project Costs and Benefits.
Enclosure 3. Techniques of Economic Analysis.

Economic Analysis of Public Investment Decisions: Interest Rate Policy and Discounting Analysis
Subcommittee on Economy in Government

Washington, US Congress (Joint Economic Committee), 1968, 25 p.

Abstract: "In this report, the Subcommittee on Economy in Government presents its conclusions on the application of discounting procedures in Federal Government bureaus and agencies and submits its recommendations on this matter. The subcommittee accepts without qualification the proposition that consistent discounting procedures and appropriate interest rate policy must be adopted throughout the Federal Government if wise and economic investments are to be made. Testimony presented to the subcommittee demonstrated that such consistency is not now present. The subcommittee recommends that no public investment be deemed "economic" or "efficient" if it fails to yield overall benefits which are at least as great as those which the same resources would have produced if left in the private sector. This report deals with the optimum discounting procedures to be used in evaluating the economics of public investments."

I. Interest Rate Policy and Discounting Analysis - An Abstract.
II. The Planning-Programming-Budgeting System is the Means for More Efficient Government Decisions.
III. The Discounting Procedure Must be Used if Good Public Investment Decisions are to be Made.
IV. Current Discounting Practices in the Federal Agencies are Neither Adequate nor Consistent.
V. The Appropriate Interest Rate Concept is the Opportunity Cost of Displaced Private Spending.
VI. The Current Risk-Free Interest Rate which should be Used for Evaluating Public Investments is at least 5 percent.
VII. All Federal Agencies should Establish Consistent and Appropriate Discounting Procedures Utilizing an Appropriate Base Interest Rate Computed and Published on a Continuing Basis.
Appendix. The SST and the Interest Rate: An example of the role of discounting.
Separate Views of Representative Patman.
Separate Views of Senator Sparkman.
Supplementary Views of Senators Symington, Jordan, and Percy.

Economic Aspects of Military Procurement and Supply
Subcommittee on Defense Procurement

Washington, US Congress (Joint Economic Committee), 1960, 125 p.

A report by the subcommittee appointed to conduct a study of the impact of defense procurement and disposal policies on the economy. This study follows the subcommittee hearings on "The Impact of Defense Procurement" which were held January 28-30, 1960.

Letter of Transmittal.
Conclusions and Recommendations: general; scope of activities; quality of operation; attempts at progress; GAO findings; recommendations.
Economic Aspects of Military Procurement and Supply: introduction; general summary.
I. Scope and Economic Impact of Military Supply and Related Functions.
II. Quality of Military Supply Management: studies and reports.
III. Congressional Efforts for Improvement: management (top management agencies); supply management; supply management in DOD.
IV. Reorganizing the supply and service functions in the Army.
Appendix 1. Quotations from previous Joint Economic Committee Reports re-effect of military procurement on the economy.
Appendix 2. Conclusions on management of general supplies in the DOD.
Appendix 3. Legislative history of competitive bid statute.
Appendix 4. President Truman's letter on negotiated procurement.
Appendix 5. Correspondence re-cataloging.
Appendix 6. Address of Secretary Lovett to Association of the US Army, August 1960.
Appendix 7. Correspondence re-stock funds.
Appendix 8. Data on GSA-DOD responsibilities.
Appendix 9. Background on integration of common supply in DOD.
Appendix 10. General Eisenhower on defense policy affecting supply management.
Appendix 11. Congressional Correspondence on integrated supply.
Appendix 12. Strengthening of National Security Act.
Appendix 13. Correspondence on unified contract audit.
Appendix 14. Correspondence on integration of electronics supply and communications.

Economic/Cost Benefit Analysis of Proposed AMC Investments
Headquarters, Army Materiel Command

Washington, Army Materiel Command, 1970, 15 p.
AMCR 11-34.

This regulation prescribes policy and procedures to be employed in applying the fundamental concepts of economic/cost benefit analysis to the AMC decision process.

I. Purpose.
II. Scope.
III. Objectives.
IV. Policy.
V. Responsibilities.
VI. Procedures.
VII. Economic Analysis in the Decision Process.
VIII. Major Concepts and Techniques: resource impact; scope of coverage; evaluating investment alternatives; role in management process; present day value; economic life; uncertainty; adjustments for inflationary trends; documentation; cost estimating.
IX. References.
Appendix. Techniques Used in Economic Analyses. Formats. Project Year Discount Factors.

Economic Forecasting
Stekler, Herman O.

New York, Praeger Publishers, 1970, 182 p.

The studies in this book present techniques and empirical results which are relevant either for evaluating or for improving quantitative economic forecasts.

I. Quantitative Economic Forecasts: Judgmental and Econometric Methods.
II. Forecasting with Econometric Models.
III. Evaluation of Econometric Inventory Forecasts.
IV. An Evaluation of Quarterly Judgmental Economic Forecasting.
V. Econometric vs. Judgmental Forecasting.
VI. Data Revisions and Economic Forecasting.
VII. Selecting Economic Data: Accuracy vs. Reporting Speed.
VIII. The Federal Budget as a Short-Term Forecasting Tool.
IX. The Future of Forecasting.
Appendix to Chapter II. A Priori Information, Models, and Forecasting.
Appendix to Chapter III. Regression Estimates of Inventory Equations.
Appendix to Chapter III. Inventory Anticipations Data.
Index.

The Economics of Defense in the Nuclear Age
Hitch, Charles J. and Roland N. McKean

Santa Monica, The Rand Corporation, 1960, 424 p.
Rand No. R-346. AD 243 098.

"Economics is concerned with allocating resources - choosing doctrines, equipment, techniques, and so on - so as to get the most out of available resources. Economizing means trying to make the most efficient use of the resources available. A major purpose of this report is to show the usefulness of this way of looking at military problems. We consider the economic problems of defense at each of three rather gross levels: the quantity of national resources available, now and in the future; the proportion of these resources allocated to national security purposes; and the efficiency with which the resources so allocated are used by the defense departments." Part 1: the resources available for defense (chapters 3-6); Part 2: efficiency in using defense resources (chapters 7-12); Part 3: special problems and applications (chapters 13-18).

I. Defense as an Economic Problem (introduction).
II. The Background: Defense against What? (introduction).
III. Resource Limitations: specific versus general constraints; role of GNP.
IV. Diverting GNP to Defense: How Big a Defense Budget?: budgetary process; program versus object; program size; military personnel.
V. Indirect Effects of Defense Spending.
VI. The Economic Strengths of the Major Powers: problems of international comparison; GNP; defense budgets.
VII. Efficiency in Military Decisions: optimal, efficient, and feasible positions; one input, two outputs; two inputs, one output; economic analysis; the requirements approach; the priorities approach.
VIII. An Illustrative Application of Economic Analysis: problem; mission; alternatives; costs; criterion; models and procedure; results and conclusions. Appendix on the models and the computations: cost coefficients; aggregation of channels; optimizing procedures.
IX. The Criterion Problem.
X. Incommensurables, Uncertainty, and the Enemy.
XI. Problems Associated with Time.
XII. Institutional Arrangements to Promote Efficiency.
XIII. Military Research and Development.
XIV. Logistics.
XV. The Economics of Military Alliance.
XVI. Economic Warfare and Disarmament.
XVII. Mobilization, Civil Defense, and Recuperation.
XVIII. Choosing Policies for Deterrence.
Appendix: The Simple Mathematics of Maximization: introduction;

constrained maxima; economic efficiency; nonlinear programming; the gradient method.

Bibliography.

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Efficiency and Economy in Government Through New Budgeting and Accounting Procedures
Novick, David

Santa Monica, The Rand Corporation, 1954, 122 p.
Rand No. R-254.

"A proposal for a new method of budgeting and accounting for the military, including in the financial process a constant attention to cost considerations, cost comparisons, and analysis thereof."

I. Introduction.
II. The Role of Budgeting and Accounting: budget functions; accounting functions; budgeting, accounting, and operations; present federal budget and proposal; present federal accounting and proposal.
III. Cost Considerations in Weapons Systems Analysis.
IV. Rand's Cost Analysis Method: major elements of operation; accumulating total cost; the distinction between investment and annual operating expenditures; present application; comparison of the two methods; possibilities of general application; general operational considerations.
V. Detailed Description of Rand Methodology: investment cost categories; annual operating cost categories.
VI. Outline of Accounting System Proposed for the US Air Force.
Appendix 1. Brief History of the Federal Budget.
Appendix 2. Coding Structure for Cost Analysis of the US Air Force.
Appendix 3. Sample Worksheet Forms.

Efficiency in Government through Systems Analysis. With Emphasis on Water Resources Development.
McKean, Roland N. (The Rand Corporation)

New York, John Wiley & Sons, 1958, 336 p.

"The inquiry deals specifically with the comparison of water-resource projects, but the comparison of alternative operations or policies of other sorts involves many of the same problems, and the broader purpose of the study is to assist in the general struggle for economy, in the improvement of analysis in government, and in the extension of its use. Part 1: Introduction (chapter 1); Part 2: some general problems of analysis (chapters 2-6); Part 3: special problems in the analysis of water-resource projects (chapters 7-10); Part 4: the problems as illustrated by specific analyses (chapters 11, 12); Part 5: other potential uses of analysis to increase governmental efficiency (chapters 13, 14).

I. Setting, Scope, and Plan of the Study.
II. The Criterion Problem: criteria; proximate criteria; sub-optimization; common errors; appropriate criteria.
III. The Appropriate Alternatives: relevant context; relevant courses; interrelationships.
IV. Intangibles, Uncertainty, and Criteria.
V. Time Streams and Criteria: time horizon; measured in dollars; in physical units.
VI. What Can Be Done: a Recapitulation.
VII. Criteria in the Selection of Water-Resource Projects.
VIII. Kinds of Benefit and Cost: Spillover Effects; technological; pecuniary; consistency; ranking of projects.
IX. Kinds of Benefit: Over-counting, and Secondary Benefits: double-counting; secondary benefits; treatment of taxes.
X. Valuation of Benefits.
XI. Case Study 1: the Green River Watershed.
XII. Case Study 2: Santa Maria Project.
XIII. Analysis for Performance Budgets: An Illustration.
XIV. Analytical Aids to Governmental Economy: A Survey of Opportunities.
Appendix on Possible Classifications of Expenditures by Program, and Indicators of Performance.
Bibliography.
Published Rand Research.
Index.

Elementary Statistical Analysis
Wilks, Samuel Stanley

Princeton, Princeton University Press, 1948, 284 p.

I. Introduction.
II. Frequency Distributions: for ungrouped and grouped measurements; cumulative polygons graphed on probability paper.
III. Sample Mean and Standard Deviation: for ungrouped and grouped measurement; simplified computation.
IV. Elementary Probability: in simple repeated trials; permutations; combinations; calculation; mathematical expectation; geometric probability.
V. Probability Distributions: discrete; continuous; mathematical manipulation.
VI. The Binomial Distribution: derivation; the mean and standard deviation.
VII. The Poisson Distribution: derivation; mean and variance; fitting to a sample distribution.
VIII. The Normal Distribution. general properties; applications.
IX. Elements of Sampling: from a finite and an infinite population; theoretical sampling distributions of sums and differences of sample means.
X Confidence Limits of Population Parameters.
XI. Statistical Significance Tests.
XII. Testing Randomness in Samples: runs; quality control charts.
XIII. Analysis of Pairs of Measurements: method of least squares; simplified computation of coefficients for regression line; generality of the method.
Index.

Elements of Defense Economics
Hitch, Charles J. and Roland N. McKean

Washington, Industrial College of the Armed Forces, 1967, 167 p.

The purpose of this text is to introduce the student to some of the essertial elements of economic analysis which have come to play a vital part in Defense management since 1961. Part 1: analytical and factual background (chapters 1, 2); Part 2: the resources available for defense (chapters 3, 4); Part 3: efficiency in using defense resources (Chapters 5-8).

I. Defense as an Economic Problem.
II. Defense Against What?
III. Resource Limitations.
IV. Diverting GNP to Defense: How Big a Defense Budget?
V. Efficiency in Military Decisions: three general approaches; optimal, efficient, and feasible positions; one input, two outputs; two inputs, one output; the elements of an economic analysis; the requirements approach; the priorities approach; some misunderstandings; efficiency in the large versus efficiency in the small; kinds of military decisions.
VI. The Criterion Problem: criteria; some criterion errors; appropriate criteria.
VII. Incommensurables, Uncertainty, and the Enemy.
VIII. Problems Associated with Time; why discount; what rate; what value for future inputs and outputs; some practical dodges; undervaluing future outputs.
Concluding Observations.
Index.

Empirical Cost Estimates for Military Construction and Price Adjustment Factors
Headquarters, Department of the Army

Washington, Department of the Army, 1969, 13 p.
AR 415-17.

This regulation provides empirical cost estimates for permanent military construction, area price adjustment factors, and unit cost adjustment chart.

I. Purpose.
II. General.
III. Explanation of Tables and Unit Cost Adjustment Chart.

Estimating Cost Uncertainty Using Monte Carlo Techniques
Dienemann, Paul F.

Santa Monica, The Rand Corporation, 1966, 49 p.
Rand Memorandum RM-4854-PR. AD 629 082.

Summary: "Suggested in this Memorandum is a technique for expressing cost estimates of future systems as probability distributions to reflect the uncertainty of the estimate. The impact of this information is shown to be relevant to the decision-making process. For the purpose of the study, the relationship between the sources of uncertainty and system cost estimates is depicted as an input-output model. Within this framework, a procedure was developed to estimate probability distribution for each of the input uncertainties. From the input distributions, a Monte Carlo procedure is used to generate a series of system cost estimates. A frequency distribution and common statistical measures are then prepared from the set of output estimates to ascertain the nature and magnitude of the system cost uncertainty. To illustrate the proposed technique, a case study involving the cost estimate of a hypothetical aircraft system with air-to-surface missles is presented."

Preface.
Summary.
I. Introduction: sources of uncertainty; relevance to decision-making; expressing cost uncertainty.
II. Monte Carlo Techniques for Estimating Uncertainty: simulating probability distributions; estimating system cost uncertainty.
III. Case Study: Individual Weapon System Cost Analysis: input probability distributions; Monte Carlo simulation of system cost uncertainty; case 1 (cost-estimating uncertainty); case 2 (total uncertainty); conclusions.
IV. The Greater Problem: Uncertainty in Cost/Effectiveness Studies.
Appendix A. Weapon System Cost Model Inputs.
Appendix B. Weapon System Cost Model Outputs.
Appendix C. FORTRAN Subroutines for Estimating Uncertainty.
Bibliography.

An Extended Concept of Model
Quade, E.S.

Santa Monica, The Rand Corporation, 1970, 13 p.
Rand No. P-4427. AD 710 639.

A slightly abbreviated version of this paper will appear in the Proceedings of the 5th International O.R. Conference. "The function of a model in operations research is to 'predict and compare'; to provide a logical way to forecast the outcomes that follow alternative actions and, hopefully, to indicate a preference among them. A mathematical formulation with which one can optimize is an extremely valuable aid to this process. But it is not crucial; there are other routes. What is crucial to every decision process is reliance on expert judgment and intuition. This reliance permeates every aspect of operations -- in deciding what approach is likely to be more fruitful, in designing the model, in determining what the facts are, and in interpreting the results. One great virtue of model building is that it provides a systematic, explicit, and efficient way to focus the required judgment and intuition.

A model, by introducing a precise framework and terminology, serves as an effective means of communication, enabling analysts and various experts to exercise their intuition and judgment in a well-defined context and in relation to each other. In addition, it provides feedback to guide the participants in the revision of their earlier judgments. It is these features of the model that are essential to its role in supplying a route from hypotheses to prediction, not how explicitly it represents the real world or whether or not it provides a formal or quantitative scheme for optimization.

"The author's contention is that "there are advantages in using approaches that sacrifice representation also. This suggests taking a broad view, accepting as a model any device that provides a logical means to predict and compare the outcomes of alternative actions, regardless of its representative features or how efficient it is at optimization. Calling such a device a 'model' in the context of operations research would help to counter the bias toward mathematical models acquired by so many analysts through their education and work with industry."

There follows a discussion of one such device, the Delphi procedure.

References.

The Feasibility of Deriving a Cost/Effectiveness Formula for Man/Machine Function Allocation
Connelly, Marilee N.

San Diego, US Naval Personnel Research Activity, 1966, 75 p.
Research Memorandum SRM 67-4. AD 639 674.

Abstract: "This report presents a summary of progress made in a continuing investigation into the feasibility of deriving a cost/effectiveness formula for man/machine function allocation. A preliminary cost/effectiveness formula is presented with an evaluation of the sources and availability of the data inputs required by the formula. Using a preliminary formula and methodology as a basis for the analysis, it was concluded that adequate measures of cost are available but that adequate measures of variable effectiveness have not yet been developed. Due to complexity of the cost/effectiveness formula and to the lack of accessibility of input data, a large amount of time and money will be required to perform function allocation analyses. It was determined that the derivation of a cost/effectiveness formula for man/machine function allocation is feasible. At this time, cost/effectiveness analysis seems applicable to most cases of function allocation and appears to offer a reliable method for the allocation of functions between man and machine."

Brief.
I. Introduction: cost/effectiveness; purpose; scope of report; research approach; background (function allocation, the concept of using cost/effectiveness for function allocation).
II. Procedure: cost (equipment, personnel, utilizing the cost formula); effectiveness.
III. Conclusions and Recommendations.
Appendix A. Branching Model of the Cost Formula.
Appendix B. Derivation of Cost Formula for Cost/Effectiveness Function Allocation Decisions.
Appendix C. Index of Symbols (Derived Order).
Appendix D. Index of Symbols (Alphabetical Order).
Appendix E. Personnel Cost Elements Source Table.
Selected References.
Table 1. A Summary of the Availability of the Inputs of the Preliminary Personnel Cost Formula.

Game Theory
Kahn, Herman and Irwin Mann

Santa Monica, The Rand Corporation, 1957, 65 p.
Rand No. P-1166.

This is a draft of a report to be included as a chapter in a book titled Military Planning in an Uncertain World. Topics include the following: matching pennies, modified matching game, a game of ruin, noisy duel, silent duel, definitions and formal results, attacking targets of unequal importance, the trader and the cannibal, n-person games.
Bibliography.

Games and Decisions
Luce, Robert Duncan and Howard Raiffa

New York, John Wiley and Sons, 1957, 509 p.

This book attempts to communicate the central ideas and results of game theory, and related decision-making models unencumbered by their technical mathematical details.

I. General Introduction to the Theory of Games.
II. Utility Theory.
III. Extensive and Normal Forms.
IV. Two-Person Zero-Sum Games.
V. Two-Person Non-Zero-Sum Non-Cooperative Games.
VI. Two-Person Cooperative Games.
VII. Theories of n-Person Games in Normal Form.
VIII. Characteristic Functions.
IX. Solutions.
X. Stability.
XI. Reasonable Outcomes and Value.
XII. Applications of n-Person Theory.
XIII. Individual Decision Making under Uncertainty.
XIV. Group Decision Making.
Appendix 1. A Probabilistic Theory of Utility.
Appendix 2. The Minimax Theorem.
Appendix 3. First Geometrical Interpretation of a Two-Person Zero-Sum Game.
Appendix 4. Second Geometric Interpretation of a Two-Person Zero-Sum Game.
Appendix 5. Linear Programming and Two-Person Zero-Sum Games.
Appendix 6. Solving Two-Person Zero-Sum Games.
Appendix 7. Games with Infinite Pure Strategy Sets.
Appendix 8. Sequential Compounding of Two-Person Games.
Bibliography.
Index.

A Generalized Cost Model for Military Systems
Eliel, L. Frank

El Segundo, Aerospace Corporation, 1965, 8 p.
Report No. TOR-469(5530 [illegible])-3. AD 484 388.

Abstract: "The rapid development of complex schemes for estimating the costs of military systems has obscured the fundamental requisite structure of systems cost models. In this paper, some of the major relationships are restated symbolically to describe the major features of these models and to permit a more logical development of the general problem. The primary interfaces between system costing and the other related design, planning, and analysis activities are discussed with reference to the requirements which these latter activities place upon the cost model."

I. Introduction.
II. General Economic Models and Definitions.
III. The Basic Estimating Technique.
IV. Cost as a Function of Quantity.
V. Synthesizing the System.
VI. Financial Planning.
VII. Economic Planning and Resource Constraints.

Government Decision-Making and the Theory of Choice
Smithies, A.

Santa Monica, The Rand Corporation, 1964, 11 p.
Rand No. P-2960. AD 607 584.

Discussion of the decision-making processes in government and the importance of recognising that this process must be designed both to determine the objective function and to achieve an efficient allocation. The central purpose of this paper is "to demonstrate the fundamental role of choice among alternative courses of action in government decision-making. The process of choice not only points to the most efficient way to attain given objectives, but is basic to the determination of the objectives themselves. Decision-making thus involves not merely determining how given objectives can be attained at minimum costs, but also exploration of the variety of ways in which resources can be effectively employed. Recognition of the latter aspect of decision-making has evoked a new set of concepts such as program budgeting, cost effectiveness, and systems analysis. This paper attempts to examine the nature of decision-making in terms of standard economic theory, and hopefully, to throw light on the implications of the new vocabulary."

Guide for Reviewers of Studies Containing Cost-Effectiveness Analysis
Heymont, I.; O. Bryk; H. Linstone; J. Surmeir

McLean, Research Analysis Corporation (Economics and Costing Department), 1966, 67 p.

"To assist in the review of studies containing cost-effectiveness analyses, a series of questions with explanatory notes have been prepared. These questions, taken together, will not necessarily cover all aspects of all cost-effectiveness analyses. No one general list of questions can do that. Rather, the questions are designed to focus the attention of the reviewer on selected aspects to assist him in evaluating the analysis. All the questions are not applicable to all studies and they are not necessarily of equal importance to those studies where they do apply . . . This document is intended only as a guide and not as a full and comprehensive treatment of all aspects of cost-effectiveness analysis."

Foreward.
I. General Background: introduction; cost-effectiveness analysis and the estimate of the situation; essential elements; the objective; alternatives; cost; models; criteria; role of judgment; review of studies.
II. Key Questions: statement of the problem; assumptions; alternatives; documentation and data; cost; relationships (models); equal effectiveness methods; effectiveness; criteria; cost-effectiveness curves; conclusions and recommendations.
Glossary.
Selected Questions.
Bibliography.
Index.

Guidebook for Systems Analysis/Cost Effectiveness (Note 1)
ARINC Research Corporation

Annapolis (Maryland), ARINC Research Corporation, 1969, 449 p.
ARINC No. 800-01-01-957.

Purpose: to provide USAECOM personnel with a text and reference material in systems analysis and cost effectiveness; intended for technical, scientific, management and administrative personnel responsible for preparing information, making decisions or reviewing decisions regarding life-cycle cost, system effectiveness, or technical feasibility of a system or equipment at any phase in its life cycle.

I. Introduction: definitions; background; methodology; applications; limitations.
II. General Methodological Approach to Systems Analysis/Cost Effectiveness Studies: input information (Army Force Development, Combat Development Objectives Guide, Qualitative Materiel Development Objective, Qualitative Materiel Requirement); defining requirements and objectives; mission profiles; critical performance parameters; alternative systems (total system, system configuration synthesis, state-of-the-art analysis); hardware characteristics; evaluating effectiveness (availability, dependability, capability); measures of effectiveness; models (assumptions, adequacy, representativeness); uncertainty, data, validity, types); effectiveness equations; cost equations (Rand method, cost-estimating relationships, problems, application); exercising the model; decision model (optimization criterion, risk and uncertainty, optimization techniques, leverage effects, interpretation).
III. Techniques: simulation; queuing theory; sequencing and markov processes; inventory and replacement; linear and dynamic programming; game theory; information theory; analytic models (Lanchester's equations, calculus of variations); decision theory; cost-estimating relationships and confidence intervals; experience curves; cost-sensitivity analysis.
IV. Basic Mathematical and Statistical Concepts: probability; algebraic principles and formulas (counting principles, permutations, combinations, basic probability laws, application to reliability); probability distributions (definitions, properties, parameters and moments, discrete probability distributions, continuous distributions); estimation (nonparametric, parametric).
Appendix A. Glossary.
Appendix B. DOD and AMC Directives: DOD Directive 3200.9 AMCR 70-28.
Appendix C. Statistical Tables: standard normal table; table of t statistic; chi-squared table; table of F values; table of critical l values; exponential table; table of $2/x^2(p,d)$; table of values of r* (required number of failures); table of r(X); confidence belts for proportions.

Appendix D. Bibliography.
Appendix E. Guide for Reviewers of Studies Containing Cost-Effectiveness Analysis.
Appendix F. An Example of a Recent Communications Cost-Effectiveness Analysis.
Index.

Note 1: This document has also been published as AMC Pamphlet AMCP 706-191, entitled: "Engineering Design Handbook - Systems Analysis and Cost-Effectiveness", April 1971.

Guidelines for the Presentation of Army Cost Analyses
Resource Management Corporation

Bethesda, RMC, 1970, 58 p.
RMC Draft Report UR-125.

Prepared for the Comptroller of the Army, the body of the report "is addressed to the formation of guidelines for presentation of Army cost analyses. The organization of the report is in the form of three questions: To whom and for what reason are cost analyses presented? What analysis should support Army cost presentations? and What is to be presented? . . . The scope of the present effort is limited to future weapon/support systems only. Additionally, the study is limited only to those types of decisions made by the Chief of Staff, which do not necessarily correspond with the same decisions as the Office of the Secretary of Defense."

I. Introduction.
II. The Organizational and Decision Context of Army Cost Analysis: current Army management of individual weapon/support systems; senior officer materiel review board; selected acquisition reports; aggregate management of Army Materiel; analysis of current practices.
III. Elements of an Army Cost Analysis Procedure; weapon/support cost analysis cost tracking procedures; review of weapon/support systems cost estimates submitted to COA/DA; system review; what are the assumptions used in the analysis; force specification; materiel and personnel specification; cost evaluation and cost estimating tools; cost estimates; force structure analysis; sensitivity and uncertainty analysis.
IV. Presentation Formats.

Guidelines in Accumulating Financial Data on Future Weapons
Pardee, F.S.

Santa Monica, The Rand Corporation, 1960, 46 p.
Rand Memorandum RM-2583-ARPA. AD 418 652.

Summary: "Weapon system evaluation involves systematic and critical examination of alternative means of performing specified military tasks of missions. In this analytical process it is necessary not only to measure technical and operational capability, but also to obtain a reasonable estimate of total financial requirements and the variations from case to case. This paper attempts to provide guidance in collecting the financial data necessary to the evaluation."

I. Background: place of cost in the over-all evaluation process; the financial data cycle; cost concepts; the uncertainty issue.
II. Description: prime hardware; development and operational concept; program phasing; potential bottlenecks - state-of-the-art and resource shortages.
III. Requirements for Financial Data: definitions; form 1 - contractor and/or arsenal development, production, and support (development, production, support, industrial facilities); form 2 - cradle-to-grave cost (research and development, initial investment, operation, example of sensitivity analysis).
General References.

How Much is Enough? Shaping the Defense Program, 1961-1969
Enthoven, Alain C. and K. Wayne Smith

New York, Harper & Row, 1971, 364 p.

"This book was written for three main purposes. The first is to record some of the valuable lessons regarding strategy, force, and financial planning learned in the 1950's and 1960's and applied in the 1960's in the hope that by doing so, they will not have to be relearned in the 1970's. The second is to make a case for what we believe to be the proper role of the Secretary of Defense: that is, personally to grasp the strategic issues and provide active leadership in developing a defense program that sensibly relates US foreign policy, military strategy, defense budgets, and the choice of major weapons and forces. The third is to increase public understanding of the uses of analysis in defense decision making and to help build support for its increased use."

Preface.
I. Unfinished Business, 1961.
II. New Concepts and New Tools to Shape the Defense Program.
III. Why Independent Analysts?
IV. NATO Strategy and Forces.
V. Nuclear Strategy and Forces.
VI. Yardsticks of Sufficiency.
VII. Three Controversial Program Decisions.
VIII. Some Problems in Wartime Defense Management.
IX. Unfinished Business, 1969.
Source Notes.
Index.

"The Impact of Discounting, Inflation and Residual Value on Life Cycle Costs of Weapon System Acquisition"
Johnston, MAJ John D.

United States Air Force, Assistant Chief of Staff (Studies and Analysis), 1 May 1970, 32 p.

A paper presented at the fifth annual Department of Defense Cost Symposium, held at the National Bureau of Standards, Gaithersburg, Maryland, 24 March 1970. "The purpose of this paper is to point out some of the fundamental economic considerations pertinent to discounting, discuss some of the factors which impact on discounting when applied to weapon system acquisition, present an example to illustrate the numerical implications, and draw a few conclusions."

Foreward.
Introduction.
The Impact of Discounting.
The Treatment of Inflation.
Planning Period and Residual Value.
Intangible Benefits.
Summary.
Bibliography.

An Individual System/Organization Cost Model
Surmeier, John J.; Jodie T. Allen; A.V. Wittner; W.H. Bennett; Alfred D. Stement; Allan Akmar

McLean, Research Analysis Corporation, 1966-68, 5 Volumes, 353 p.
RAC-TP-183. AD 627 418, 820 645, 825 700, 825 701, 827 100.

Volume I. Concept and Application.
  Introduction.
  Concepts of the Design and Use of Cost Models.
  The ISOC Model.
  Example of a Specific Cost Model.
  Example of the Use of the ISOC Model.
Volume II. Computer Program Design and Operation.
  Computer Model Structure.
  Data Preparation for the ISOC Model.
  Model Operation.
Volume III. The Tactical Air Defense (TAD) Model: a Time-Phased ISOC Application.
  The TAD Model: Phase 1
  The TAD Model: Phase 2.
Volume IV. Review of Selected Applications.
  Introduction.
  General Description of the ISOC Model.
  Review of Applications.
  Typical Models and Specific Model Variations.
  Detailed Descriptions of Selected Models.
  Further Developments of the ISOC Model.
Volume V. The Army Division Cost Model.
  Introduction.
  The Army Division Cost Model - Its Characteristics and Applications.
  The Division Cost Model as an ISOC Application.
  Inheritance.
  Hypothetical Case Study - Costing Alternative Tank Programs.

Individual Weapon System Computer Cost Model
Boren, H.E., Jr.

Santa Monica, The Rand Corporation, 1964, 166 p.
Rand Memorandum RM-4165-PR.

"This memorandum describes the present state of development of a computer model used to determine the resource requirements associated with individual weapon systems. The discussion is oriented toward describing the actual operation of the model rather than the underlying reasons for the methodology used."

Summary.
I. Introduction.
II. Weapon System Cost Model - General Description.
III. Subroutine READ.
IV. Subroutine INDEX.
V. Subroutine BASIC.
VI. Subroutine PERSO.
VII. Subroutine APCO.
VIII. Subroutine COST.
IX. Subroutine ASMB.
X. Subroutine OUT1, OUT2, and DUMP.
XI. Conclusions.
Appendix A. Fixed-point and floating-point number systems.
Appendix B. Program Variables.
Appendix C. Sample Input Sheets.
Appendix D. FORTRAN II Symbolic Program of Rand Cost Analysis Department Individual Weapon System Cost Model.
Bibliography.

Information for Decision Making: Quantitative and Behavioral Dimensions Rapport, Alfred, Editor

Englewood Cliffs, Prentice-Hall, 1970, 447 p.

The book is addressed to the informational aspects of management systems. The primary objective is to relate advances in information technology, quantitative methods, and the behavioral sciences, to the task of effectively designing and using decision-oriented information systems. Part 1: background and approach (chapters 1, 2); Part 2: information for planning and control (chapters 3-8); Part 3: behavioral aspects of information (chapters 9, 10).

I. A Setting for Information and Decisions: the structure of management decision theory; accounting for decision making; management misinformation systems; basic concepts for designing a fundamental information system.
II. Development and Use of Models: on the art of modeling; computer simulation - a solution technique for management problems; heuristic models - mapping the maze for management.
III. Basic Framework for Planning and Control: framework for analysis; longrange planning - challenge to management science; a program of research in business planning.
IV. Coping with Uncertainty of Relevant Planning and Control Variables: forecasting consideration in design of management information systems; multiple regression analysis of cost behavior; sensitivity analysis in decision making.
V. Integrated Planning and Control Models - Selected Applications: simulation in financial planning; a linear programming model for budgeting and financial planning; an accounting system structure on a linear programming model.
VI. Information for Production and Marketing Decisions: cost-volume profit analysis under conditions of uncertainty; PERT/Cost - the challenge; a design for the firm's marketing nerve center.
VII. Information for Evaluation of Risky Capital Investments: uncertainty and its effect on capital investment analysis; a review of same; stochastic decision trees for the analysis of investment decisions; limit DCF in capital budgeting.
VIII. Decentralized Financial Control Systems; return on investment - the relation of book yield to true yield; new system for divisional control; accounting implications of a mathematical programming approach to the transfer price problem.
IX. Motivational Information Systems.
X. Impact of Information on Decision Making.

An Introduction to Cost-Effectiveness Analysis
Grosse, Robert N.

McLean, Research Analysis Corporation, 1965, 27 p.
RAC Paper RAC-P-5. AD 622 112.

This paper is designed to show the basic theory underlying cost-effectiveness analysis and to be a beginning for developing the tools and language that would permit greater ease in use and understanding of cost-effectiveness analysis.

An Introduction to Equipment Cost Estimating
Batchelder, C.A.; H.E. Boren; H.G. Campbell; J.A. Del Rossi; J.P. Large

Santa Monica (California), The Rand Corporation, 1969, 121 p.
Rand Memorandum RM-6103-SA. AD 702 424

Prepared for the Office of the Assistant Secretary of Defense (Systems Analysis) and dealing with the fundamentals of cost analysis. This memorandum constitutes the introductory portion of a book on the subject of military cost-estimating procedures. Bibliographies on pp. 77 and 121.

I. Cost-Estimating Methods: industrial engineering, analogy, statistical approaches.
II. Data Collection and Adjustment: collection (historical, resource, physical and performance characteristics, program); adjustment (definitional differences, physical and performance considerations, non-recurring and recurring costs, price-level changes, cost quantity adjustments, other possible cost adjustments).
III. Statistical Methods in Development of Estimating Relationships: simple linear regression (least-squares estimating, statistical inference, prediction intervals); curvilinear analysis; multiple regression analysis; documentation.
IV. Use of Cost-Estimating Relationships: characteristics, hardware considerations, judgment.
V. The Learning Curve: the log-linear hypothesis (unit curve, cumulative average curve); nonlinear hypothesis; plotting a curve; variations; applications.

An Introduction to Equipment Cost Estimating (Note 1)
Large, J.P.

Santa Monica, The Rand Corporation, 1968, 139 p.
Rand Memorandum RM-5470-SA. AD 664 825.

Summary: "This memorandum discusses the fundamental problem of estimating major equipment costs and suggests that for many purposes, particularly for government cost analysis, a statistical approach is the most suitable. The kind of data required and the adjustments needed to make the data useful are discussed in some detail. The use of regression analysis in deriving cost-estimating relationships is described, but it is emphasized that unquestioning use of estimating relationships obtained in this manner can result in serious errors. The concepts underlying the cost-quantity relationship generally known as the learning curve are presented along with instructions for its use. Finally, the problem of uncertainty in cost estimating is discussed and a few suggestions for dealing with the problem are included."

Preface.
Summary.
I. Cost-Estimating Methods.
II. Data Collection and Adjustment.
III. Using Statistics in the Development of Estimating Relationships: curvilinear analysis (logarithmic regression, second-degree equation); multiple regression analysis; documentation; bibliography.
IV. Using Estimating Relationships: understanding the estimating relationship; understanding the hardware; judgment.
V. The Learning Curve: the linear hypothesis; nonlinear hypotheses; plotting a curve; variations; applications; bibliography; appendix.
VI. Uncertainty: proposals for treatment of uncertainty.

Note 1: This is an earlier version of the Publication described on Page 99.

Introduction to Operations Research
Churchman, Charles West; Russell L. Ackoff; E. Leonard Arnoff

New York, John Wiley and Sons, 1957, 645 p.

"This book has two objectives: (1) to provide operations researchers with a basis for evaluating the field and for understanding its potentialities and procedures, and (2) to provide potential practitioners with a survey of the field and a basis on which they can plan the further education required for competence with the methods and techniques." Part 1: introduction (chapters 1-3); Part 2: the problem (chapters 4-6); Part 3: the model (Chapter 7); Part 4: inventory models (chapters 8-10); Part 5: allocation models (Chapters 11-13); Part 6: waiting-time models (chapters 14-16); Part 7: replacement models (chapter 17); Part 8: competitive models (chapters 18, 19); Part 9: testing, control, and implementation (chapters 20, 21); Part 10: administration of operations research (chapter 22).

I. The General Nature of Operations Research.
II. An Operations Research Study of a System as a Whole.
III. Research Team Approach to an Inspection Operation.
IV. Analysis of the Organization.
V. Formulation of the Problem.
VI. Weighting Objectives.
VII. Construction and Solution of the Model.
VIII. Elementary Inventory Models.
IX. Inventory Models with Price Breaks.
X. Inventory Models with Restrictions.
XI. Linear Programming.
XII. The Assignment Problem.
XIII. Some Illustrations of Allocation Problems.
XIV. Queuing Models.
XV. Traffic Delays at Toll Booths.
XVI. Sequencing Models.
XVII. Replacement Models.
XVIII. The Theory of Games.
XIX. Bidding Models.
XX. Data for Model Testing.
XXI. Controlling and Implementing the Solution.
XXII. Selection, Training, and Organization of Operations Research.
Author Index.
Subject Index.

Introduction to Probability and Statistical Decision Theory
Hadley, George

San Francisco, Holden-Day, 1967, 580 p.

This work is intended as a modern introduction to probability and statistical decision theory for those with no previous training in these areas. The Bayesian approach to decision theory, based on the use of prior probabilities and utilities, is emphasized.

I. Foundations of Probability Theory: statistical decision theory; mathematical models; probability and relative frequencies; probability and the degree of rational belief; set theory; the event set; the basic probability model; evaluation of the probabilities of the simple events; the case of equally likely simple events; some simple results; random variables; expected value of a random variable; distribution of a random variable; the summation notation; functions of a random variable; variance of a random variable.

II. The Theory of Utility: projects; decision rules; introduction to uncertainty; single stage, two stage, and n-stage lotteries; the model of rational behavior; use of expected monetary values.

III. Single Stage and Sequential Decision Problems, and Their Solution.

IV. Single-Stage Decision Problem: the normal form; the general single stage inventory problem; incremental analysis; the scrap allowance problem; the expected cost of uncertainty; opportunity loss; periodic review inventory systems; probabilities not known; mixed strategies; geometric interpretation; Bayes' strategy.

V. Additional Developments of Probability Theory: decomposable experiments; product models; independence; combinatorial analysis; the binomial distribution; the Poisson distribution; the Pascal distribution; sampling and hypergeometric distribution.

VI. Conditional Probability Models and Joint Distributions: Bayes' law; linear combinations of random variables.

VII. Continuous Random Variables: the normal distribution; treatment; use of calculus; normal distributions; gamma distributions; joint and conditional density functions; geometric probability problems; linear combinations of random variables; the central limit theorem; simulation.

VIII. Use of Experiments in Decision Problems.

IX. Connection with Classical Statistics: hypotheses testing; estimation; errors of selection or measurement.

X. The Poisson Process: stochastic processes; the Poisson process; as a recurrent event process.

XI. Sequential Decision Problems: the backward solution; multistage inventory problems.

An Introduction to Systems Analysis
Hoag, Malcolm W.

Santa Monica, The Rand Corporation, 1956, 21 p.
Rand Memorandum RM-1678. AD 101 071.

"This material was given as an orientation talk to an Air Force group visiting Rand. Its limited purpose is an elementary exposition of some conceptual issues that are relevant for a critical understanding of Systems Analysis. Many conceptual subtleties and all issues of analytic techniques are avoided." Any rational choice involves the balancing of objectives against the cost of their attainment. This in turn involves several issues: determination of relevant alternatives, establishment of criteria, preparation of a "model", and interpretation of the results of analysis. The author approaches each one of these issues in this memorandum, then concludes with a reminder of the importance of judgment. "It is very clear that Systems Analysis as currently practiced, and probably as practiced in the future, is much more an art than a science."

Introduction to Systems Cost-Effectiveness
Seiler, Karl III

New York, Wiley-Interscience, 1969, 108 p.

An outgrowth of lecture notes prepared for courses in systems cost-effectiveness, with suggested readings to depth studies of the mathematics involved.

Introduction.

I. Cost Factors: level of use; inheritance; research and development; inputs; outputs (total, variable, fixed, average, marginal costs; optimal return output versus optimal efficiency output; relative activity levels; short-run, long-run costs); time (discounted cost, obtainability cost); performance; geographic location.

II. System Cost Models: matrix models; cost of elements; model expansion; minimizing total system cost; period costing; time phasing; fixed cost proration; variable cost nonlinearity; cost model aggregation; differential cost models; probabilistic cost.

III. System Effectiveness Models: probability product model; basic performance (confidence limits, multiple performance parameters); availability; reliability; survivability (microanalysis, macroanalysis); model expansion; maximizing total system effectiveness; period versus mission effectiveness; time phasing; probabilistic effectiveness.

IV. System Cost-Effectiveness Models: domain of feasibility; homogeneity (time, geography, possession, scale); ratio model (optimal efficiency system versus optimal effectiveness system); indifference curve model (combination of two systems, combination of three and more than three systems, limitations); mathematical programming; theory of games; probabilistic cost-effectiveness; decision making and the cost-effectiveness criterion (technological advances, resource availability, political sensitivity, psychological stimulus).

Other References.

Index.

Learning Curve Methodology for Cost Analysts
Dahlaus, Frank and Joseph S. Roj

Washington, Headquarters US Army Materiel Command, 1967, 21 p.
AD 661 052.

"This paper puts down the main framework of necessary concepts in the application of the learning curve with appropriate references to the literature. Experience shows that, at some point in an analysis, the estimator is required to enter opinions because of lack of data, incomplete knowledge of the process or other causes beyond his control. The emphasis in this paper is to distinguish between mathematics and judgment; between calculation and intuition; putting cautions on the analyst to provide the reviewer with visibility as to where one ends and the other begins. Topics include a description of the forms of the learning curve with distinctions among possible variables, various necessary calculations and conversions, fundamental concepts related to the location of a straight line in two-dimensional space, factors which contribute to learning in industrial processes and adjustments for special circumstances. The document was prepared to provide guidance to cost analysts in the US Army Materiel Command."

I. Introduction.
II. The Learning Model: description; applicability; data collection and uncertainty.
III. Calculations and Conversions: fundamental relationship; power expressed as a slope; lot mid-points.
IV. Log-linear Learning Curve Analysis: geometry of the straight line; regression analysis.
V. Factors Contributing to Learning: improved methods; management learning; debugging of engineering data; production processes and slopes.
VI. Engineering and Other Major Changes: effect of engineering changes; adjustment procedures.
VII. General Considerations: detailed investigation; responsibilities of the analyst.
VIII. Summary.
Appendix. Learning Curve. Regression Analysis.
References.

Learning Curve Tables
Volume I. 55-69 Percent Slopes
Volume II. 70-85 Percent Slopes
Volume III. 86-99 Percent Slopes
Boren, H.E. and H.G. Campbell

Santa Monica, The Rand Corporation, 1970, 3 Vol, 919 p.
Rand Memorandum RM-6191-PR. AD 708 713, 708 714, 709 178.

"This memorandum comprises three volumes of learning-curve data, including unit curve midpoints for plotting first-lot quantities. Accurate representation of the first-lot quantity is important, because misplacing this point could lead to incorrect conclusions about the cost-quantity relationship. In the past, unit curve midpoints were estimated by various approximation methods because the calculations to obtain tables of true midpoints were complex and laborious. Now, through use of high-speed computers, such calculations can be made quickly and inexpensively. Accordingly, these volumes were prepared to assemble all the information a cost analyst is likely to need in using or plotting learning-curve data."

Preface.
Summary.
I. The Learning Curve: the log-linear hypothesis; plotting a curve; derivation of midpoint equations.
II. Use of Learning Curve Tables.
III. Learning Curve Tables.

Life Cycle Cost Modeling
Hamilton, John L.

Washington, Army Materiel Command, 1968, 21 p.
Technical Report 68-8. AD 684 335.

Abstract: "This report discusses the mathematical aspects of life cycle cost modeling with emphasis on treatment of parameters, time-phasing of models, and sensitivity analysis. Learning curves, percentage factors, and simple additive cost categories are discussed. General and specific time-phased equations with constant and changing learning curves are presented in detail. The use of partial differential equations for sensitivity analysis is developed."

I. Introduction.
II. The Basic Model.
III. Time-Phase and Non-Time Phase Implications of the Model.
IV. Sensitivity Analysis.
V. Summary.
VI. References.

Life Cycle Costing in Equipment Procurement
Task 4C-5

Washington, Logistics Management Institute, 1965, 117 p.
AD 619 871.

This paper "identifies and studies major categories of cost that are incurred during the useful life of equipment; establishes the relative importance of these categories with respect to life cycle costs, by equipment types; develops methods for measuring and forecasting these costs when procurement of a specific equipment type is being planned, and guidelines for evaluating these costs in the process of reaching a procurement decision."

I. Introduction: relationship of life cycle costing to other studies; relationship of life cycle costing to the competitive procurement decision; major area of study.
II. Summary of Conclusions and Recommendations.
III. Findings and Analysis: scope of the logistics cost problem; logistics cost categories; relative importance of logistics cost categories; quantification of logistics costs (corrective and preventive maintenance; inventory management; training; inspection, installation, and check-out; transportation; documentation; operation); application of logistics cost analyses (feasibility of competition and logistics cost analysis, utilization of logistics cost analysis); problems of applications of logistics cost analysis (impediments to logistics cost analysis, application of logistics cost analyses to formal advertising; application of logistics cost analysis at the subcontract level); alternatives to logistics cost analysis (detailed specifications, plans, and drawings; failure free warranty.)
IV. Conclusions and Recommendations.
Exhibit 1. Analysis of Procurement Funds Obligated in FY 1964.
Exhibit 2. Analysis of Procurement Subjected to Price Competition.
Exhibit 3. Support Cost Categories.
Exhibit 4. Equipment Examined.
Appendix. Corrective and Preventive Maintenance Cost.

Life Cycle Management Model for Army Systems
Headquarters, Department of the Army

Washington, Department of the Army, 1968, 54 p.
Pam 11-25.

This pamphlet supplements AR 11-25 (which prescribes the process by which Army systems are developed, fielded, and modified) and provides broad guidance for supporting activities.

I. General: purpose; objectives; description of the life cycle management model; applicability; revision to model; supporting materials and publications; material requirements review committee; machine processing of information under the life cycle management model.
II. Concept Formulation Phase: general; the Army and joint family of plans; major Army studies; evolution of OCO, QMDO, ADO, QMR, and SDR; the combat development objective guide; prerequisites for contract definition; cost effectiveness analysis; basis of issue, personnel and logistics planning; DA system staff officers; preliminary project manager charter; concept phase system status evaluation; approval to enter contract definition.
III. Contract Definition Phase: general; source selection; approval of contract definition contractors; analysis of trade offs and appraisal of development proposals; contract definition systems status evaluation.
IV. Development and Production Phase: general; development and test plans and coordination; training planning; fund programming; test plans and testing; prototype system characteristics SSE; development of doctrine and organizations; development acceptance SSE; program element and publications; production validation SSE; production.
V. Operations and Disposal Phase: objectives; user field tests and evaluations; review and revision of doctrine and organizations; overhaul, product improvement, and retrofit; revisions to the AMP and the EDP; reclassification; disposal.
Appendix A. Life Cycle Management Model for Army Systems Flow Chart Guide.
Appendix B. Narrative Explanations.
Appendix C. Abbreviations.

Linear Programming and Associated Techniques
Riley, Vera and Saul I. Gass

Baltimore, The John Hopkins Press, 1958, 613 p.
Bibliographic References Series No. 5.

A comprehensive bibliography on linear, nonlinear and dynamic programming, containing references to over 1000 items, an intermixture of articles, books, monographs, documents, theses, conference proceedings, etc. Closing date for inclusion was June 1957. Alphabetically by author, with a brief description of the work.

I. Introduction: mathematical summary; introduction to the literature; basic references.
II. General Theory: mathematical theory; computational techniques; methods for solving linear systems; linear inequalities and convex sets; game theory.
III. Applications: general survey; industrial applications; transprotation problems; assignment problems; contract awards; military applications; agricultural applications; economic analyses; production scheduling and inventory control; structural design; equipment replacement; other applications.
IV. Nonlinear and Dynamic Programming.
Appendix. Author Index.

Linear Programming and Extensions
Dantzig, George B.

Santa Monica, The Rand Corporation, 1963, 621 p.
Rand No. R-366-PR.

"This book is concerned with the theory and solution of linear inequality systems."

I. The Linear Programming Concept.
II. Origins and Influences.
III. Formulating a Linear Programming Model.
IV. Linear Equation and Inequality Systems.
V. The Simplex Method.
VI. Proof of the Simplex Algorithm and the Duality Theorem.
VII. The Geometry of Linear Programs.
VIII. Pivoting, Vector Spaces, Matrices, and Inverses.
IX. The Simplex Method Using Multipliers.
X. Finiteness of the Simplex Method Under Perturbation.
XI. Variants of the Simplex Algorithm.
XII. The Price Concept in Linear Programming.
XIII. Games and Linear Programs.
XIV. The Classical Transportation Problem.
XV. Optimal Assignment and Other Distribution Problems.
XVI. The Transshipment Problem.
XVII. Networks and the Transshipment Problem.
XVIII. Variables with Upper Bounds.
XIX. Maximal Flows in Networks.
XX. The Primal-Dual Method for Transportation Problems.
XXI. The Weighted Distribution Problem.
XXII. Programs with Variable Coefficients.
XXIII. A Decomposition Principle for Linear Programs.
XXIV Convex Programming.
XXV. Uncertainty.
XXVI. Discrete Variable Extremum Problems.
XXVII. Stigler's Nutrition Model: An Example of Formulation and Solution.
XXVIII. The Allocation of Aircraft to Routes Under Uncertain Demand.
Bibliography.
Index.

Linear Programming Under Uncertainty
Dantzig, George B.

Santa Monica, The Rand Corporation, 1954, 18 p.
Rand No. P-596.

Summary: "A class of linear programming models is considered where the activities are divided into two or more stages. The quantities of activities in the first stage are the only ones that can be determined in advance because those in the second and later stages depend on the outcome of random events. Theorems on convexity of the objective (cost) functions are established for the general m-stage case. A complete computational procedure is given for a special class of two-stage problems in which allocations in the first stage are made to meet an uncertain but known distribution of demands occurring in the second stage."

Management and Mathematics: the Practical Techniques Available
Fletcher, Allan and Geoffrey Clarke

New York, Gordon and Breach, 1964, 235 p.

This book is designed to give the executive a wider comprehension of the basic mathematics underlying the techniques of operations research, computer applications, etc.

Introduction.
I. Linear Programming - the Transportation Technique.
II. Linear Programming - the Simplex Algorithm.
III. Networks Methods.
IV. Program Evaluation and Review Technique.
V. Inventory Control.
VI. Forecasting Techniques.
VII. Queuing Theory.
VIII. Simulation.
IX. Replacement Theory.
X. Dynamic Programming.
XI. The Theory of Games.
XII. Response Surface Analysis.
Appendix. Electronic Computers and the Development of Data-Processing Centers.
Index.

Management Sciences: Models and Techniques
Proceedings of the Sixth International Meeting of the Institute of Management Sciences.

New York, Pergamon Press, 1959, 2 volumes, 1113 p.

Volume 1: Sessions 1-7; Volume 2: Sessions 8-14.

Opening of the Conference.

Session 1. Management Economics: limits to the laws of integration and specialization of labor; choosing the best moment for overhaul; on the theory and computation of delegation models, k-efficiency, functional efficiency and goals; the optimum dividend rate; operations research - experience in an underdeveloped economy; the role of economics in management science.

Session 2. Simulation: survey in simulation; integration of modelling and simulation in organizational studies; on the feedback approach to industrial systems design; simulation in dynamic models; a study in planning - scheduling using simulation and linear programming methods.

Session 3. Management Games: remarks on some experiments in management games; contributions and experiences in management games; a decision game of managerial strategy as a research tool; the appreciation of operational research through a management exercise; business gaming in management science education; the future of management gaming.

Session 4. Decision Processes: pricing, investment and games of strategy; mathematical programming in marketing; linear programming under uncertainty; the effect of forecasting errors on optimal programming; the interplay between decision makers; remarks on linear programming with integer solutions.

Session 5. Computer Systems: automatic treatment of information and management; comparison of computer approach in Europe and America; use of a computer 'gamma tambour' for the planning of a shop; a computation for the bounded variables problem using FACOM 128 B; on the analysis of structural properties of largescale micro-economic input-output models.

Session 6. Fundamentals in Management Education.

Session 7. Production and Inventory Management: a model of financial control of inventory in a complex organization; determining cost factors for an inventory model; marginal analysis of lost sales; plant production management; control of finished goods inventory; economic aspects of inventory control.

Session 8. Measurements in Management.

Session 9. Behavioral Sciences.

Session 10. Organizational Theory and Management Communications.

Session 11. Research and Development Management.

Session 12. Long-Range Planning: a quasi-analytic method for long-range planning; the state of the art in using long-range plans; on

the long-range study of the investments in the French Power Industry; forecasting at the level of a firm or a group of firms.

Session 13. Case Histories.

Session 14. Methodology: management economics and operations research; applied management sciences research in a decentralized industrial firm; management decision making with research information; marketing strategy; operations research approaches to sales incentives and distribution cost analysis; an operational approach to the design of work; problems of inventory under limited capacity; a method for management.

Summation.

Appendix. The Institute of Management Sciences.

Indexes: author, subject (French), subject (English).

Managerial Economics
Spencer, Milton H.

Homewood, Richard D. Irwin, third edition, 1968, 515 p.

I. Introduction: Risk and Uncertainty: classification of decision making; the concept of certainty; the concept of risk; the concept of uncertainty; a modern analytical concept of management; conclusion.
II. Approaches to Management Decision Making and Theories of the Firm: microeconomics; linear programming; statistical decision making; behavioral science; theory of games; conclusions.
III. Forecasting: mechanical extrapolations; barometric techniques; opinion polling; econometric models.
IV. Profit: profit theories; unresolved considerations in profit theory; profit measurement; profit planning and control.
V. Demand: analytical framework; price; constructing elementary demand models; prices of substitutes and complements; income; elasticity interrelations.
VI. Production: theoretical production functions; analytical framework; techniques of optimum input analysis; theory of returns to scale of plant.
VII. Cost: nature and types; incremental; cost-output functions; cost measurement; statistical cost functions.
VIII. Advertising.
IX. Pricing.
X. Antitrust.
XI. Capital Budgeting.
XII. Capital Measurement and Financial Policy.
XIII. Simulation: symbolic models; some simulation processes.
XIV. Linear Programming and Economic Analysis: elementary geometry of linear programming; elementary algebra of linear programming; the dual problem; the generalized linear programming problem and methods.
Appendix. Discount Tables and Charts; Common Logarithms.
Index.

Mathematical Analysis for Business Decisions
Howell, James Edwin and Daniel Teichroew

Homewood, Richard D. Irwin, 1963, 320 p.

This book is written for the student or the business practitioner who needs to learn enough about the literature and understand recent developments in the several fields of business as well as to understand and be able to work with the ever-growing number of specialists who are becoming increasingly important in business, industry, and the government.

I. Elementary Mathematical Relations: functions; graphs of functions and equations.
II. Rates of Change: slope of a line and rate of change; limits and continuity; instantaneous rate of change.
III. Differentiation of Functions: elementary differentiation theorems; composite functions; higher-order derivatives; implicit functions; inverse functions.
IV. Optimizing Functions of One Variable: Maxima and minima; solving equations.
V. Applications of the Derivative: cases; break-even analysis, optimization, and the marginal analysis.
VI. Algebraic and Transcendental Functions: exponents and exponentials; logarithmic functions; algebraic functions.
VII. Multivariate Functions: functions of several variables; partial differentiation; theory of extrema for multivariate functions; lagrangian multipliers.
VIII. Summation and Integration: the definite integral as a sum; the fundamental theorem of the calculus; integration; area.
IX. Probabilistic Models: random variables and distribution functions; discrete distribution functions; an application of probability theory.
X. The Mathematics of Finance and Accounting: types of interest; uniform periodic payments; present value; cases.
XI. Applications to Business Decisions: cases.
XII. Linear Systems and Matrices: matrices; matrix solutions of linear systems; subscript notation; existence of an inverse; linear regression analysis.
XIII. Linear Programming: the linear programming model; a three-product problem; additional information from LP solutions; applications of linear programming.
XIV. Management Science Models: the management science approach; limitations and extensions of the management science approach; the present status of management science.
Appendix 1. Differentiation Formulas.
Appendix 2. Integration Formulas.
Appendix 3. Notes on Probability.
Appendix 4. Properties of Exponents and Logarithms.
Appendix 5. Tables.
Index.

Mathematical Optimization Techniques
Bellman, Richard

Santa Monica, The Rand Corporation, 1963, 346 p.
Rand No. R-396-PR.

"The papers collected in this volume were presented at the Symposium on Mathematical Optimization Techniques held in Santa Monica, California, 18-20 October, 1960. The techniques discussed included recent developments in linear, integer, convex, and dynamic programming as well as the variational processes surrounding optimal guidance, flight trajectories, statistical decisions, structural configurations and adaptive control systems." Part 1: aircraft, rockets, and guidance (chapters 1-4); Part 2: communication, prediction, and decision (chapters 5-9); Part 3: programming, combinatorics, and design (chapters 10-14); Part 4: models, automation, and control (chapters 15-17).

Introduction (Richard Bellman).
I. A Survey of the Problem of Optimizing Flight Paths of Aircraft and Missiles (Angelo Miele).
II. Estimating Performance Capabilities of Boost Rockets (P. Dergarabedian and R.P. Van Dyke).
III. The Optimum Spacing of Corrective Thrusts in Interplanetary Navigation (J.V. Breakwell).
IV. The Analysis and Solution of Optimum Trajectory Problems (Stuart E. Dreyfus).
V. A New Approach to the Synthesis of Optimal Smoothing and Prediction Systems (Emanuel Parzen).
VI. Adaptive Matched Filters (Thomas Kailath).
VII. Optimization Problems in Statistical Communication Theory (David Middleton).
VIII. Estimators with Minimum Bias (William Jackson Hall).
IX. On the Optimal Replacement Rules When Changes of State Are Markovian (C. Derman).
X. Simplex Method and Theory (A.W. Tucker).
XI. The Present Status of Nonlinear Programming (P. Wolfe).
XII. The Number of Simplices in a Complex (Joseph B. Kruskal).
XIII. Optimization in Structural Design (William Prager).
XIV. Geometric and Game-Theoretical Methods in Experimental Design (G. Elfving).
XV. Automation and Control in the Soviet Union (J.P. LaSalle).
XVI. The Theory of Optimal Control and the Calculus of Variations (R.E. Kalman).
XVII. Mathematical Model Making as an Adaptive Process (Richard Bellman).
Index.

Mathematical Statistics
Wilks, Samuel Stanley

Princeton, Princeton University Press, 1943, 284 p.

I. Introduction.
II. Distribution Functions: cumulative distribution functions; marginal distributions; statistical independence; conditional probability; the Stieltjes integral; transformation of variables; mean value; moment generating functions; regressions.
III. Some Special Distributions: discrete distributions; the normal distribution; Pearson system of distribution functions; the Gram-Charlier series.
IV. Sampling Theory: application of theorems on mean values to sampling theory; sampling from a finite population; representative sampling; sampling theory of order statistics; mean values of sample moments when sample values are grouped, Sheppard corrections, appendix on Lagrange's multipliers.
V. Sampling from a Normal Population: distribution of sample mean; the χ^2-distribution; the student t-distribution; Snedecor's F-distribution; distribution of second order sample moments in samples from a bivariate normal distribution; independence of second order moments and means in samples from a normal multivariate distribution.
VI. On the Theory of Statistical Estimation: confidence intervals and confidence regions; point estimation, maximum likelihood statistics; tolerance interval estimation; the fitting of distribution functions.
VII. Tests of Statistical Hypotheses: statistical tests related to confidence intervals; likelihood ratio tests; the Neyman-Pearson theory of testing hypotheses.
VIII. Normal Regression Theory: case of one fixed variate; case of k fixed variates; a general normal regression significance test; the minimum of a sum of squares of deviations with respect to regression coefficients which are subject to linear restrictions.
IX. Applications of Normal Regression Theory to Analysis of Variance Problems: testing for the equality of means of normal populations with the same variance; randomized blocks or two-way layouts; three-way and higher order layouts, interaction; latin squares; greco-latin squares; analysis of variance of incomplete layouts; analysis of cavariance.
X. On Combinatorial Statistical Theory: the theory of runs; application of run theory to ordering within samples; matching theory; independence in contingency tables; sampling inspection.
XI. An Introduction to Multivariate Statistical Analysis: The Wishart distribution; reproductive property of same; independence of means and second order moments in samples from a normal multivariate

population; Hotelling's generalised student test; the hypothesis of equality of means in multivariate normal populations; the hypothesis of independence of sets of variables in a normal multivariate population; linear regression theory in normal multivariate populations; remarks on multivariate analysis of variance theory; principle components of total variance; canonical correlation theory; the sampling theory of the roots of certain determinantal equations.

Literature for Supplementary Reading.

Index.

Mathematics and Statistics for Economists
Tintner, Gerhard

New York, Rinehart and Company, 1954, 363 p.

This book includes some applications of elementary mathematics to economics, as well as topics in calculus, probability, and elementary statistics.

Preface.
Sources of Numerical Examples.
I. Some Applications of Elementary Mathematics to Economics: functions and graphs; linear equations in one unknown; systems of linear equations; quadratic equations in one unknown; logarithms; progressions; determinants; linear difference equations with constant coefficients.
II. Calculus: functions, limits, and derivatives; rules of differentiation; derivatives of logarithmic and exponential functions; economic applications of the derivatives; additional applications of derivatives; higher derivatives; maxima and minima in one variable, inflection points; derivatives of function of several variables; homogeneity; higher partial derivatives and applications; elements of integration.
III. Probability and Statistics: probability; random variables; moments; binomial and normal distributions; elements of sampling; tests of hypotheses; fitting of distributions; regression and correlation; index numbers.
Postscript. Suggestions for Further Reading.
Answers to Odd-Numbered Problems.
Tables: four-place common logarithms of numbers; natural trigonometric functions for decimal fractions of a degree; four-place natural logarithms; areas of the normal probability curve; students' t-distribution; x^2 probability scale.
Indexes: names; mathematical and statistical terms; economic terms.

Mathematics of the Decision Sciences
Lecture notes

Stanford, Stanford University, 1967, 906 p.
AD 658 894.

Lecture notes prepared in connection with the summer seminar on mathematics of decision sciences, held at Stanford University July 10 to August 11, 1967.

Survey of Mathematical Programming (R.M. Thrall).
Necessary Conditions of Optimacity in Control and Programming (E. Polak).
Mathematical Programming (George B. Dantzig).
Survey of Mathematical Programming (Michel L. Balinski).
Nonlinear Programming (Terry Rockafellar).
Mathematical Economics (Kenneth Arrow).
Mathematical Economics (David Gale).
Computational Aspects of Control Theory (J.B. Rosen).
Mathematical Programming (A.W. Tucker).
Mathematical Programming (Richard Cottle).
Networks and Graphs (D.R. Fulkerson).
Combinatorial Methods (Jack Edmonds).
Integer Programming (Ralph E. Gomory).
Mathematical Programming (Carlton Lemke).
Optimal Inventory Control (Arthur F. Veinott, Jr.).
Diffusion Approximations in Applied Probability (Donald L. Inglehart).
Optimal Stochastic Control (Herman Chernoff).
Reliability Theory (Richard E. Barlow).
Markovian Decision Processes (Cyrus Derman).
Learning Theory (M. Frank Norman).
Measurement and Psychophysics (David Krantz).
Computer Science (Abraham Taub).
Perception Problems (Andrze J. Ehrenfeucht).

A Method for Deriving Confidence Estimates in Cost Analysis
Yates, E.H.; H.M. Stanfield; D.K. Nance

Santa Barbara, Defense Research Corporation, 1966, 19 p.
Technical Memorandum 231. AD 811 034.

Abstract: "Predictive cost estimates often contain large uncertainties. Bias errors arise from unforeseen requirements, and are difficult to predict. However, a substantial part of the uncertainty is due to incomplete definition of the system elements, and can be treated as a random error, which can be quantified. Large-system cost estimates are made up of many cost elements. If their probability distributions are known, the distribution of the system cost can be obtained. Element cost distributions can be found by applying cost estimating relationships to data on similar elements of known costs, and treating the results as a frequency distribution. In the absence of sufficient data, distributions can be crudely estimated by common-sense procedures. Because the element distributions are generally difficult to define, the system cost distribution has only limited validity. However, predictions of the form 'System cost will lie between A and B with probability p' can be made with considerable confidence if they are restricted to fairly broad intervals, and will bound the estimate much more closely than merely estimating the maximum and minimum possible costs."

I. Introduction.
II. Foundations: kinds of uncertainty; statistical background.
III. Estimating Distributions of Cost Elements: basic approach; other techniques.
IV. Estimating the Distribution of Total Cost.
V. Validity of the Overall Method.
Appendix. Distribution of Total Cost When There Are Few Elements.

Methodology Notebook for Action Officers
Operations Research/Systems Analysis Executive Course

Fort Belvoir, US Army Management School, 143 p.
GT-501-N.

Abstract: "This document presents descriptions, illustrations, and applications of various tools and techniques used in military operations research. Topics covered include the role of operations research in the United States Army Combat Developments Command; the nature of models and their development; simulation; research wargaming; field experimentation in USACDC; troop testing and field evaluation; cost/effectiveness analysis; computer utilization, capabilities, and limitations; human behavioral systems, models, and data collection techniques; human factors analysis; systems analysis, its planning, scheduling, and synthesis of results; and computer applications. A glossary and bibliography are included."

Part One: Command
I. Introduction.
II. The Research Problem.
III. Models.
IV. Simulation.
V. Research War Games.
VI. Field Experimentation.
VII. Troop Testing.
VIII. Cost/Effectiveness Analysis.
IX. Human Factors Analysis.
X. Systems Analysis.
XI. Computer Applications.
Glossary.
Bibliography.

Methods and Procedures for Economic Analysis of Proposed Government Investments

Palmour, Vernon E.; Stephen K. Dietz; Paul H. Earl; Robert R.V. Wiederkehr

Westat Research, Inc., 1969, 89 p.
WR PO-21. AD 855 605.

"The primary purpose of this investigation is, first, to consider the present value (discounted present value) method of aggregating costs and/or benefits over time and, second, the use of this approach in economic analysis of proposed investments in weapon systems. The concept of present value, or discounting as it is sometimes called, will be discussed especially as applied in the comparison of weapon systems. Also analyzed in this report will be the associated problems of choosing a discount rate, the length of planning period and the estimation of residual values, and the treatment of risk and inflation. This investigation is concerned only with the problem of selection between alternative systems in order to accomplish a specified objective. The problem of choosing a set of projects to exhaust a given budget is not treated."

I. Introduction: general problem of economic choice; scope of present study; major conclusions and recommendations.
II. The Present-Value Criterion in the Analysis of Proposed Government Investments: the present-value criterion; discount rate (schools of thought, summon errors and misconceptions); planning period and residual value; use for selecting alternatives (performance level, alternative system, effect of benefit and cost constraints, the more general case); risk and uncertainty (definitions, other interpretations, when benefits not in dollars, government recklessness, treatment of risk); treatment of inflation in discounting analysis (inclusion and exclusion approaches, conclusions and recommendations).
III. Economic Analysis of Proposed Investments in Weapon Systems: cost-effectiveness analysis; criteria for selecting between alternative weapon systems; discount rate, inflation, and risk; planning period and residual value; effect of expenditure profile, planning period and interest rate on present value of systems costs.
Appendix. Derivation of an Expression for the Discount Reduction Factor, F.
References.

Methods for Evaluating the Cost/Effectiveness of Alternative Support Plans for Major Weapon Systems
LMI

Washington, Logistics Management Institute, 1965, 64 p.
LMI Project 6P. AD 476 471.

Summary: "The purpose of the study was to develop and demonstrate certain quantitative techniques or methods as the first steps toward equipping the DOD with improved methods for measuring and evaluating the relative cost/effectiveness of alternative logistics/support programs for such weapon systems. This report contains a description of the measurement methods which we have developed and some examples of how they could be used in logistics/support planning. Some of the methods could be used now in the planning and management of individual weapon systems." The report also deals with the gaps left for study and their relationship to cost/effectiveness measurement.

Preface.
Summary of Report.
I. Introduction: background; study assignments (study methods, developments affecting the conduct of the study).
II. Findings and Discussion: logistics/support planning and management (scope of logistics/support for a weapon system, the F-4 system and the evolution of logistics/support concepts); requirements for improved concepts of cost/effectiveness logistics/support (general, simulations and models).
III. Model for Measuring Integrated Logistics/Support System Cost/Effectiveness: objectives and criteria; uses of common measures and rules; measurement techniques (definitions, symbology, concepts, measures of total system logistics/cost/effectiveness, cost of a weapon per unit of time).
IV. Conclusions and Recommendations.

Methods of Operations Research
Morse, Philip M. and George E. Kimball

New York, John Wiley and Sons, 1951, 158 p.

I. Introduction: definition of operations research; examples; methods; personnel and organization.
II. Probability: fundamental concepts (probability, distribution functions, compound probability, expected values); simple distribution laws (binomial, normal, Poisson); sampling (chi-squared test, examples).
III. The Use of Measures of Effectiveness: sweep rates; exchange rates; comparative effectiveness; evaluation of equipment performance.
IV. Strategical Kinematics: force requirements; Lanchester's equations; probability analysis of Lanchester's equations; generalized Lanchester's equations; reaction rate problems.
V. Tactical Analysis: statistical solutions; analytical solutions involving search theory; measure and counter measure; theoretical analysis of counter measure action.
VI. Gunnery and Bombardment Problems.
VII. Operational Experiments with Equipment and Tactics.
VIII. Organizational and Procedural Problems.
Tables.
Bibliography.
Index.

Military Analysis
Quade, E.S.

Santa Monica (California), The Rand Corporation, 1965, 36 p.
Rand Memorandum RM-4808-PR. AD 624 463.

This memorandum points out the need for the application of analytic techniques to military problems and for an understanding of these techniques by military officers. It defines systems analysis, describes its essential features, illustrates the process of analysis with examples, points out its virtues and limitations, and concludes with some remarks about its future.

Introduction.
Definitions.
The Essence of the Method: the objective, the alternatives, the costs, a model, a criterion.
A Narrow Example: Selection of a new aircraft engine.
A Broader Example: Defense of a Missle Force.
The Process of Analysis.
The Virtues.
The Limitations.
The Future.
Concluding Remarks.

Military Cost Analysis
Grosse, Robert N. and Arnold Proschan

McLean, Research Analysis Corporation, 1965, 8 p.
RAC Paper RAC-P-6. AD 622 113.

This paper was prepared for presentation at the NATO Conference on Applications of Operations Research to Military Resource Allocation and Planning, Sandefjord, Norway, August 1965.

Military Systems Analysis
Quade, E.S.

Santa Monica, The Rand Corporation, 1963, 29 p.
Rand Memorandum RM-3452-PR. AD 292 026.

This memorandum was sponsored by the US Air Force under Project Rand and prepared for publication as a chapter in a book, Military Operations Research, Bernard O. Koopman, Editor, to be published by the Operations Research Society of America in its series, Publications in Operations Research. "Systems analysis is an approach to complex problems of choice under uncertainty by systematically examining the costs, effectiveness, and risks of the various alternatives. This Memorandum attempts to survey the problems and procedures of such an analysis when applied to a military context."

Introduction.
Formulation of the Problem: context; objectives, criteria; hypotheses.
Search: facts; probabilities; alternatives; costs.
Explanation: model building; approximation; computations; results.
Interpretation: nonquantifiables; incommensurables; uncertainties; conclusions.
Concluding Comments.
Reference.

Military Systems Cost Analysis (A Summary Lecture for the AFSC Cost Analysis Course)
Fisher, G.H.

Santa Monica, The Rand Corporation, 1962, 22 p.
Rand Memorandum RM-2975-PR.

Summary: "In the context of this memorandum, cost analysis refers to the determination of the probable economic resource impact of future Air Force weapon and support systems. Five major aspects of cost analysis are stressed: understanding the problem or context in which cost estimates are to be used, assembling the basic data, deriving cost-estimating relationships, using these relationships to make an estimate, and presenting the results. Both hardware and nonhardware system cost components are discussed, and the sensitivity of total system cost to variations in the cost and characteristics of these components is considered."

Preface.
Summary.
General Remarks.
The Cost Analysis Process.
Further Comments on Cost-Estimating Relationships.
Hardware Cost Analysis.
Research and Development.
Non-Hardware System Cost Components.
Pulling Together the Total System Cost Estimate.
Weapon System Cost Sensitivity Analysis.
Concluding Remarks.

Models in Cost-Effectiveness Analysis: An Example
Bryk, Oliver

McLean, Research Analysis Corporation, 1965, 29 p.
RAC Paper RAC-P-2. AD 622 109.

This paper describes some approaches to modeling for systems analysis or cost-effectiveness studies.

Introduction: elements of cost-effectiveness analysis; role of models; objective; conceptual design of the models; description of models (effectiveness, systems, cost, cost-effectiveness models).
References.

A Modern Design for Defense Decision: A McNamara-Hitch-Enthoven Anthology
McNamara, Robert S.; Charles J. Hitch; Alain C. Enthoven

Washington, D.C., Industrial College of the Armed Forces, 1966, 259 p.

A compilation of the thinking of the three principal architects of the contemporary approach to decision making. Part 1: the budget as a management tool for integrating national and defense policy (chapters 1-5); Part 2: the organizational framework and agency responsibilities (chapters 6-8); Part 3: the programming system (chapters 9-12); Part 4: systems analysis (chapters 13-17); Part 5: US defense policy for the 1960's (chapter 18).

Foreword (LTG August Shomburg).
Introduction (A. Enthoven).
I. Managing the Department of Defense (R. McNamara).
II. Decision-Making in the Department of Defense (R. McNamara).
III. The Formulation of Political Objectives and their Impact on the Budget (R. McNamara).
IV. The Foundation for Defense Planning and Budgeting (R. McNamara).
V. The Department of Defense Budget and the National Economy (C. Hitch).
VI. Evolution of the Department of Defense (C. Hitch).
VII. Agency Responsibility for Planning and Budgeting (R. McNamara).
VIII. The Joint Chiefs of Staff and the Defense Budget (R. McNamara & General Maxwell Taylor).
IX. Development and Salient Features of the Programming System (C. Hitch).
X. Programming and Budgeting in the Department of Defense (A. Enthoven).
XI. Program Packages (C. Hitch).
XII. Retrospect and Prospect. (C. Hitch).
XIII. Cost Effectiveness (C. Hitch).
XIV. Choosing Strategies and Selecting Weapon Systems (A. Enthoven).
XV. Operating Research at the National Policy Level (A. Enthoven).
XVI. Systems Analysis and the Navy (A. Enthoven).
XVII. Cost-Effectiveness Analysis of Army Divisions (A. Enthoven).
XVIII. US Defense Policy for the 1960's (A. Enthoven).
Appendix 1. Introduction of New Government-Wide Planning and Budgeting System (President Lyndon Johnson).
Appendix 2. An Illustrative Example of Systems Analysis (MAJ William Snyder).
Suggestions for Further Reading.
Index.

Modern Research for Administrative Decisions
Hough, Louis

Englewood Cliffs, Prentice-Hall, 1970, 609 p.

This book attempts to meet the need for broad familiarity with methods, suggestive theory, and practical guidance in modern decision theory.

I. Scientific Techniques in Administration: controlled quantitative investigation; the scientific pursuit of knowledge; the need for administrative research.
II. Procedural Concepts in Scientific Research: rationalism versus the analysis of data; system of explanation; scientific methods and truth; the development of the research problem; discovering working hypotheses; statistical design in experiments.
III. The Structure of Administrative Research: adaptation and control; a new administrative technology; the operations research movement; the managerial applications; difficulties in the research; pure research in administration; the phases in an investigation.
IV. The Elements of Decision Theory: microeconomic decisions and the research requirements; an illustration; and algebraic model of the decision criteria; appraising the theory.
V. Objectives and Criteria for Decisions: suboptimization; the objectives of business decisions; maximizing utility; contentment levels.
VI. Research Problems and Administrative Diagnosis: methods as a guide to research; the dominance of the problem; utilizing existing data; the identification of problems; stating the problem.
VII. Predictive Models and Simulations: decisions and predictions; assumptions and validity; the model-building sequence; the classical model of gravitation; the rent or buy model.
VIII. The Various Forms of Administrative Models.
IX. Selecting the Variables.
X. The Model Building Process.
XI. Standard Theoretical Models.
XII. Estimating Parameters and Applying the Model: the parameters and the data; verification; revision; manipulation; making the choice.
XIII. Management by Multistage Models.
XIV. Computerization in Administrative Research.
XV. Research for Inventory Decisions.
XVI. An Introduction to Queue Theory.
XVII. The PERT Network for Scheduling.

XVIII. The Elements of Linear Programming.
XIX. The Assignment Problem.
XX. The Transportation Method.
XXI. The Simplex Method.
XXII. Linear Programming Research.
XXIII. Monte Carlo Research Techniques.
XXIV. The Analytic Study of Total Systems.
XXV. Information for System Administration.
Appendix A. Developing the Fundamental Data.
Appendix B. Mathematical Rates of Change.
Appendix C. Bayesian Probability Theory.

A Monte Carlo Simulation Approach to Cost Uncertainty Analysis
Schaefer, Donald F.; Frank J. Husic; Michael F. Gutowski

McLean, Research Analysis Corporation, 1968, 82 p.
Economics and Costing Department Study 009.135. AD 850 054.

Abstract: "An important aspect of cost research is the measurement of the uncertainty inherent in the projection of system cost. Approaches to this problem have in the past centered on intuition of the decision maker or in sensitivity analysis. Only recently have approaches utilizing such tools as statistical decision theory and probability theory been formulated. This study focuses on the Monte Carlo simulation approach to uncertainty in cost analysis. This approach requires: (a) expression of input estimates as probability distributions reflecting uncertainty, and (b) cost equations pertinent to a particular model. The Monte Carlo simulation approach then generates: (a) the frequency distribution for system cost, and (b) statistical measures that illustrate the nature and magnitude of system cost uncertainty. Two models are developed, the Beta model and the Weibull model, each of which reflects a particular distribution form for the inputs. The relative costs and advantages of each model are compared. A user's guide to the program and complete program listings are presented in the appendix."

Foreward.
Abstract.
Introduction.
Cost Undertainty Analysis: An Overview: cost uncertainty in decision making (value of probability information); methodology (overview of logic, beta variant, Weibull variant); model input requirements (beta model, Weibull model); output format; computer time requirements; conclusions.
Appendix. User's Guide to Beta and Weibull Programs: Weibull input requirements; beta input requirements; error messages; computer hardware and software requirements; program logic; Weibull program listing; beta program listing; computer program flow charts.
References.

Multivariate Logarithmic and Exponential Regression Models
Graver, C.A. and H.E. Boren, Jr.

Santa Monica, The Rand Corporation, 1967, 138 p.
Rand Memorandum RM-4879-PR. AD 655 768.

Summary: "This memorandum presents a statistical study of a regression function of the form $Y = e^{\mu_0} X_1^{\mu_1} X_2^{\mu_2} \cdots X_p^{\mu_p}$. The study is concerned primarily with (1) how to pick the best values for the unknown parameters $(\mu_0, \mu_1, \mu_2 \cdots \mu_p)$ given a set of historical data $(Y_i, X_{1i}, X_{2i} \cdots X_{pi}, i = 1, 2, \ldots n)$, and (2) how to describe the predictive capability of the choice in (1)."

Preface.
Summary.
I. Introduction.
II. The Multiplicative Model: assumptions and implications of the case (median case, mean case); estimators of the parameters; distribution of the estimators; prediction intervals.
III. The Additive Model: general model; estimations; distribution of the estimators; prediction interval.
IV. Comparison of the Models.
V. Computer Program: introduction; restrictions; sequence of operations; input procedures (title card, order card, format card, data cards, blank card, summary of input cards); outputs; future studies.
Appendix A. Matrix Definitions and Operations: matrix; equality of matrices; matrix operations (addition, scalar multiplication, matrix multiplication); special matrices (square matrix, identity matrix, transpose matrix, symmetric matrix, inverse matrix, positive definite matrix).
Appendix B. Statistical Facts and Relationships: measures of central tendency (the expected value or mean of X, median of X); percentiles of a continuous random variable; measures of variability (variance, covariance, covariance matrix); linear combinations of random variables; distributions related to the normal (chi-square distribution, the t-distribution).
Appendix C. Conversion of e^{μ_0} to μ_0.
Appendix D. Absolute Minimum and Positive Definiteness of the Matrices of Second Partials: general discussion; specific case.
Appendix E. Variance-Covariance Matrix.
Appendix F. FORTRAN IV Symbolic Program.
References.

New Decision-Making Tools for Managers
Bursk, Edward C. and John F. Chapman, Editors

Cambridge, Harvard University Press, 1963, 413 p.

A collection of articles on a variety of decision-making tools that are still valid today, in the areas of finance (chapters 6,7), marketing (chapters 8-11), product strategy (chapters 12-14), and production (chapters 15-17).

I. Operations Research for Management (Cyril C. Hermann and John F. Magee).
II. Mathematical Programming: Better Information for Better Decision Making (Alexander Henderson and Robert Schlaifer).
III. How to Plan and Control with PERT (Robert W. Miller).
IV. Meaningful Costs for Management Action (Robert Beyer).
V. Econometrics for Management (Edward G. Bennion).
VI. How to Evaluate New Capital Investments (John G. McLean).
VII. Mathematical Models in Capital Budgeting (James C. Hetrick).
VIII. Simulation: Tool for Better Distribution (Harvey N. Shycon and Richard M. Maffei).
IX. Marketing Costs and Mathematical Programming (William J. Baumol and Charles H. Sevin).
X. Tests for Test Marketing (Benjamin Lipstein).
XI. Less Risk in Inventory Estimates (Robert G. Brown).
XII. Prudent Manager Forecasting (Gerald A. Busch).
XIII. Strategies for Diversification (H. Igor Ansoff).
XIV. Selecting Profitable Products (John T. O'Meara, Jr.).
XV. Mathematics for Production Scheduling (Melvin Anshen, Charles C. Holt, Franco Modigliani, John F. Muth, and Herbert A. Simon).
XVI. The Statistically Designed Experiment (Dorian Shainin).
XVII. Quality Control (Theodore H. Brown).
List of Contributors.
Index.

New Tools for Planners and Programmers
Novick, David

Santa Monica, The Rand Corporation, 1961, 21 p.
Rand No. P-2222.

"It is the purpose of this paper to discuss (1) some of the conditions which make the current decision-making machinery inadequate, and (2) new tools which can meet the needs of the planners and decision makers."

The Normative Interest Rate
Berman, E.B.

Santa Monica, The Rand Corporation, 1959, 39 p.
Rand No. P-1796. AD 663 408.

"The normative interest rate is defined as the discount rate the government ought to use in making its investment decisions. In this paper, various alternative ways of setting the level of the normative interest rate are examined . . . . The appropriate normative interest rate is then determined as a rate that is consistent with itself through the rate of growth of national product and the rate of decline in the marginal utility of national product that it implies."

Introduction.
I. Welfare Return and Investor's Return: incremental taxation; risk premium; direct gains.
II. Three Traditional Devices for Setting the Level of the Normative Interest Rate: rate of return on marginal private investment; national time preference; long-term government bond rate.
III. Should the Normative Interest Rate be Zero?
IV. The Rate of Growth of National Product Implied by an Arbitrarily Determined Interest Rate.
V. The Normative Interest Rate as a Function of the Rate of Growth of National Product.
VI. The Normative Interest Rate and the Equilibrium Rate of Growth: removing the investment opportunity; the accelerator; the endogenous generation of investment opportunities.
VII. Note on the Normative Interest Rate and the Level of Employment.

Notes on Parametric Linear Programming
Manne, Alan S.

Santa Monica, The Rand Corporation, 1953, 7 p.
Rand No. P-468.

I. The General Linear Programming Problem.
II. P (θ).
III. Q (θ).
IV. Extension of the Technique.

On the Choice of Objectives in Systems Studies
Hitch, Charles J.

Santa Monica, The Rand Corporation, 1960, 13 p.
Rand No. P-1955.

An essay on the choice of objectives. There are three difficulties in determining the right objectives:

(1) "It is impossible to define appropriate objectives without knowing a great deal about the feasibility and cost of achieving them. And this knowledge must be derived from the analysis."

(2) There frequently is no national or other high level objective that can be taken as "given".

(3) "Objectives are multiple and conflicting, and alternative means of satisfying any one are likely to produce substantial and differential 'spillover' effects on others."

"Learning about objectives is one of the chief objects of systems analysis. We must learn to look at objectives as critically and as professionally as we look at our models and our other inputs. We may, of course, begin with tentative objectives, but we must expect to modify them or replace them as we learn about the systems we are studying - and related systems. The feedback on objectives may in some cases be the most important result of our study."

On the Construction of a Mathematical Theory of the Identification of Systems
Bellman, Richard

Santa Monica, The Rand Corporation, 1966, 13 p.
Rand Memorandum RM-4769-PR. AD 642 678.

This memorandum discusses some of the problems involved in the formulation of a mathematical theory for system identification. By system identification is meant the task of determining the structural parameters on the basis of observations over time and position of the inputs and outputs.

I. Introduction.
II. A Fundamental Problem.
III. Search Techniques.
IV. Quasilinearization.
V. Use of Transform Techniques.
VI. Basic Uncertainties of On-Line Identification and Control.
VII. Decomposition into Subsystems.
VIII. Pattern Recognition.
IX. Concluding Remarks.
References.

On Discounting and Risk in Military Investment Decisions
Broussalian, V.L.

Washington, D.C., The Franklin Institute (Systems Evaluation Group, Center for Naval Analyses), 1966, 12 p.
SEG Research Contribution No. 10. AD 641 170.

A revised version of an earlier paper entitled "Discounting, Bias and Risk in Military Investment Decisions: A Theoretical Discussion."
Abstract: "The term, discounting, is often applied indiscriminately to two distinct operations. One operation, which attempts to simulate the capital market's evaluation of an investment, represents a conceptual exchange between current and future income resulting in a 'present value'. The other refers to an essentially subjective revision, normally downward, of an expected future benefit or cost, for any of a number of reasons. It is pointed out that in the case of a military effectiveness stream (a typical example of a non-marketable benefit stream), it is meaningful to discount in the first sense. On the other hand, whereas discounting in the second sense could be meaningfully applied, there is no single rate which the analyst acting on behalf of the decision-maker can apply. The practice of raising the discount rate by a premium to take care of risk and uncertainty may be appropriate when discounting in the second sense."

Abstract.
The Two Senses of Discounting.
"Discounting" on Account of Risk.

On the Role of the Cost Analyst in a Weapon System Study
Kermisch, J.J. and A.J. Tenser

Santa Monica, The Rand Corporation, 1966, 22 p.
Rand No. P-3360. AD 636 497.

This study makes the following two points: (1) that the role of the cost analyst is not to appear after decisions are made and provide some kind of estimate which justifies the decisions, and (2) that cost analysis is not an activity which is carried out by itself, but is an important part of a larger analytic activity which is sometimes called systems analysis, sometimes cost-effectiveness analysis, and sometimes cost-utility analysis.

On the Theory of Dynamic Programming
Bellman, Richard

Santa Monica, The Rand Corporation, 1952, 48 p.
Rand No. P-300.

Summary: "Some general problems are formulated and the existence and uniqueness of the analytic equivalents are proved. A discussion and solution of a number of simple examples are given."

I. Introduction.
II. General Mathematical Formulation.
III. Existence and Uniqueness.
IV. A Particular Functional Equation.
V. Generalisations.
VI. A Simple Testing Problem.
VII. Another Testing Problem.
VIII. The Functional Equation: $f(x) = \text{Max}[g(y) + h(x-y) + f(ay + b(x-y))]$.
IX. The Equation: $f(x) = \text{Max}[g(x) + f(ax), h(x) + f(bx)]$.
X. g and h both convex.
XI. A Particular Solution.
XII. A Problem in Optimal Performance.
Bibliography.

Operations Research - Methods and Problems
Sasieni, Maurice; Athur Yaspen; Lawrence Friedman

New York, John Wiley & Sons, 1959, 316 p.

This book deals with a selection of the mathematical techniques that have been found useful in operations research. The approach is mainly through the medium of worked examples, against a background furnished by some discussion of the relevant problem area.

I. Introduction.
II. Probability: simple events; composite and related events; discrete distributions; continuous distributions.
III. Sampling: types; estimates from samples; curve fitting; simulated sampling.
IV. Inventory: known demand; probabilistic demand; probabilistic demand with production lead time.
V. Replacement: capital equipment that deteriorates with time; items that fail completely; staffing problems.
VI. Waiting Lines: Poisson arrivals and exponential service times; Poisson arrivals and Erlang service times; Monte Carlo solutions.
VII. Competitive Strategies.
VIII. Allocation: the assignment problem; the transportation problem; the linear programming problem; the simplex method; applications of linear programming.
IX. Sequencing: processing each of n jobs through n machines; the traveling salesman problem.
X. Dynamic Programming: problems with a finite number of consecutive decisions; problems with an indefinite number of consecutive decisions.
Appendix 1. Finite Differences.
Appendix 2. Differentiation of Integrals.
Appendix 3. Row Operations.
Index.

Operations Research/Systems Analysis Glossary
Operations Research/Systems Analysis Executive Course

Fort Belvoir, US Army Management School, 28 p.
AM-605-N.1.

Short vocabulary reference to aid the student in familiarizing himself with the specialized vocabulary of operations research and systems analysis.

Planning, Programming, Budgeting: a Systems Approach to Management
Lyden, Fremont and Ernest G. Miller

Chicago, Markham Publishing Company, 1967, 443 p.

The readings in this book have been assembled to provide the contemporary public manager or student of public administration with information on what the PPB approach to budgeting is, how it has developed to this point in time, how it relates to other kinds of budgeting approaches, how it is related to and underpinned by systems analysis generally, how it may be applied, and what its limitations and deficiencies may be. Part 1: PPB in perspective (chapters 1,2); Part 2: budgeting and political process (chapters 3,4); Part 3: approaches to planning and program budgeting (chapters 5-7); Part 4: the PPB approach to budgeting (chapters 8-12); Part 5: the system base of PPB (chapters 13-16); Part 6: applications and critique of PPB (chapters 17-19).

I. PPBS Comes to Washington (Virginia Held).
II. The Road to PPB - the Stages of Budget Reform (Allen Schick).
III. Budgeting in a Political Framework (Jesse Burkhead).
IV. Public Attitudes Toward Fiscal Programs (Eva Mueller).
V. The Planning Process - a Facet Design (Yehezkel Dror).
VI. Toward a Theory of Budgeting (Verne B. Lewis).
VII. Comprehensive vs. Incremental Budgeting in the Department of Agriculture (Aaron Wildavsky and Arthur Hammann).
VIII. Program Budgeting - Applying Economic Analysis to Government Expidenture Decisions (Murray L. Weidenbaum).
IX. The Role of Cost-Utility Analysis in Program Budgeting (Gene H. Fisher).
X. Costs and Benefits from Different Viewpoints (Roland N. McKean).
XI. Benefit-Cost Analysis - Its Relevance to Public Investment Decisions (Arthur Maass).
XII. Quality of Government Services (Werner Z. Hirsch).
XIII. Systems Analysis and the Navy (Alain C. Enthoven).
XIV. Systems Analysis Techniques for Planning-Programming-Budgeting (E.S. Quade).
XV. Guaranteed Income Maintenance - a Public Welfare Systems Model (Helen O. Nicol).
XVI. Cybernetics (Magoroh Maruyama).
XVII. Limitations, Risks, and Problems (Roland N. McKean and Melvin Anshen).
XVIII. Planning-Programming-Budgeting Systems and Project PRIME (Steven Lazarus).
XIX. The Political Economy of Efficiency - Cost-Benefit Analysis, Systems Analysis, and Program Budgeting (Aaron Wildavsky).
Appendix. Planning-Programming-Budgeting Bulletin No. 66-3, Supplement to Same, Bulletin No. 68-2.

The Planning, Programming, and Budgeting System
Office of the Assistant Secretary of Defense (Comptroller)

Washington, Department of Defense, 1969, 37 p.
DODI 7045.7

References.
I. Purpose.
II. Applicability and Scope.
III. Definitions.
IV. Cancellations.
V. Program/Budget Review Schedule.
VI. Strategic Objectives.
VII. Fiscal Guidance.
VIII. Program Objectives.
IX. Component Comments.
X. Decision Implementation.
XI. Budget Estimates.
XII. Approved Program Changes.
XIII. Limitations.
XIV. FYDP Handbook.
XV. Implementation and Effective Date.
Enclosure 1. Preparation and Processing of Program Objective Memorandum.
Enclosure 2. Preparation and Processing of Program Change Request: general; processing; specific information; DD Forms 1570, 1570-1, 1570-2, 1570-3, and 1570-4.
Enclosure 3. Use and Preparation of Program Change Decisions and Program/Budget Decisions: general; specific entries; PBD forms: SD Forms 428, 428-1, 428-1c, 428-3, 428-4, 428-5, 428-6.

Potentials of Economic Analysis in the Department of Defense
Defense Economic Analysis Council

Washington, Office of the Assistant Secretary of Defense (Comptroller), 1970, 92 p.

Proceedings of the DOD one-day meeting on implementation of economic analysis, 30 October 1970.

Foreward.
Keynote Address: Economic Analysis in Today's Management Environment in the Pentagon (Hon. Robert C. Moot).
Office of the Assistant Secretary of Defense Addresses:
Instigators of Analysis (Edward E. Winchester).
Output Makes the Difference (COL Vincent J. Klaus).
Economic Analysis for Food Service (Herbert M. McCarthy).
Office of Management and Budget Address: Development of Effective Methodology for Economic Analysis (Dr. William Niskanen).
Army Address: Implementation of Economic Analysis in the Department of the Army (T. Arthur Smith).
Navy Address: Economic Analysis - Where do We Go from Here? (CPT Lloyd Yeich).
Air Force Address: Implementation of Economic Analysis in the Department of the Air Force (MAJ Stephen J. Opitz, Jr.).
Panel Discussion: Implications of the Blue Ribbon Defense Panel Recommendation to Strengthen Analytic Capability throughout DOD.
Appendix 1. Biographies.
Appendix 2. Blue Ribbon Defense Panel Recommendation III-7.
Appendix 3. Points of Contact on Economic Analysis.

PRC Capabilities in Resource and Cost Analysis
Cost Analysis Department, System Economics Division

Washington, Planning Research Corporation, 1966, 99 p.
PRC G-127.

"This document serves to introduce potential clients to the cost analysis activities conducted by Planning Research Corporation. The body of the report includes the techniques and methods employed and a discussion of the costing concepts and procedures applied to problems of resource allocation; also a brief history of PRC and a description of its areas of service, facilities, and management. Finally, experience gained during the last decade related to cost analysis is presented in the form of briefs."

I. Introduction.
II. PRC Corporate Background: general background; project management and approach; service areas; corporate facilities; security clearances.
III. Costing for Resource Allocation: general; cost synthesis (general, major considerations, alternative cost-synthesizing approaches); cost estimation (major considerations, alternative cost estimating approaches); cost relevancy considerations (general, sunk versus incremental costs, remaining values, inherited assets, spillover costs, relevant prices, joint costs, intangibles); summary.
IV. Related PRC Experience: cost-effectiveness analysis; development of cost effectiveness methodology; cost/management control systems; cost analysis.
V. Selected Personnel Resumes.

A Preliminary Cost-Effectiveness Handbook
Barfoot, Charles B.

Technical Operations, 1963, 34 p.
CORG Report CORG-R-180. AD 446 700.

Abstract: "This preliminary handbook was developed for use by Army Combat Development Command field agencies and ad hoc study groups in the preparation of cost-effectiveness studies. The handbook discusses the purpose of cost-effectiveness Analysis, general methods for comparing alternative systems, and the major elements of the analysis. Two examples of cost-effectiveness evaluations are presented. General references and a bibliography of published sources for cost data and of publications on systems and force structure costing are included."

Abstract.
Purpose and Scope of Handbook.
Purpose of Cost-Effectiveness Analysis.
General Methods for Evaluating Materiel Systems.
Elements of the Analysis: general; objectives; alternatives; costs; models; criteria.
Sources for Cost Data.
Examples of Cost-Effectiveness Evaluations.
Appendix A. Examples of Cost Effectiveness Evaluations.
Appendix B. Reference and Bibliography.
Appendix C. Study Directive.

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Preparation and Submission of Annual Budget Estimates
Bureau of the Budget

Washington, Executive Office of the President, 1969, 201 p.
BOB Circular A-11.

General Information and Policies: general requirements; general policies; format of material.
Information Required for Budget Examination Generally: concepts, classifications, and sequence of material; summary statements; analysis and justification of programs; justification of particular requirements.
Information Required for the Budget Appendix: language sheets and explanations; programming and financing schedules; object classification and personnel summary; schedules on detail of permanent positions; narrative statements on program and performance; business type budget statements; special statements.
Additional Data Required for Analysis: supplementary source document; data on Federal credit programs; summary information on construction of Federal civil public works; data on research and development; data on health programs; data on education and related programs; data on agency borrowing and investment; data on programs for reduction of crime; data on Federal income security programs; data on Federal manpower programs.
Appendix A. Chapter and Organization Codes.
Appendix B. Character Classification Definitions and Codes.
Appendix C. Coverage of Federal Credit Programs.
Appendix D. Receipt Categories.
Index.

A Primer of Cost-Effectiveness
Sutherland, William H.

McLean, Research Corporation, 1967, 95 p.
Technical Paper RAC-TP-250. AD 816 751.

I. The General Purpose of Studies: why this primer? what goes into studies; responsibility for decisions and responsibility in studies; measurables and unmeasurables; commensurables and incommensurables.
II. The Five Essentials of a Cost-Effectiveness Study: objectives and effectiveness; problems in devising measures of effectiveness; broad and narrow measures; costs as one of the essentials; models; a model for an artillery study; criteria.
III. Costing Procedures: costs as measures of resources; opportunity loss; what goes into the costs of forces and equipment; cost-estimating relations; learning curves; sunk costs; discounting and amortization.
IV. Analysis Techniques: the place of techniques in systematic quantitative analysis; ways of showing cost effectiveness of alternatives; more about cost-effectiveness curves; analyzing mixes of alternatives; sensitivity analysis.
V. Summary and Concluding Remarks.
References.

Problems in the Use of Discounting
Cownie, John

Washington, DC, Office of the Assistant Secretary of Defense (SA) Economics, 1967, 11 p.

"This paper describes and briefly evaluates some of the objections which have been raised against the use of discounting in DOD cost analysis. Some objections may be entirely misconceived, but many have a sort of partial validity; arguments from the latter group often serve the function of delimiting the areas within which the discounting procedure is properly applicable. The function of 'answers' to such objections is not to rationalize them away, but rather to specify clearly the restrictions which they impose upon the use of discounting."

Introduction.
The "Borrowing Rate" Argument.
Indefinite Cost Streams.
Juggled Cost Streams.
Unequal Effectiveness.
Risk and the Discount Rate.
"Future Generations" Arguments.
Uncertainty about the Discount Rate.
Relative Factor Prices.
Unemployment and Discounting.
Conclusion.

Proceedings of the First Annual US Army Materiel Command Systems Analysis Symposium
Pollard, Robert

Washington, US Army Materiel Command, 1969, 210 p.
Technical Report 69-1. [redacted] AD-689 485

Welcome Remarks (COL Leonard D. Mitchell).
A View of Systems Analysis (LGEN William B. Bunker).
The Systems Analysis Effort Within AMC (William J. Tropt).
Organization and Functions of the Army Materiel Systems Analysis Agency (Dr. Joseph Sperrazza).
Preliminary Concepts for a Tactical Logistic Vehicle Evaluation Methodology (CPT Martin Wachs).
A Conceptual Framework for Tactical Logistic Vehicle Evaluation (A.L. Smith).
Informal Remarks to AMC Systems Analysis Symposium (Hon. Alain C. Enthoven).
Cost Analysis Technical Manual (CATEM) (LT Barry E. Feldman).
A New Graphic Probabilistic Approach to PERT (Dr. Donald T. Barsky).
TROMOD - A Cost Presentation Model (LT James Wormley).
A Panel from the Research Analysis Corporation.
Operations Research in AMC - Past and Future (Abraham Golub).
A Time Dependent Artillery Evaluation Model (Alan S. Thomas).
Semigaming Methodology for Dynamic Threat Description (Arand N. Reid).
Systems Analysis Capabilities at the US Army Electronics Command (Daniel Salvano).
Effectiveness Analysis of Common User Communication System (Michael A. Benanti).
The Organizational Structure of the US Army Aviation Systems Command (Havard M. Hauer).

Proceedings of the NMSE Systems Performance Effectiveness Conference

Washington, US Naval Applied Science Laboratory, 1965, 223 p.
AD 629 145.

This Document contains nineteen papers presented at the NMSE Systems Performance Effectiveness Conference held in Washington, DC, on April 27 and 28, 1965. These papers summarize the status of the rapidly expanding Navywide effort in systems effectiveness. Some of the topics covered in these papers include: reliability, maintainability; logistics and technical support, and subsystem performance of both the man and the machine.

Welcome (RADM G.A. Curtis).
Introductory Remarks (VADM I.J. Galantin).
Systems Effectiveness in the Bureau of Naval Weapons (RADM E.E. Fawkes).
NMSE Program for System Effectiveness (John W. Stone).
System Performance Effectiveness Program and Program for Advanced Concepts in Electronic Design (Paul J. Giordano).
System Effectiveness Analysis: Illustrative Example of Methodology (Sol Seltzer).
Designing for Integrated Maintainability: Concepts and Approaches (John Sanderson).
Life Cycle and Implications (Pantelis Spouros).
Naval Aviation Maintenance and Material Management System (CDR T.W. Teal).
Integrated Maintenance Management, WR-30, Applied to Feasibility Phase (J.F. Witten and James Genovese).
Reliability and Maintainability Tradeoffs (Sidney Orbach).
Design Criteria for Throwaway Versus Repair Maintenance (A.E. Rupp).
Design Disclosure Format Development (Ralph DePaul).
Microelectronics for Integrated Shipboard Systems (Tom McDuffie).
Enhanced Maintainability Through Automatic Performance Monitoring and Fault Isolation (CDR C.W. Postlethwaite).
Technical Data Base for Integrated Logistic Support (C.L. Kerr).
The Allowance List as a Function of System Effectiveness (A.S. Rhode).
Human Factors and Training Aspects of ILS (W.L. Hopkins)

Proceedings of the Second Symposium in Linear Programming
Office of Scientific Research

Washington Department of the Air Force, 1955, 2 vol., 685 p.

Part 1: applications (chapters 1-12); Part 2: economic theory (chapters 13-18); Part 3: computation (chapters 19-26); Part 4: theory of linear inequalities (chapters 27-32); Part 5: developments on linear programming (chapter 33).

I. Military Applications of Linear Programming (Walter Jacobs).
II. Linear Programming in Bid Evaluations (Leon Gainen).
III. Linear Programming in the Face of Uncertainty (J.M. Danskin).
IV. The Assembly Line Balancing Problem (M.E. Salveson).
V. A Commercial Use of Linear Programming (James H. Batchelor).
VI. A Model for Optimizing Production by Reference to Cost Surrogates (A. Charnes, W.W. Cooper, B. Mellon).
VII. A Production Smoothing Problem (George Dantzig and Selmer Johnson).
VIII. A Linear Programming and Structural Design (J. Foulkes).
IX. Application of Linear Programming to Optical Filter Design (Alex Orden).
X. Programming under Conditions of Uncertainty (D.F. Votaw, Jr.).
XI. Stochastic Linear Programming with Applications to Agricultural Economics (G. Tintner).
XII. Dynamic Programming and Multi-Stage Decision Processes of Stochastic Type (Richard Bellman).
XIII. Linear Programming and Economic Theory (Paul A. Samuelson).
XIV. On a Theorem of Wald (H.W. Kuhn).
XV. Competitive Equilibrium with Dependent Consumer Preferences (Lionel W. McKenzie).
XVI. Limitationality, Limitativeness, and Economic Equilibrium (Nicholas Georgescu-Roegen).
XVII. An Activity Analysis Approach to Location Theory (M. Beckmann and T. Marschak).
XVIII. The Linear Team (Roy Radner).
XIX. How to Solve a Linear Programming Problem (A.J. Hoffman).
XX. Projection Methods in Calculation (C. Tompkins).
XXI. Reduction of Systems of Linear Relations (Philip Wolfe).
XXII. Optimizing a Function of Additively Separated Variables Subject to a Simple Restriction (Andrew Vazsonyi).
XXIII. Some Results in Non-Linear Programming (R.M. Thrall).
XXIV. A First Feasible Solution to the Linear Programming Problem (Saul I. Gass).
XXV. Concepts and Computing Procedures for Certain X_{ij} Programming Problems (Harry Markowitz).
XXVI. Linear Programming Activities in England (S. Vajda).
XXVII. Linear Inequalities and Convex Polyhedral Sets (A.W. Tucker).

XXVIII. Consistency Conditions for Finite and Infinite Systems of Linear Inequalities (Ky Fan).
XXIX. The Probability of Solvability of Linear Inequalities (T.S. Motzkin).
XXX. Optimal Rays for Linear Programs (A.J. Goldman).
XXXI. Distribution of a Product by Several Properties (Emil D. Schell).
XXXII. On the Travelling Salesman's Problem (I. Heller).
XXXIII. Developments in Linear Programming (George B. Dantzig).

PROCESS - A Probabilistic Cost Estimating System Simulator
Durrwachter, Henry W.; C. Richard Conger; D.W. Lucsak; R.D. Sheeder; J.M. Zrno.

Science Park, HRB-Singer, 1967, 58 p.
Singer Report S-160. AD 813 331

Abstract: "This report presents one method of evaluating uncertainties. The cost analyst estimates for each significant system cost or requirement a high and low value. In addition, he selects one of nine Beta distributions which he feels best describes the uncertainties associated with the cost or requirement. Each distribution and its associated data are then inserted into a total life cycle system cost model and combined through a series of computer routines using a Monte Carlo sampling technique, to establish a single distribution. This distribution is plotted as a histogram which represents the uncertainties associated with probable total system cost."

I. Introduction.
II. Technical Approach: discussion of problem; problem solution alternatives.
III. Discussion of PROCESS: assumptions; programming approach.
IV. Program Usage and Case Studies: general program usage; case studies (operating costs, life cycle system cost, equipment design project).
Appendix A. Definition of Terms, Flow Charts, and Program.
Appendix B. Input Data Format.
Appendix C. PROCESS Computer Program.

Program Budgeting . . .
Novick, David, Editor

Santa Monica, The Rand Corporation, 1965, 236 p.

Preface: This book concentrates on the program aspects of the budget. It avoids problems of fiscal policy, revenue, and related issues. Part 1: government decision making and the program budget (chapters 1,2); Part 2: actual and potential applications of the program budget idea (chapters 3-8); Part 3: implementation and operation (chapter 9).

I. Conceptual Framework for the Program Budget (Arthur Smithies).
II. The Role of Cost-Utility Analysis in Program Budgeting (Gene H. Fisher).
III. The Department of Defense (David Novick).
Appendix. Illustrative Example of Cost-Utility Considerations in a Military Context (Gene H. Fisher).
IV. The Space Program (Milton A. Margolis and Stephen M. Barro).
V. Transportation in the Program Budget (John R. Meyer).
VI. Education in the Program Budget (Werner Z. Hirsch).
VII. Federal Health Expenditures in a Program Budget (Marvin Frankel).
VIII. Program Budget for Natural Resources Activities (Werner Z. Hirsch).
IX. Problems, Limitations, and Risks (Roland N. McKean and Melvin Anshen).

Project Modelling: A Technique for Estimating Time-Cost-Performance Trade-Offs in System Development Projects
Zschau, E.V.W.

Santa Monica, The Rand Corporation, 1969, 94 p.
Rand Memorandum RM-5304-PR. AD 691 810.

Summary: "This memorandum outlines a preliminary methodology for estimating time-cost-performance trade-offs to help with the planning of system development projects. In addition to describing how the models might be constructed, this study discusses how the information derived from them could be used in the system planning process, and focuses on some important methodological problems that must be solved in order to make the project modelling approach operational."

Preface.
Summary.
I. Introduction: the structure of system development decisions; four reasons why project trade-offs are difficult to measure; an outline of the project modelling approach.
II. Formulating Project Models: introduction; the system design model; the project schedule model; gathering activity cost function estimates; synthesizing the system model and the schedule model.
III. Using Project Models: the project model as a trade-off function; replanning projects using feedback information; analyzing and reducing the effect of uncertainty with project modelling; using project modelling within the framework of current DOD and AF management practices.
IV. Extensions and Needed Research: developing efficient computational methods; developing extensions to the basic approach; conducting field studies.
References.

The Quantity versus the Quality for the Data Used in the Derivation of a Cost Estimating Relationship
Zumman, Morris

Arlington, Institute for Defense Analyses (Cost Analysis Group), 1969, 29 p., Research Paper P-481. IDA Log No. HQ 69-10701. AD 699 131.

Presented at the Joint National Meeting of the Operations Research Society of America and the American Astronomical Society, 18 June 1969. Summary: "One of the most important, time consuming, and expensive steps necessary in the development of a cost model is the collection and analysis of data that will be used to derive the model's cost estimating relationships. Tradeoffs on how a cost analyst might best allocate his time between collecting the data on additional programs and analysing in further detail the data already in his possession are presented. The measure of the cost analyst's productivity is the reduction in the confidence bandwidth about the cost estimate. These trade-off curves indicate that the cost analyst rapidly runs into the law of diminishing returns for effort expended gathering additional data and/or refining the data in his possession when his productivity is measured as the reduction in the confidence bandwidth about the cost estimate. Curves and equations showing the ratio of confidence bandwidth for an estimate derived from a data base of size n, to the confidence bandwidth for an estimate derived from an infinite data base are presented for both the cases where the costs are assumed to have a normal distribution and a log normal distribution. The analyses presented are only applicable to confidence statements that are made about estimates for a single future occurence and not for estimates about a population mean. It is argued that the uncertainty about an estimate is caused by essentially three factors, the randomness of the actual cost distribution, the randomness of the cost estimator's distribution, and the bias of the estimator. For most practical problems only the estimator's variance can be reduced by increasing the data base size and refining the data. The cost randomness and estimator bias are essentially independent of the data base size and degree of refinement."

Foreward.
Summary.
A. Basic Assumptions: measure of productivity (cost randomness, estimator bias, randomness of the estimator); preparation of CERs.
B. The "Quantity" versus "Quality" Trade-Off.
Appendix. Confidence Bandwidths for the Log Normal Distribution.

Quasilinearisation and Nonlinear Boundary-Value Problems
Bellman, Richard E. and Robert E. Kalaba

Santa Monica, The Rand Corporation, 1965, 208 p.
Rand No. R-438-PR. AD 470 604.

"This volume is intended as an introduction to quasilinearization, aimed both at those who are solely interested in the analysis, and those who are primarily busied with applications . . . . The objectives of the theory of quasilinearization are easily stated. First, we desire a uniform approach to the study of the existence and uniqueness of the solutions of ordinary and partial differential equations subject to initial and boundary-value conditions. Furthermore, we want representation theorems for these solutions in terms of the solutions of linear equations. Finally, we want a uniform approach to the numerical solution of both descriptive and variational problems which possesses various properties and rapidity of convergence." Bibliography follows each chapter.

Introduction.

I. The Riccati Equation: Newton-Raphson method; multidimensional version; square roots; quasilinearization; Riccati equation; first order linear equation; solution of Riccati equation; upper and lower bounds; successive approximations; monotonicity; a a fundamental lemma.

II. Two-Point Boundary-Value Problem for Second-Order Differential Equations: inhomogeneous equation; vector-matrix approach; Green's functions; convexity; quasilinearization; existence and boundedness; convergence; general second-order nonlinear differential equations; calculus of variations; solution of inner problem; dynamic programming; invariant imbedding.

III. Monotone Behavior and Differential Inequalities: positivity result; characteristic values; variational approach.

IV. Systems of Differential Equations, Storage and Differential Approximation: quasilinearization applied to systems; solution of linear system, multipoint boundary-value problems; simultaneous calculation of approximations; back and forth integrations; a renewal equation.

V. Partial Differential Equations: parabolic, elliptic, Hopf-Lax.

VI. Applications in Physics; Engineering; and Biology.

VII. Dynamic Programming and Quasilinearization: basic functional equation; dynamic programming and differential approximations.

Appendix 1. Minimum Time Program.
Appendix 2. Design and Control Program.
Appendix 3. Program for Radiative Transfer - Inverse Problem for Two Slabs, Three Constants.
Appendix 4. Van Der Pol Quation Program.
Appendix 5. Orbit Determination Program.
Appendix 6. Cardiology Program.
Index.

Readings in Command Management: Modern Analytical Methods
US Army Command and General Staff College

Fort Leavenworth, USACGSC, 1967, 386 p.
Reference Book RB 20-5, Volume II.

I. Military Technology and the Policy Process (Tarr).
II. Systems Analysis (Hayes).
III. Systems Engineering Barney).
IV. Decision Theory and Systems Analysis (Enthoven).
V. The Army and Cost/Effective (von Kann).
VI. Cost-Effectiveness: an Introduction and Overview (Quade).
VII. Cost-Effectiveness - Fact and Fancy (Tucker).
VIII. Guide for Reviewers of Studies Containing Cost-Effectiveness Analysis.
IX. Operations Research - A New Science? (Hoag).
X. Operations Analysis in the Department of Defense (Hitch).
XI. Operations Research (Hazelwood).
XII. Military Systems Analysis (Quade).
XIII. Some Facets of Systems Analysis (Murray).
XIV. Firepower - Tool for Systems Analysis? (Rice and Hatch).
XV. The Myth of Decision by Computer (Seigle).
XVI. "On Line" in "Real Time" (Burck).
XVII. Illustrated Problems.
XVIII. An Over-all View of PERT (Getz).
XIX. Project Management and PERT (AMETA).
XX. Program Evaluation and Review Technique (PERT) (ASD, USAF).
XXI. Common Problems Associated with Implementation of the PERT Cost System (PERT Coordination Group, BuWeps, Department of Navy).
XXII. How to Plan and Control with PERT (Miller).
XXIII. PERT (Armed Forces Management, Jan 1963).
XXIV. Panel. Network Techniques (Army OR Symposium 1964).
XXV. Practical Advice for the Use of PERT (Francis).
XXVI. The Critical Path Method and Military Planning (Hatch).
Appendix A. Glossary.
Appendix B. Bibliography.

Research and Development - Program/Budget Costs - Definitions
Office of the Assistant Secretary of Defense (Comptroller)

Washington, Department of Defense, 1968, 18 p.
DODI 7220.5.

References.
I. Purpose.
II. Applicability and Scope.
III. Cancellations.
IV. Policy and Definitions.
V. Uniform Program/Budget and Accounting Classification for R&D Resources.
VI. Effective Date and Implementation.
Enclosure 1. R&D and RDT&E Program/Budget Aggregates Definitions.
Enclosure 2. References (continued).

Resource Analysis and Long-Range Planning
Novick, David

Santa Monica, The Rand Corporation, 1963, 22 p.
Rand Memorandum RM-3658-PR. AD 406 844.

Summary: "Program budgeting, cost effectiveness, and cost analysis are terms used with increasing frequency in our military establishment. This memorandum discusses each of the terms, with emphasis on cost analysis, and shows how the concepts that they represent are important for Air Force long-range planning. Since this memorandum is intended primarily for persons who must provide inputs to, as well as use the results of, cost analyses, examples are given of the kind of detailed information required."

Preface.
Summary.
Text.
Bibliography.

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Resource Analysis in Military Long-Ranging Planning
Novick, D.

Santa Monica, The Rand Corporation, 1964, 13 p.
Rand No. P-2861. AD 431 524.

"Military planning in the Department of Defense is now administered through the program budget procedure. This arrays the national security objectives in terms of major missions and the major systems for accomplishing them. In this process a wide range of alternative equipments are considered as well as varying possibilities for deployment or operation of them. Each possibility is translated in terms not only of military effectiveness but also of the cost of obtaining and operating that capability. This paper discusses the elements of the new decision-making process introduced by Robert McNamara in 1961."

Program Budgeting.
Cost Effectiveness.
Cost Analysis.
Conclusion.

The Role of Cost Analysis
Yates, Edward H.

Santa Barbara, Defense Research Corporation, 1964, 11 p.
IMR-183. AIAA Paper No. 64-408.

"A discussion of the general procedures involved in cost analysis and the derivation of costs for inclusion in the overall procedure. Specific applications of cost analysis are presented, followed by a discussion of accuracy and future developments in cost analysis."

Introduction.
General Procedures.
Derivation of Costs.
Cost Tasks as Related to Program Bases.
Applications of Cost Analysis.
Accuracy of Cost Estimates.
Future Developments in Cost Analysis.
List of References.
Appendix. Independent Variables Used in Estimating Various Cost Categories.
Table 1. Typical Cost Elements for Missile or Space Systems.
Table 2. Forms of Estimating Equations.
Table 3. Examples of Estimating Equations.
Table 4. Applications of Cost Estimating Relationships.
Figure 1. Development of CERs.
Figure 2. Progress Curves Resulting from the Assumption of a Linear Cumulative Average Curve on Logarithmic Grids.
Figure 4. Cumulative Total Costs of Alternate Communication Systems as a Function of Cumulative Years.
Figure 5. Effectiveness Versus Budget for Alternative Weapon Systems.
Figure 6. Force Plan #1 - Total Cost Analysis.
Figure 7. Illustration of Sensitivity Analysis.

The Role of Cost-Utility Analysis in Program Budgeting
Fisher, G.H.

Santa Monica, The Rand Corporation, 1964, 39 p.
Rand Memorandum RM-4279-RC. AD 608 055.

"This memorandum outlines the main characteristics of cost-utility analysis and some of the major considerations involved in carrying out such an analysis.

Preface.
Summary.
Introduction.
What is Cost-Utility Analysis?
The Primary Purpose of Cost-Utility Analysis.
Some of the Major Considerations Involved in Doing Cost-Utility Analysis: proper structuring of the problem and design of the analysis; the conceptual framework; building the model; treatment of uncertainty; treatment of problem associated with time; validity checking; qualitative supplementation; summary comments.
A Military Illustrative Example: general statement of the problem; further consideration of the problem; some considerations in the strategic bombardment area; summary analyses of cost and utility; a purely qualitative analysis; a sub-system illustrative example.
A Non-Military Example: the project's estimated utility; cost considerations; summary of utility considerations; ranking of projects.
Summary of the Chapter.

The Simple Mathematics of Maximization
Enthoven, Alain C.

Santa Monica, The Rand Corporation, 1959, 70 p.
Rand No. P-1833.

"Formulated in economic terms, a problem of choice can often be reduced to that of determining the maximum or minimum of a function of variables that are constrained to lie within a limited region. The function is an index of the extent to which some objective or set of objectives has been achieved. It provides a ranking of all possible combinations of the variables on which it depends, at least in the region of interest. The variables represent the extent to which various resources are employed in the achievement of the objective. Their values are constrained to lie within a limited region corresponding to the resources available because the resources are limited."

I. Introduction.
II. Constrained Maxima
III. Economic Efficiency.
IV. Generalizations - Nonlinear Programming.
V. How to Find the Maximum - The Gradient Method.
VI. Decentralization and Sub-Optimization.
VII. Maximization against an Opponent.
Footnotes.

Some Applications of the Theory of Dynamic Programming - A Review
Bellman, Richard

Santa Monica, The Rand Corporation, 1954, 23 p.
Rand No. P-490.

Summary: "The purpose of this paper is to provide an expository account of the theory of dynamic programming. To illustrate the general principles, two particular problems, one of deterministic type and one of stochastic type, are treated."

I. Introduction.
II. Optimal Allocation - Classical Formulation.
III. Optimal Allocation - Functional Equation Approach.
IV. Computational Techniques.
V. Some Typical Results.
VI. Gold Mining.
VII. Functional Equation Approach.
VIII. The Solution.
IX. Discussion of the Solution.
X. A General Description of the Dynamic Programming Problems.
XI. Some Typical Problems.
References.

Some Interest Rate Aspects of Weapon Systems Investment Policy
Sobin, B.

Arlington, Institute for Defense Analyses (Weapons Systems Evaluation Division), 1965, 70 p.
Research Paper P-171.

"This paper presents a formal examination of the theoretical basis for the use of interest rates in weapons systems evaluations and an analysis of economic data that yield a numerical estimate of a suggested rate of interest. The model on which the interest rate concept is based uses techniques that economists have used in analysis of consumer behavior and in some monetary theory. The novel aspects of the model are the kinds of data used and the emphasis placed on Department of Defense problems."

Introduction.
Conclusions.
Definitions.
Discussion: the place of interest in a simple optimizing model; the place of interest in DOD planning; rates of return applicable to DOD investment decisions.
Appendix. Current Government Interest Rates Outside the Department of Defense.

Some Curve-Fitting Fundamentals
Petruschell, R.L.

Santa Monica, The Rand Corporation, 1968, 134 p.
Rand Memorandum RM-5766-SA. AD 680 613.

Prepared for the Office of the Assistant Secretary of Defense (Systems Analysis). Summary: "Much of the difficulty cost analysts have with curve fitting results from an inadequate grounding in the analytic geometry of the empirical equations with which they work. This Memorandum attempts to provide a concise but relatively thorough discussion of this subject while at the same time demonstrating selected methods for doing mechanical curve fitting. The material is presented in three parts. Section I discusses the properties of the straight line, the exponential, the power function, and the parabola. Included in the discussion of the exponential are the laws for exponents and hence logarithms. Emphasis is on providing insights into the impact of the parameter values on the form of the resultant curves. Graphical illustrations are used extensively. Section II presents different methods of using these curves to describe the relationship between two variables. It discusses the method of selected points, the method of averages, and the method of least squares, making considerable use of scatter diagrams. It describes a number of measures of goodness of fit including the standard deviation, the coefficient of variation, and an average percent deviation. Throughout this section, computational procedures are carried out in complete detail. The discussion of curve fitting is continued in Section III, where cases with more than two variables are considered. By using the method of successive approximations, the initial discussion attempts to convey the idea of a net relationship between two variables, eliminating influence of any others, and thus to clarify the meaning of the coefficient in the multivariate linear equation. The method of least squares is shown to produce the same results as did the method of successive approximations and with significantly less computational effort. The discussion turns next to the nonlinear case. Each of the functional forms described earlier - the exponential, the power function, and the parabola - is used to describe a nonlinear relationship between three variables. Although the method of successive approximations may be used for fitting curves to nonlinear relationships, only the method of least squares is described. The decision to discuss the analytics and the curve-fitting methods in separate sections of the Memorandum was purely arbitrary. For many purposes, the user of this material will want to combine his readings in the first section with his readings in subsequent sections. The parallel nature of the presentations in each section was designed to facilitate this."

Preface.
Summary.
I. Curve Fitting and Empirical Equations: introduction; some basic analytic geometry (straight line, parabola, exponential, power function).
II. Fitting Curves to Two-Variable Relationships: straight line (selected points, averages, least squares); parabola (form 1, form 2); exponential; power function.
III. Three-Variable Curve Fitting: linear case; nonlinear case.
Appendix A. Derivation of the Normal Equations for a Least-Squares Fit of a Straight Line, a Parabola, and a Three-Variable Linear Equation.
Appendix B. Derivation of the Formula for Calculating the Constant.
Bibliography.

Standard Rates for Costing Military Personnel Services
Office of the Assistant Secretary of Defense (Comptroller)

Washington, Department of Defense, 1970, 7 p.
DODI 7220.25.

This instruction prescribes the standard rates to be used in computing costs of military personnel services as an element of operating expenses.

I. Purpose.
II. Cancellation.
III. Applicability.
IV. Standard Rates.
V. Elements of the Standard Rates: basic pay; basic allowance for quarters; miscellaneous expense; incentive and special pay (aircrew and submarine pay, other hazardous duty, physicians and dentists, sea and duty at certain locations, proficiency pay, hostile fire pay); retirement entitlement accrual.
VI. Effective Date and Implementation.
Enclosure 1. Elements of the Annual Standard Rates - FY 1971.

Statistical Cost Estimating Relationships - Some Basic Issues (Aircraft Examples)
Hatry, Harry P.

Washington, Office of the Assistant Secretary of Defense (Systems Analysis), 1966, 25 p.
TP 66-3. AD 659 321.

This paper discusses some of the basic issues of statistical cost estimating relationships and describes briefly some of the recent studies which have attempted to develop such CERs on aircraft programs.

I. Purpose.
II. The Major Characteristics of Statistical CER Techniques.
III. The Cost Estimating Task Addressed Here.
IV. Why CERs?
V. Major Problems in the Development of Statistical CERs.
VI. Specific OSD Aircraft Studies.
VII. Summary of Advantages and Disadvantages of Statistical CERs.

Statistical Inference
Walker, Helen M. and Joseph Lev

New York, Holt, Rinehart and Winston, 1953, 510 p.

I. Inferences Based on Simple Experiments.
II. Probability Distributions.
III. Inferences Concerning Proportions.
IV. Chi-Square.
V. Populations and Samples on a Continuous Variable.
VI. Sampling Distributions.
VII. Inferences Concerning the Mean or the Difference Between Two Means.
VIII. Inferences Concerning Variances and Standard Deviations of Normal Populations.
IX. Analysis of Variance.
X. Linear Regression and Correlation.
XI. Other Measures of Relationship.
XII. The Statistics of Measurement.
XIII. Multiple Regression and Correlation.
XIV. Analysis of Variance with Two or More Variables of Classification.
XV. Analysis of Covariance.
XVI. Percentiles.
XVII. Transformation of Scales.
XVIII. Non-Parametric Methods.
Appendix. Tables and Charts.
Glossary and Symbols.
Answers to Problems.
Index to Subject Matter.
Index of Authors.

Statistical Manual: Methods of Making Experimental Inferences
Churchman, C.W.

Philadelphia, Pitman-Dunn Laboratory, 1951, 214 p.

"This manual attempts to emphasize clarity in the method of applying statistical tests, together with the logic of their application. The manual minimizes to the greatest possible extent the mathematical and technical foundations of the methods; it presents only those terms that are presumably essential in understanding the logic of statistical methods and the steps in their application."

Introduction.
Glossary.

I. Some Standard Procedures: test of a mean, variance known; test of a mean, variance unknown; test equality of two means, variance known; test equality of two means, variance unknown; test of equality of means of paired differences; test of equality of a set of means, variance known; test of equality of a set of means, variance unknown; test of a simple variance; test of equality of two variances; test of equality of a set of variances; test of equality of two probabilities; factorially designed experiments; test of equality of a set of means and variances; test of correlation; tests of normality; test for erratic observations; test for independence of observations; test for proportion of a universe in the tail.

II. Estimation: common point estimates; confidence intervals; estimate of slope and intercept, both variables subject to error; estimate of mean and variance for sensitivity data.

III. Sequential Analysis: test of a probability; test of equality of two probabilities; test of a mean, variance known; test of a variance.

IV. Simplified Procedures: statistical sign test; ranking tests for differences; test of runs of some property of the observations; test of differences among a set of universes.

Tables and Figures.

Statistical Methods for Decision Making
Chance, William A.

Homewood, Richard D. Irwin, 1969, 442 p.

This book is intended to serve as an introduction to the wide range of statistical methods which are available to the modern decision maker. This range includes the traditional statistical methods which have served so well for many years, as well as techniques of Bayesian analysis which have regained major impetus in the last decade. Attention is also given to the category of statistical inference commonly designated as 'nonparametric statistics.'

I. Probability and Uncertainty: uncertainty and risk; probability and uncertainty; basic properties of uncertainty; experiment, sample space, events; rules for calculating probabilities; conditional probability; rules for counting; comparison of the binomial and the hypergeometric distribution; probability and experience.
II. Tests of Hypotheses, Part 1: flow diagram; the Wilcoxon test; role of information; the null hypothesis and its alternatives; logarithms.
III. Random Variables and Probability Distributions: expected values; mean and variance; standard deviation; Tchebycheff's inequality; graphs of discrete probability distributions; the median and the mode; cumulative probability distributions; skewness and kurtosis.
IV. The Binomial Distribution and the Normal Distribution: characteristics; tables; appropriateness; the Bernoulli model; approximating hypergeometric probabilities with binomial probabilities; large samples; the standardized normal distribution.
V. Samples, Frequency Distributions, and Sampling Distributions: populations and samples; purpose of randomness; sample statistics; finite and infinite populations.
VI. Tests of Hypotheses, Part 2: decision errors; students' t-distribution; types of tests.
VII. Estimation Procedures: regression and correlation analysis; terminology and notation; the model; the scatter diagram; the regression equation; the problem of prediction; the coefficient of determination; a test for the significance of the relationship.
VIII. Fitting a Probability Distribution to a Set of Data.
IX. Simulation, Monte Carlo Methods.
X. Some Elements of Statistical Decision Theory: determination of the costs associated with the state of the process; determination of the conditional costs resulting from the testing procedure; procedure for minimizing expected cost; Bayes' theorem; the role of sample information.

Appendix. Statistical Analysis and the Computer
Tables: selected values of Wilcoxon's distribution; binomial distributions; areas under the normal curve; random digits; critical values of student's t for specified degrees of freedom; critical values of χ_α^2 for specified degrees of freedom; four-place logarithms; logarithms of factorials.
Index.

Statistical Theory
Lindgren, B.W.

New York, MacMillan Company, 1962, 427 p.

This book expounds clearly and objectively some modern statistical theory, together with the elements of the more classical theory of statistics, in a mathematical setting that can be completed and amplified at a later stage.

I. Probability Models: model spaces; probability spaces; dependence and independence.
II. Univariate Distributions: distribution of probability in the space of values; expectation; moments and generating functions; some useful discrete models; continuous cases.
III. Several Random Variables: vibariate distributions; multivariate distributions.
IV. Sums of Random Variables: distribution of a sum; distribution of a sum of independent variables; limit theorems.
V. Statistical Problems and Procedures: utility, loss and regret; the no-data decision problem; sampling; using data in decisions; sufficient statistics; some properties of procedures; monotone problems and procedures; sample size and cost of sampling.
VI. Estimation: some properties of estimators; determination of estimators.
VII. Testing Hypotheses: simple H_0 and H_1; composite hypotheses; sequential tests.
VIII. Some Distribution Theory: order statistics and related distributions; distributions related to normal populations.
IX. Some One-Sampling Problems: goodness of fit; some special one-parameter models; normal populations; a large-sample test for the mean; location as measured by the median; randomness.
X. Comparisons: based on sample distribution functions; large sample comparison of means; bernoulli populations; normal populations; nonparametric comparison of locations.
XI. Linear Models and analysis of variance: regression; analysis of variance; a general linear model.

References.
Appendix - Tables.
Answers to Problems.
Index.

Statistics in Cost Prediction Problems and Potential
Piccariello, Harry

Washington, Office of the Assistant Secretary of Defense (Systems Analysis), 1966, 10 p.
TP 66-5. AD 659 322.

"A discussion of the application of statistical techniques for determining cost estimates (predictors), in particular: a) why the use of statistics, b) problems associated with their use, and c) some possible approaches which avoid the problems or may lead to a solution of these problems."

Introduction.
Why the Use of Statistics.
Problems: normal regression analysis; separate estimation of components parts.
Other Approaches: historical simulation; direct estimation of total costs; selection of functional forms.
Summing Up.

Structuring Cost Effectiveness Analyses
Abert, James G.

Logistics Review and Military Logistics Journal, Vol. II, No. 7, 1966, pp. 19-34.

"The objective of this paper is to set forth in relatively simple terms an analytical framework for structuring cost-effectiveness studies and to point out some of the pitfalls involved in framing these studies. The main emphasis is on the problem associated with time phasing in the design of cost-effectiveness studies and the evaluation of what are called, in the paper, time-phased cost and effectiveness profiles."

I. Introduction.
II. Types of Cost Effectiveness Analysis: equal cost; equal effectiveness; unequal cost/effectiveness.
III. Evaluating the Economic Effects of Time-Phased Costs.
IV. Discounting as a Means of Evaluating Alternative Resource Allocations.
Appendix. The Use of Discounting in Computing Program Costs; Calculating the Resource Impact of Investment Expenditures; Calculating the Impact of Operating Costs.

"A Suggested Treatment of Time-Distributed Expenditures in Defense Systems Analysis"
Niskanen, W.A.

Arlington, Institute for Defense Analyses (Economic and Political Studies Division), 17 October 1966, 17 p.
Internal Note N-39(R). Log No. IDA/HQ 66-5423.

A paper presented at the 30th national meeting of the Operations Research Society of America at Durham, North Carolina, on 17 October 1966.

This paper argues "that the maximization conditions for either the government or the economy suggest the use of a consistent set of rules for the aggregation of costs for all systems analyses. These rules apply to the three primary problems of aggregating systems costs: (a) selection of the planning period, (b) estimation of the value of resources at the beginning and end of the planning period, and (c) selection of the rate of interest for present value computations. In several cases, a roughly accurate rule-of-thumb is suggested as a substitute for the conceptually precise rule. Special attention is focused on the rationale for the use of interest in systems analyses and on the selection of the appropriate rate."

Introduction.
Presentation of the Basic Cost Estimates: fixed; investment; operating.
Selecting the Planning Period.
Estimating the Residual Values.
Selecting the Interest Rate.

A Survey of Army Automated Cost Models
Curd, Paul and Ogden Allsbrook, Compilers

Washington, Department of the Army, 1968, 178 p.
AD 829 321.

This survey is designed to catalog and describe all cost models which are either operational or under development for the benefit of personnel in cost research and cost analysis.

Abstracts:
- Resource and Capabilities Model (RECAP).
- Modular Force Planning System (MFPS).
- Cost Factoring System for Force Readiness Projection.
- Selected Analysis of Intratheater Transportation Systems.
- Revaluation of the Army Tactical Vehicle Program (REVAL - Wheels).
- Individual System/Organization Cost Model (ISOC).
- The Army Division Cost Model.
- Army Depot Materiel Maintenance and Support Activities Cost Model.
- Combat Vehicle Production Cost Model.
- Forewon Cost Model.
- Army Aviation Cost Model.
- Production Costs US Army Weapon Systems.
- Army Air Defense Weapon System Cost Model.
- Army Aircraft Flying Hour Cost Model (AAFCOM).
- The MICOM Cost Model.
- Penetration Aids Cost Effectiveness Model.
- Army Aircraft Cost Model.
- Tank, Anti-Tank, and Assault Weapons Study (TATAWS - Phase II, Part 1).
- An Automated Cost Methodology and Data for the Small Arms Weapons System (SAWS) Study.
- Main Battle Tank 70 (MBT-70) Secondary Armament Study.
- Analytical Estimation of System Cost Uncertainty.
- A Model for the Determination of Intra-Theater Logistic Support Funding.
- Cost Models for AAFSS, Phase II.
- Army Division Cost Model/TATAWS Modification.
- A Basic Cost Model for Ammunition.
- The Role of Cost Effectiveness in the Preliminary Design of Vertical Lift Military Aircraft.
- Cost Effectiveness Study of Heavy Lift Aerial Vehicles.

Model Descriptions:
- Army Depot Materiel Maintenance and Support Activities Cost Model.
- The Army Division Cost Model.
- Combat Vehicle Production Cost Model.
- Analytical Estimation of System Cost Uncertainty.
- Selected Analysis of Intratheater Transportation Systems.
- Army Aircraft Cost Model.

Survey of Use by Federal Agencies of the Discounting Technique in Evaluating Future Programs
The Comptroller General of the United States

Report to the Joint Economic Committee, Congress of the United States, 28 January 1968, 32 p.

"The General Accounting Office has made a survey of the use by 23 selected Federal Agencies of the technique of discounting in making evaluations of future programs. The nature of the discounting technique is described in the background section of this report. The survey was made pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67). The survey was performed in Washington, DC, and was completed in December 1967 . . . . The survey was directed primarily toward determining the extent to which the discounting technique is presently employed by Federal agencies and the extent to which those agencies not employing this technique plan to do so and toward identifying the discount rates currently in use by the agencies. We did not evaluate the appropriateness of the agencies' stated policies and practices as they were revealed to us, neither did we examine into the actual discounting techniques and practices followed by the agencies or into other policies and practices used by them when evaluating Federal programs."

Letter to the Committee from the Comptroller General.
Introduction.
Back ground: explicit and implicit discount rates; effect of changes in discount rates on benefit-cost ratios; determination of discount rate.
Results of Survey: summary of agency practices; divergent agency views; significance of differing practices.
Appendix I. Discount Rates used by Federal Agencies in the Analysis of Individual Programs in Fiscal Year 1969.
Appendix II. Federal Agencies Not Using Discounting in the Analysis of Individual Programs in Fiscal Year 1969.
Appendix III. Illustration of Calculation of Total Cost to the Government of Borrowed Funds.
Appendix IV. Illustrative Copy of a Request for Information Concerning Discounting sent to Selected Agencies.
Appendix V. Letter Dated 19 December 1967, to the Comptroller General of the United States from the Chairman of the Joint Economic Committee.

System and Cost Effectiveness Manual for System Developers
Chop, Allen

Sunnyvale, Lockheed Missiles and Space Company, 1970, 269 p.
RADC-TR-69-358. AD 867 397.

Abstract: "The manual defines and describes the system and cost effectiveness management implementation process which will provide both Air Force and contractor management with the necessary mission responsive criteria, authoritative perspective, and visibility for critical system development decisions. Technical activities, procedures, guidelines, and objectives for the efficient and meaningful formulation of effectiveness criteria, and for the evaluation and assurance of effectiveness, are detailed on a step-by-step and time-phased, action basis for each of the systems management phases of concept formulation, contract definition, and acquisition. Further, the integration of the effectiveness implementation procedures with the system program management procedures and systems engineering management procedures is outlined for each major effectiveness activity and polarized with information flow networks." Air Force oriented.

I. Introduction: general; purpose of manual; use of manual; abbreviation and definition of terms used.
II. Implementation Overview of the System and Cost Effectiveness Technology: general; integrated system and cost effectiveness and systems management networks; system and cost effectiveness measures.
III. System and Cost-Effectiveness Implementation for Concept Formulation Phase: general; mission analysis; specifying preliminary figures of merit; performance requirements analysis; operational requirements analysis; effectiveness parameter selection; model structuring; system and cost effectiveness analysis; report.
IV. System and Cost Effectiveness Implementation for Contract Definition Phase: general; effectiveness analysis refinement; apportionment analysis; effectiveness progress monitoring and demonstration planning; report.
V. System and Cost Effectiveness Implementation for Acquisition Phase: general; detail effectiveness analysis; effectiveness progress monitoring demonstration; final report.
VI. System and Cost Effectiveness Technical Management: general; Air Force management; contractor management.
VII. Application Guidelines for Specific Major Classes of Air Force Systems.
Appendix A. Example of Implementation Procedures.
Appendix B. Synthesis and Analysis Methods for Determining Transfer Functions, Outputs, and Inputs.
Appendix C. Combination of Sensitivity Functions.
Appendix D. Apportionment Procedures.

System and Total Force Cost Analysis
Novick, David

Santa Monica, The Rand Corporation, 1961, 141 p.
Rand Memorandum RM-2695-PR.

Summary: "This memorandum describes the aims, concepts, and methods of military cost analysis as developed by the Cost Analysis Department of the Rand Corporation. It is concerned basically with the estimation of costs for proposed military activities so that informed choices can be made among them."

I. Aims and Concepts of Analysis.
II. Cost Analysis of Individual Systems: investment costs (installations, equipment, stocks, initial training, miscellaneous investment); operation costs (equipment and installations replacement; maintenance; training; pay and allowances; fuels, lubricants, and propellants; services and miscellaneous; intermediate and support major command operations); R&D costs (system development, system test and evaluation, other system R&D costs).
III. Cost Analysis of Total Force Structures: force composition and assumptions; incremental costing and long-term programming; costs as expenditures and as program requirements; mission and other lower-level cost analyses; sensitivity, timeliness, and clarity; cost categories reconsidered (investments, operations, R&D); electronic data processing; summary.
IV. Cost Sensitivity Analysis: examples; uses and advantages.
V. Presentation of Results.
Appendix. Analysis of Manpower Requirements.
Bibliography.

A System for Development of Mathematical Models
Hendricks, J.W.

San Francisco, US Naval Radiological Defense Laboratory, 1964, 53 p.
USNRDL-TR-749. AD 602 733.

Abstract: "This paper presents a general quantitative system for association of theory and observation. The system, in formulation and presentation, is directed toward the needs of the user investigator. It is well organized for use with automatic machines in the computing and information processing. A multivariate distribution approach to model construction is used in accounting for errors and other sources of variation. As usual, hypothesized mathematical descriptions are modified in accordance with the observational data. The requirement of a state of control is regarded as fundamental. The question of unidentifiability is given prominent consideration; and in this connection, the general necessity of calibration is established and emphasized. The principle of maximum likelihood is suggested as the most acceptable ranking criterion for the system; but modifications or decision-theoretic extensions are not precluded. In short, the ordinary restrictive conditions are not imposed in this system. The fundamental ideas are discussed within the contextual framework of the system. The general principles for applying the system are presented and discussed. The most important classes of models are dealt with mathematically in detail."

Abstracts.
Descriptors.
Summary.
Introduction.
The Basic Principle of the System.
Association of Theory and Observation.
Designation of the Phenomenon Described by the Model.
Distributions May Result from either Random or Systematic Selection.
Mathematical Theory and Discussion: initial hypotheses; the error transformation; surface density functions; concordant hypotheses; available techniques; purposeful distributions.
Model Types: simple measurement with error; all object variables distributed; structural relationships; regression on observable variables; discrete distribution; constrained distributions; uniform or discontinuous models; other type models.
Problems in Computation.
Unidentifiability.
Interpretation of Results: surface of unidentifiability; calibration; considerations in ranking models; state of control.
Concluding Remarks.
References.

System/Cost Effectiveness Notebook
Harkins, James A. and Paul C. Shemanski

Griffiss Air Force Base, Rome Air Development Center, 1969, 2 Volumes, 663 p. RADC-TR-68-352. AD 854 651 and AD 854 652.

Abstract: "This notebook describes techniques by which the cost and effectiveness of modern-day weapon systems may be evaluated. It is the purpose of the notebook to present current state-of-the-art of system/cost effectiveness, to develop proper foundations for system/cost effectiveness concepts and to make recommendations pertinent to the future technological needs of the effectiveness discipline. The techniques offered are based on the results of general studies in the areas of technical, cost and management disciplines. These studies are now completed. The basic foundations for system/cost effectiveness analyses have been established, validity and practicability proven and overall feasibility demonstrated. As new and improved methods are developed and refined, the notebook will be updated."

I. Introduction.
II. Systems Analysis: role; objectives, methodology; models; costs; types; criteria; risk and uncertainty; limitations and cautions.
III. Management and the Acquisition Process: phases; organization; planning; programming; budgeting; procurement planning and implementation; reporting and control.
IV. System Effectiveness Analysis: steps; special topics.
V. The Availability Attribute: factors; computer programs; logistics models; data resource and information.
VI. The Dependability Attribute: repair of failed equipment; transition matrix; computer programs; device level programs; system level programs.
VII. The Capability Attribute: transfer function; capability rationale; computer programs.
VIII. Cost Analysis: cost as a parameter; system costing.
IX. System Effectiveness Management: monitoring system effectiveness; definition; selection; contract definition; engineering development; production; operations.
X. Topics in Analysis: decision models; risk and uncertainty; utility-value; optimization; allocation.
XI. Mathematics of Analysis: probability; statistics; analysis of variance; design of experiments; matrix algebra; calculus of variations; difference equations; alternative methodologies.
XII. Techniques in Analysis: mathematical programming; queuing theory; game theory; replacement theory; inventory theory; graph theory.
Appendix A. Applicable Mathematical Techniques.
Appendix B. Glossary of Definitions.
Appendix C. Bibliography.

Systems Analysis: a Computer Approach to Decision Models
McMillan, Claude and Richard F. Gonzalez

Homewood (Illinois), Richard D. Irwin, 1968, 520 p.

A computer and business oriented text, but showing adaptations of techniques to computers, using FORTRAN.

I. Systems and Models: system classification, systems analysis; models.
II. Simulation: definition; why systems simulation?; methodology; simulation and decision making.
III. Introduction to Programming.
IV. Value Analysis and Iterative Processes: difference equations; present value; annuities; chain of machine problem and optimum useful life.
V. The Inventory System under Certainty.
VI. Probability Concepts: probability; events; random variables; Markov Chain processes; random numbers.
VII. The Inventory System under Uncertainty - Discrete Distribution.
VIII. The Inventory System under Uncertainty - Continuous Distributions.
IX. Binomial and Poisson Processes: binomial; poisson; negative exponential distribution; gamma distribution.
X. Basic Queuing Concepts.
XI. Process Generator.
XII. Simulation of Queuing Systems.
XIII. Management Planning Models: the moving average; exponential smoothing; impulse response; step response; tracking signal; double smoothing.
XIV. Matrix Methods: input-output analysis; matrix inverter; parts requirement; linear programming.
XV. Large-Scale Simulation Models and Methodologies.
XVI. Industrial Dynamics.
XVII. A Study in "Total" Systems Simulation.
XVIII. Experimentation.
Appendix A. Tables: present values; approximation of the first integral of the standard normal density function; approximation of the second integral of same; areas of the standard normal distribution.
Appendix B. Expected Stock-out during Lead Time; A Polynomial Approximation of Cumulative probabilities of the Standard Normal Probability Density Function.
Appendix C. Matrix Operations.
Index.

Systems Analysis and Cost Effectiveness
Letters from the Office of the Adjutant General

Washington, Department of the Army, 1964, 98 p.
AD 450 411.

"This letter is intended to provide to all Army agencies guidance and information on the subjects of systems analysis and cost effectiveness. These procedures and techniques, if properly and thoughtfully used, can materially assist the decision maker."

I. Systems Analysis as a Part of the Total Management Process.
II. Systems Analysis - An Informal Summary.
III. Some Thoughts on Cost Effectiveness from the Army Viewpoint.
IV. An Example of a Cost-Effectiveness Analysis - The Analyst's Thoughts.
V. Summary of a Recent Military Operations Research Symposium.
VI. Operations Analysis in the Department of Defense.
VII. Limited Warfare: Some Possibilities and Pitfalls.
VIII. Systems Analysis and Decision Making.
IX. Costing Strategy.
X. Cost/Effectiveness - Tool or Club?

Systems Analysis and Policy Planning: Applications in Defense
Quade, E.S. and W.I. Boucher, editors.

Santa Monica, The Rand Corporation, 1968, 456 p.
Rand No. R-439-PR (Abridged). AD 695 765.

Prepared for the United States Air Force Project Rand, this volume "attempts to demonstrate that systems analysis can and does provide knowledge that decision-makers need; that it can serve to sharpen intuition; that its usefulness is not limited solely to questions of policy and planning that can be quantified; and, most important, that whatever its weaknesses, it produces more fruitful results, of far greater consequence and reliability, than any of its alternatives. It is intended more as a sophisticated guide to users of analysis than as a manual for those to prepare such material."

I. Introduction: definition; origins; types; essence; elements; current status.
II. An Introductory Example of Systems Analysis (M.G. Weiner).
III. Principles and Procedures of Systems Analysis (E.S. Quade): essence; alternatives; process (formulation, search, evaluation, interpretation).
IV. Criteria and the Measurement of Effectiveness (L.D. Attaway): elements; three examples (overspecification of criteria, maximizing effectiveness/cost, dominance, interceptors, scale of effectiveness, suboptimization, aggregation, criteria).
V. Uncertainty (Albert Madansky): probabilities; utilities; models; treatment (time, information, flexibility, a fortiori analysis, sensitivity analysis).
VI. Technological Considerations (H. Rosenzweig): types of decisions; technical feasibility; selection of best technical approach; comparison with competing systems.
VII. Resource Analysis (G.H. Fisher): definitions and concepts; context (time horizon, type of decision, scope of the problem).
VIII. Cost-Sensitivity Analysis: An Example (P.L. Petruschell).
IX. The B-X: a Hypothetical Bomber Cost Study (W.E. Moos).
X. The Nature of Models (R.D. Specht): design and use; types.
XI. Mathematical Models of Conflict (Melvin Dresher): game theory.
XII. Simulation (Norman C. Dalkey): basics; choice of techniques, pros and cons.
XIII. SAMSOM: a Logistics Simulation (Chauncey F. Bell).
XIV. Gaming (M.G. Weiner): types, requirements; characteristics; conditions; phases; examples.
XV. The Analysis of Force Policy and Posture Interactions (Roger Levien): role of analysis; the SAFE game.
XVI. Scenarios in Systems Analysis (Seyom Brown).
XVII. US Space Policy: an Example of Political Analysis (Alton Frye).
XVIII. When Quantitative Models are Inadequate (E.S. Quade): role of judgment; utilizing experts (contextual map, operational game, Delphi technique).

XIX. Pitfalls and Limitations (E.S. Quade): common fallacies, limitations.
XX. The Changing Environment for Systems Analysis (James R. Schlesinger).
XXI. The Trade-Off Study Revisited (L.H. Wegner).
XXII. By Way of Summary: precepts for the analyst; principles of good analysis; the decision-maker; dangers of analysis; future of analysis.

Selected Bibliography.
Bibliographic Note.
Index.

Systems Analysis for Effective Planning: Principles and Cases
Rudwick, Bernard H.

New York, John Wiley & Sons, 1969, 469 p.

"Although much has been written on the philosophical and intellectual level regarding the need for systems analysis or cost-effectiveness analysis as part of the systems planning process, there has been a lack of unclassified methodological material which showed explicitly how to attack complex, unstructured problems involving choice among system alternatives. This book is about the application of systematic, quantitative methods and techniques to the task of planning." Part 1: systems planning and the decision-making process (chapters 1-3); Part 2: foundations of systems analysis (chapter 4); Part 3: an illustrative example: mission oriented systems analysis (chapters 5-8); Part 4: principles of resource analysis (chapter 9); Part 5: subsystems planning (chapters 10-13); Part 6: the role of analysis in source selection (chapters 14, 15); Part 7: conclusions (chapter 16).

I. Introduction and Overview.
II. The Work Process for Systems Planning: background; the work process; required skills; summary.
III. Systems Analysis as Part of the Management Process: systems planning and budgeting in DOD; the improved DOD management information system.
IV. Developing the Systems Analysis Procedure: basic terminology; factors involved; objectives; interrelationship of models; cost model; criteria for system selection.
V. The Strategic Force Planning Case: Qualitative Aspects.
VI. Developing Quantitative Relationships.
VII. Model Exercise.
VIII. Coping with Uncertainties.
IX. Resource Analysis: problems involved in estimating costs of required resources; units of costs; development of key principles of cost analysis; coping with uncertainty; costing; CERs; cost sensitivity analysis.
X. System Selection: Helmet Case.
XI. Sectalying an Uncertain Demand: Spare Parts Management Planning Case Determining the Capacity of a Bridge.
XII. The Information Systems Planning: The Strategic Force Management System Case.
XIII. Intrasystem Tradeoffs: Guidance and Control System Selection Case.
XIV. Dealing with Job Uncertainties: Electronic Data Processing Systems Selection Case.
XV. Dealing with Development Uncertainties.
XVI. Concluding Remarks.
Appendix 1. Notes on Probability and Statistics.
Appendix 2. Source Selection: Evaluation Criteria to be Employed.

Bibliography.
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The Systems Approach and Public Policy
Quade, E.S.

Santa Monica, The Rand Corporation, 1969, 29 p.
Rand No. P-4053. AD 685 126.

An essay on the need for enlarging the concept of what constitutes acceptable analysis and seeking ways to adapt it to a new decision-making environment, and the need for public officials to provide status and support for the systems approach.

The Nature of the Systems Approach.
An Enlarged Concept of Model.
Adaptation of the Analysis to the Environment.
Analysis must be Given Recognition.
A Stong Analytic Capability Must be Supported.
In Conclusion.
References.

Systems Effectiveness
Systems Effectiveness Branch

Washington, Office of Naval Material, 1965, 165 p.

A collection of papers reflecting the attitude and philosophy of the Chief of Naval Material towards various aspects of systems effectiveness. "It also provides a discussion of the planning, design and cost considerations in system development, as well as some techniques now being utilized in order to realize the development of effective systems."

Future Navy Weapons and Support Systems (VADM W.A. Schoech).
Analytical Techniques in System Design (Leroy Rosen).
Reliability and Maintainability Considerations in System Design (Paul J. Giordano).
Engineering Integration in System Design (William D. Rohe).
Planning Integration in System Design (LCDR Gordon H. Jayne).
Cost Factors in System Design (John W. Stone).
Man Parameters in System Support (CDR Keith N. Sargent).
The Key to Development Pay-Off (RADM E.A. Ruckner).
System Effectiveness Assurance Management (Dr. Leslie W. Ball).
Systems Effectiveness - A Tool for Appraisal (CDR Keith N. Sargent).
Systems Effectiveness - Navy (CDR Keith N. Sargent).

Techniques of Systems Analysis
Kahn, Herman and Irwin Mann

Santa Monica, The Rand Corporation, 1957, 161 p.
Rand Memorandum RM-1829-1. AD 133 012.

Preliminary draft of Part I of a book (Military Planning in an Uncertain World), this memorandum includes the first five chapters and covers some of the contributions that systems analysis and operations research can make to military planning.

Introduction.
The Problem: design of the offense; probabilistic considerations; design of the defense; the two-sided war.
I. Designing the Offense: models; area defense models; local defense model; airfield model; tactics; specializing and simplifying the model; expected-value models; nemerical calculation of an allocation; insensitivity by design; optimal allocation and performance; the central problem; elementary economics.
II. Probabilistic Considerations: qualitative discussion of accuracy; probabilistic model; the monte carlo technique; simulating the area defense; the monte carlo calculation; analysis of a fixed budget; results of probabilistic calculations; deferred decision operation; modelism; probabilistic objectives; deterrence vs. win the war; requirements for these objectives; sample calculation; performance under deterrence objective; performance under other objectives; high and low confidence measures; expected-value vs. probabilistic calculations.
III. Designing the Defense: bias for the offense; general considerations; the parametric defense model; optimal allocation of a fixed budget; maximizing procedures in general; contingency planning; uncertainty in objectives; uncertainty in costs; context uncertainties; some important contingencies (magnitude and type of attack; degradation of our performance; variation in enemy's performance; chance factors; strategic and political changes; technological progress); simulating different contingencies; non-contingency planning; contingency analysis; contingency design; soft spots and time phasing.
IV. The Two-Sided War: asymmetrics (technological skill; military skill; allies; geography; resources; intelligence); objectives - two kinds of deterrence; both sides with fixed military budgets; the approximations; the two-sided calculation.
V. Evaluation and Criticism: analysis omits (research, development, procurement, operations; scale and detail; mixed forces; unconventional tactics; time phasing; re-examination stage; unsettled questions; convincing comparison of alternatives).
Appendix 1. Graphs of Partial Sums of the Binomial Distribution.
Appendix 2. The Mathematical Model.
Appendix 3. Summary of Ideas.

Ten Common Pitfalls
Kahn, Herman and Irwin Mann

Santa Monica, The Rand Corporation, 1957, 55 p.
Rand Memorandum RM-1937.

A preliminary draft of a report to be included in a book (Military Planning in an Uncertain World), this memorandum identifies and discusses some of the common mistakes made in operations and systems analyses.

Introduction.
I. Modelism.
II. Statistical Uncertainty.
III. Real Uncertainty.
IV. Enemy Reaction.
V. Over-Concentration.
VI. Phasing.
VII. Over-Ambition.
VIII. Fanaticism.
IX. Hermitism.
X. Butch.

Theory of Games and Economic Behavior
Von Neumann, John and Oskar Morgenstern

Princeton, Princeton University Press, 1953, 641 p.

I. Formulation of the Economic Problem: the mathematical method in economics; qualitative discussion of the problem of rational behavior; the notion of utility; structure of the theory.

II. General Formal Description of Games of Strategy: introduction; the simplified concept of a game; the complete concept of a game; sets and partitions; the set-theoretical description of a game; axiomatic formulation; strategies and the final simplification of the description of a game.

III. Zero-Sum Two-Person Games - Theory: preliminary survey; functional calculus; strictly determined games; games with perfect information; linearity and convexity; mixed strategies - the solution for all games.

IV. Zero-Sum Two-Person Games - Examples.

V. Zero-Sum Three-Person Games: preliminary survey; the simple majority game of three persons; the general case; discussion of an objection.

VI. Formulation of the General Theory - Zero-Sum n-Person Games: the characteristic function; construction of a game with a given characteristic function; strategic equivalence, inessential and essential games; groups, symmetry and fairness; the exact form of the general definitions; first consequences; determination of all solutions of the essential zero-sum three-person game.

VII. Zero-Sum Four-Person Games: discussion of some special points in the cube Q; discussion of the main diagonals; the center and its environs; a family of solutions for a neighborhood of the center.

VIII. Some Remarks Concerning n = 5 participants: the number of parameters in various classes of games; the symmetric five person game.

IX. Composition and Decomposition of Games: modification of the theory; the decomposition partition; decomposable games; limitations of the excess; determination of all solutions of a decomposable game; the essential three-person game in the new theory.

X. Simple Games: winning and losing coalitions and games where they occur; characterization; majority games; methods for enumeration; simple games for small n; determination of all solutions in suitable games.

XI. General Non-Zero-Sum Games: extension of the theory; the characteristic function and related topics; interpretation of the characteristic function; the solutions of all general games with n = 3; economic interpretation of the results for n = 1, 2; economic interpretation of the results for n = 3; economic interpretation of the results for n = 3; the general market.

XII. Extension of the Concepts of Domination and Solution; the extension, special cases; generalization of the concept of utility; discussion of an example.
Appendix. The Axiomatic Treatment of Utility.
Index of Figures.
Index of Names.
Index of Subjects.

The Use of Classical Statistics in Deriving and Evaluating CERs
Graver, Charles

Washington, Office of the Assistant Secretary of Defense (Systems Analysis), 1966, 34 p.
TP 66-8. AD 659 323.

A discussion of "some of the commonly used statistics and the differences between common interval estimates" and of the "applicability of the usual interpretation of these statistics and interval estimates in cost analysis and of the possible meanings that might be attached to them even if statistical assumptions are not fully satisfied." Specific topics: (1) assumptions of the multiple linear regression model and how well they are fulfilled in the cost analysis application; (2) least-squares estimators as "best" estimators; (3) properties of some commonly used statistics from a geometrical point of view; (4) differences in commonly used interval estimates.

Introduction.
The Model.
The Selection of a Criterion of "Best".
Commonly Used Statistics.
Interval Estimates.
Conclusion.

The Utilization of Military Resources
Smith, T. Arthur and Ogden O. Allsbrook

Washington, Department of the Army, 1967, 243 p.
AD 824 660.

The purpose of this book is "to promote access to information generated at Department of the Army and at Army installations everywhere . . . . Take note especially of the two categories into which these articles might fall. These are the categories of idea and action. Although the separation of one from another cannot always be based on the criterion of 'in the present' or 'in the future,' this separation should be useful as a first, personnel orientation in the Army cost research program."

Introduction (T. Arthur Smith & Ogden O. Allsbrook).
The Utilization of Military Resources (T. Arthur Smith).
Army Operating Costs (Saul Hoch).
The Resource Management System and Operating Cost Data (John Wallace).
The Army Cost Handbook (Donald Gillies).
The Impact of Electronic Maintenance Costs on Life Cycle Costs (Joseph L. Townsend & Amelia C. Yetman).
Analysis of Combat Vehicle Operating and Maintenance Costs (Anne Rhoder & William T. Towles).
Army Equipment Operations Costs (John O'Flaherty & Richard O'Rorke).
United States Army Field Operating Cost Agency (Leslie R. Sears, Jr.).
Airmobile and Infantry Division Cost of Operations in Vietnam (Joseph W. Noah).
Criteria, Analysis, and Techniques for Estimation of Operating and Maintenance Resources (John G. Phillips).
The Army Division Cost Model (Paul Curd).
The Military Manpower Cost Model (Sidney Kaplan).
Military Personnel Program and Budget Costing (George H. Ensley).
The Costs of Army Training (Donald H. Strope).

Weapon/Support Systems Cost Categories and Elements
Headquarters, Department of the Army

Washington, Department of the Army, 1968, 20 p.
AR 37-18.

This regulation establishes a set of cost categories and elements to be used by weapon/support systems' cost analysis activities of the Department of the Army staff agencies and commands.

I. Purpose.
II. Objective.
III. References.
IV. Definitions.
V. General.
VI. Programming, Budgeting, and Accounting Systems.
VII. Functional Work Areas.
VIII. Exceptions.
IX. Weapon/Support Systems Cost Categories and Elements.
X. Cost Element Definitions.
Appendix. Work Breakdown Structure.

Weapon System Cost Analysis
Fisher, G.H.

Santa Monica, The Rand Corporation, 1956, 20 p.
Rand No. P-823.

I. Introduction.
II. Estimating Weapon System Cost: the total activity cost concept; distinction between investment and annual operating cost; incremental investment costing; time phasing of expenditures; system cost components; consistency in costing method.
III. Application to Long Range Military Planning.
Appendix. Figures.

Weapon System Cost Methodology
Novick, David

Santa Monica, The Rand Corporation, 1956, 52 p.
Rand No. R-287.

Summary: "A method is described for estimating the costs of existing and hypothetical weapon systems of the United States Air Force. It is intended to be a quick and flexible means of establishing approximate resource and cost requirements, and it provides a basis for evaluating alternative systems in terms of both cost of a given capability and capability obtainable for a fixed cost. The method is also useful for military planning, programming, and budgeting activities."

Summary.
I. Introduction: weapon system cost analysis; the role of cost estimates in systems analysis.
II. Rand Techniques for Computing Air Force Weapon System Costs: objectives (identifying system cost elements; accumulating total cost; the distinction between investment and annual operating expenditures); present application.
III. Description of Rand Methodology: investment cost categories (installations, equipment, stocks, transportation, personnel, intermediate command cost and support major command cost); annual operating cost categories (installations maintenance; equipment - annual replacement; transportation; personnel; maintenance; petroleum, oil, and lubricants; services and miscellaneous; intermediate command cost; support major command cost).
Appendix. Worksheets: manpower requirements summary; installations; primary mission equipment summary; organizational equipment summary; stocks - initial stock level; stocks - readiness reserve; stocks - aircraft spares and spare parts; transportation; personnel training; personnel pay and allowances; personnel travel; maintenance - mission aircraft; maintenance - support aircraft; POL - mission aircraft; POL - support aircraft; POL - miscellaneous; services and miscellaneous; intermediate commands; support major command cost.
References.

The Weapons Acquisition Process: An Economic Analysis
Peck, Merton J.; Frederic M. Scherer

Boston, Harvard University Graduate School of Business Administration, 1962, 736 p.

Government/business relationships of weapons acquisition activities and their effects of quality, time, cost, and value outcomes of weapons programs. Research based on case histories of 12 weapon system developments. Part 1: the nature of the process (chapters 1-3); Part 2: the structure and dynamics of the weapons industry (chapters 4-7); Part 3: the execution of weapons program (chapters 8-20).

I. Introduction.
II. The Unique Environment of Uncertainty in Weapons Acquisition: the predictability of time, quality, and cost; internal uncertainties and technological character; external uncertainties; risk, lead time, and project cost.
III. The Nonmarket Character of the Weapons Acquisition Process.
IV. The Government as Buyer.
V. The American Weapons Makers: over-all statistics; categories; small businesses as prime contractors; interbusiness transactions.
VI. The Factors of Production: importance; supply of capital and facilities; supply of technical personnel; economies of scale.
VII. Entry into and Exit from the Weapons Industry: record; barriers; incentives.
VIII. Innovation and the Choice of Weapons: program decision, innovation, institutional framework.
IX. The Structure of Weapon System Program Decisions: basic elements; possibilities of choice; problem of choice.
X. Buyer Preferences in Weapons Programs.
XI. Uncertainty and Time in Program Decisions.
XII. Competition for Weapons Program Participation.
XIII. The Criteria for Contractor Selection.
XIV. The Selection of Subcontractors.
XV. Contractor Efforts in the Competition for New Programs.
XVI. The Conduct of Weapons Development Programs: time, quality, and cost effectiveness; time, cost, and quality variances.
XVII. The Optimal Conduct of Weapons Programs: end product; R&D approach; allocation of contractor talent.
XVIII. The Efficient Conduct of Weapons Programs.
XIX. The Evaluation of Weapons Program Performance.
XX. In Conclusion.
Appendix 5. Statistical Appendix.
Appendix 7. Small Business in Weapons Research and Development
Appendix 9A. The Construction of Military Value Functions.
Appendix 9B. Numerical Data - Defender Nation Assumption.

Appendix 12. Data on the 99 Programs.
Appendix 19. Technical Notes on the Evaluation Experiment.
Appendix 19B. The Program Evaluation Experiment Questionnaire.
Selected Bibliography.
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What is Resource Analysis?
Fisher, G.H.

Santa Monica, The Rand Corporation, 1963, 14 p.
Rand No. P-2688. AD 294 994.

I. Introduction.
II. Context: time horizon; decision context; scope of the problem.
III. Impact of Context on Concepts, Methods and Techniques Used in Resource Analysis.
IV. Summary Remarks.

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