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DEPARTMENT OF NATIONAL DEFENCE
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0204a ^{LC} CHIEF OF ^{LC} PLANS

04a BIBLIOGRAPHY

- ON

- METHODOLOGIES FOR EVALUATING RESEARCH AND DEVELOPMENT PROJECTS

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PREFACE

During the past four years, the planning staff has attempted to bring itself up to date in all aspects of technical planning, forecasting and decision-making.

University students have been employed during the summer months to assist in this effort by doing literature surveys on various aspects. (Plans Reports 69-1 "Bibliography on Technological Forecasting and Long Range Planning" and 70-5 "The Use of Existing Technological Forecasts for Decision-Making".)

This year, the author of this report was asked to search for useful papers dealing with ways of evaluating research and development projects. One cannot expect a thorough survey to be made in a period of two and a half months. It is anticipated, however, that this bibliography will provide useful information for readers interested in planning, forecasting, and decision-making.



G.D. Watson
Chief of Plans
Defence Research Board

1 November 1971

Bibliography on Methodologies for Evaluation Research
and Development Projects

Abstract

80 / This bibliography is a survey of literature published between 1967-71 on the subject of project evaluation. The articles were evaluated according to criteria laid out in the introduction.

The methodologies were rated on a subjective scale according to how they measured up to the given criteria. /

Bibliographie des Méthodologies pour l'Evaluation des
Projets de Recherches et de Développements

Résumé

Cette bibliographie comprend des communications qui ont été publiées pendant les années 1967-71 traitant du sujet de l'évaluation de projets. Les articles s'évaluent d'après certains critères exposés dans l'introduction de ce document.

Les différentes méthodologies sont appréciées par une échelle subjective suivant la façon dont elles se rapprochent des critères sélectionnés.

TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	i
PREFACE	ii
I. Introduction	1
II. Brief Description of Key Methodologies	2
III. Sources of References Consulted	3
IV. Author's Evaluation	4
V. Bibliography	4
A. Decision Theory Approach	4
B. Operations Research Approach	5
C. Mathematical Models	7
D. Systems Analysis and Planning, Programming, Budgeting Systems	7
E. Miscellaneous Methodologies	8
F. Review Articles	8
G. Bibliography of Fundamental Literature	9
VI. Footnotes	10

Bibliography on Methodologies for Evaluating Research
and Development Projects

I. Introduction

Since World War II, the technologically advanced countries of the western world have been faced with increasing involvement in large and costly R&D programs. Typically, programs in aerospace, defence, ocean technology, transportation, urban development, pollution control, earth resources surveys, etc., have placed heavy demands on a country's economic and manpower resources. Because of this, it has become important for government and industry to be more judicious in selecting the R&D programs to be supported.

It was not until the last decade that a concerted effort was made towards the development of a methodology for the evaluation and selection of research and development projects. An effective methodology was sought which would significantly improve the decision making process in selection of programs. The outstanding problem which remains is still the development of workable methodologies capable of surmounting the difficulty of quantifying the uncertainty involved in any research and development undertaking.

The purpose of this bibliography is to list some references which deal with this subject and in particular at the introductory level. The references reviewed indicate that program evaluations are generally made on the basis of the following criteria.

1. economic utility
2. relevance to a given objective
3. probability of achieving expected technological and scientific objectives
4. probability of completion by a predetermined date.

Most references reviewed were published between the years 1967 and 1971. Because of rapid advances made in the field during that period, earlier publications on this subject were considered outmoded.

The time allotted for compiling this bibliography was not sufficient to cover every aspect of the subject but rather represents a cursory survey of the subject. In addition, this report should not be considered as an expert's evaluation of the literature, but rather that of a layman. The bibliography presented is intended to be of use to the planner or manager who wants to improve the efficiency of his program/project decision-making but who lacks an expert's knowledge in this field. All references cited in this bibliography are unclassified and readily obtainable.

II. Brief Description of Key Methodologies

The literature surveyed during the accumulation of this bibliography has been classified by the following headings for easier reference.

- A. Decision theory approach
- B. Operations research approach
- C. Mathematical models
- D. Systems Analysis and Planning, Programming Budgeting Systems
- E. Miscellaneous methodologies
- F. Review articles
- G. Bibliography of fundamental literature

The definitions of the decision theory and operations research approaches were taken from the article by N.R. Baker and W.H. Pound entitled "R and D Project Selection: Where we Stand."

In the decision theory approach, "project proposals are rated with respect to a number of evaluation criteria. An overall score is computed and used to rank the alternatives."¹ The selection criteria used as a guide to choosing the references in this bibliography were those listed above in the introduction.

An operations research approach is described in the same article as defining a methodology whereby "for each alternative project, an estimate is made of the probability distribution of net value. Selection is accomplished by maximizing expected discount net value to constraints on the total budget, facilities, and personnel."²

Systems analysis refers to the approach pioneered by the Rand Corporation. It is described by E.S. Quade as being: "A systematic approach to helping a decision-maker choose a course of action by investigating his full problem, searching out objectives, and comparing them in the light of their consequences, using an appropriate framework -- insofar as possible analytic -- to bring expert judgment and intuition to bear on the problem."³ This bibliography includes very few references using systems analysis as a methodology. It is the author's view that systems analysis is only a methodological manner of breaking down a problem for ease of viewing and not really a decision-making methodology.

Planning, programming, budgeting system (P.P.B.S.) is similar to that of the systems analysis. When using this method, one would evaluate research projects in terms of how it fulfills the objectives of the nation or supporting institution instead of cost.

III. Source of References Consulted

Documents and reports were located through the various government reports indices. Most reports reviewed were of American origin but a significant number came from Great Britain and France. The British Steel Corporation and the relatively new Programmes Analysis Unit⁴ have both contributed much towards advancement in the field.

In France, Gen. H. de l'Estoile, director of the Centre de Prospective et d'Evaluation au Ministère des Armées, presented one of the most important methodologies for the O.E.C.D. entitled "Une Méthode pour la Sélection des Programmes de Recherche et Développement".

Of the periodicals reviewed the following were found to contain the most relevant articles.

1. I.E.E.E. Transactions on Engineering Management
2. Operations Research Quarterly
3. Operations Research/Management Sciences
4. Harvard Business Review

The following agencies have published important articles on project evaluation.

1. Abt Associates, Cambridge, Mass.
2. British Steel Corporation, United Kingdom.
3. Centre de Prospective et d'Evaluations, Paris, France.
4. General Electric, TEMPO, Santa Barbara, Calif.
5. Massachusetts Institute of Technology, Cambridge Operations Research Centre, Cambridge, Mass.
6. National Biomedical Research Foundation, Silver Springs, Md.
7. Northwestern University, Evanston, Ill.
8. O.E.C.D.
9. Planning Research Corporation, Los Angeles, Calif.
10. Programmes Analysis Unit, United Kingdom.
11. Rand Corporation, Santa Monica, Calif.
12. Research Analysis Corp., McLean, Va.
13. U.N.E.S.C.O.

IV. Author's Evaluation

The references listed in the bibliography were rated 1, 2 or 3 (1 being the best) by the writer based on a subjective evaluation of the article's readability from a lay viewpoint. Subjective factors considered were:

- a) Depth of technical presentation i.e., amount of higher mathematics used to develop points of view.
- b) Clarity of presentation and coverage of fundamental principles.
- c) Presentation of case examples which illustrates application of techniques discussed to representative real life problems.
- d) The degree of quantitative element as opposed to degree of qualitative or intuitive judgment involved in proposed approach (i.e. suitability of method for objective decision theory).
- e) Practical application.

V. Bibliography

A. Decision Theory Approach

1. de l'Estoile, H., "La Programmation de la Recherche Appliquée - La Méthode du Centre de Prospective et d'Evaluations (C.P.E.)", Le Progrès Scientifique, no. 118, April 1968. (1)
2. de l'Estoile, H., "La Programmation de la Recherche Appliquée - Méthode et Critères", Le Progrès Scientifique, no. 108, March 1967. (1)
3. de l'Estoile, H.; Lecerf, D.; and Gastaut, G., "Une Méthode pour la Sélection des Programmes de Recherche et Développement", O.E.C.D., August 1967. (1)
4. Krasnican, M.J., "Managing the Development of an Experimental Computer-Aided Technology Planning System (PLANET)", I.E.E.E. Transactions on Engineering Management, vol. EM-18, no. 2, May 1971. (1)
5. Mayo, Louis H., "Scientific Method, Adversarial System, and Technology Assessment", George Washington University, Washington, D.C., Program of Policy Studies in Science and Technology, Report No. GWPS-MON-5, November 1970. (1)
6. Moore, Jr., John R. and Baker, Norman R., "An Analytical Approach to Scoring Model Design - Application to Research and Development Project Selection", I.E.E.E. Transactions on Engineering Management, vol. EM-16, no. 3, August 1969. (1)

7. Proschan, Arnold, "Improvement of Army Methods of Determining Research and Exploratory Development Programs", Research Analysis Corp., Rep. No. RAC-T-482, 1966. (2)
8. Ross, A.W., "The Choice and Balance of a Defence Research Programme", OTAN, Groupe pour la Recherche de Défense, Paris 27-29 novembre, 1967. (2)
9. Smith, Barnard E., "Decision Analysis on Research and Development", Research Management, vol. 12, no. 6, November 1969. (2)

B. Operations Research Approach

1. Baker, A.G. and Smith, W.J., "Control of Research - Possible Aids", Operations Research Quarterly, vol. 18, no. 1, March 1967. (2)
2. Binning, K.G.H., "The Analysis of Research and Development in the Ministry of Technology", Programmes Analysis Unit, London, PAU M3/67, 1967. (2)
3. Cetron, Marvin J., "QUEST Status Report", I.E.E.E. Transactions on Engineering Management, vol. EM-14, no. 1, March 1967. (1)
4. Cetron, Marvin, J. and Davidson, Harold, F., "Macro R & D", Industrial Management Review, vol. 10, no. 2, Winter 1969. (1)
5. Ebert, Ronald J., "Methodology for Improving Subjective R & D Estimates", I.E.E.E. Transactions on Engineering Management, vol. EM-17, no. 3, August 1970. (1)
6. Ferguson, Allen R., Deavers, Kenneth L., and Jones, Norman N., "Project Evaluation - Project Scoring for the Economic Development Administration", Planning Research Corp., Los Angeles, Calif., PRC R-883, November 1966. (1)
7. Haas, R.J. and Allori, R.A., "The Selection of Research and Development Projects Under Multiple Objectives - A Case Study", BIRSA - The Corporate Labs of the British Steel Corp., London, BIRSA OR/40/70; 1970. (1)
8. Galloway, E.C., "Evaluating R&D - Keep it Simple", Research Management, vol. 14, no. 2, March 1971. (2)
9. Harman, A.J., "A Methodology for Cost Factor Comparison and Prediction", Rand Corp., RM-6269-ARPA, August 1970. (2)
10. Hart, A.- "A Chart for Evaluating Product Research and Development Projects", Operations Research Quarterly, vol. 17, no. 4, December 1966. (2)

11. Ledley, Robert S., Belson, Marilyn; Rotolo, Louis S., Wilson, James B., Bartelmehs, Richard, "Methodology for Organizing and Processing Qualitative Relationships in Operations Research", National Biomedical Research Foundation, Silver Springs, Md., Report No. NBR-6806/4496, February 1970. (2)
12. Ledley, Robert S., "Methodology to Aid Research Planning", I.E.E.E. Transactions on Engineering Management, vol. EM-14, no. 2, June 1967. (1)
13. Marsden, P.S.S.F., "Operational Research in Research and Development", Programmes Analysis Unit, U.K., PAU M 13, 1969. (1)
14. Martino, Joseph P., "A Classification System for Military Functions, Technologies, and Sciences", I.E.E.E. Transactions on Engineering Management, vol. EM-14, no. 1, March 1967. (2)
15. Meadows, Dennis L. "Estimate Accuracy and Project Selection Models in Industrial Research and Development", Industrial Management Review, vol. 9, no. 3, Spring 1968. (3)
16. Nutt, Ambrose Ben, "Testing TORQUE - A Quantitative Research and Development Resource Allocation System", I.E.E.E. Transactions on Engineering Management, vol. EM-17, no. 4, November 1969. (1)
17. Persemier, Edgar A., "Financial Planning and Control of Research and Development", Long Range Planning, vol. 3, no. 2 December 1970. (2)
18. Reader, R.D. and Beattie, C. J., "The Evaluation and Selection of Research Projects", British Steel Corporation, London, BIRSA-OR/49/67, 1967 (1)
19. Sabin, Bernard and Proschan, Arnold, "Proposal Generation and Evaluation Methods in Research and Exploratory Development", Research Analysis Corp., McLean, Va., November 1965. (1)
20. Souder, William E., "Experience with an R&D Project Control Model", I.E.E.E. Transactions on Engineering Management, vol. EM-15, no. 1, March 1968. (2)
21. Williams, Bruce R., "Cost-Benefit Analysis of Investment in Science and Technology", U.N.E.S.C.O., Paris, June 1968. (3)
22. Williams, D.J., "A Study of a Decision Model for Research and Development Project Selections", Operations Research Quarterly, vol. 20, no. 3, September 1969. (3)

C. Mathematical Models

1. Atkinson, Anthony C., and Bobis, Arthur H., "A Mathematical Basis for the Selection of Research Projects", I.E.E.E. Transactions on Engineering Management, vol. EM-16, no. 1, February 1969. (1)
2. Beale, E.M., Applications of Mathematical Programming Techniques, English Universities Press, Ltd., London, 1970. (2)
3. Cochran, M.L.; Bender, A.D., Pyle III, E.M.P.; Green, L.C.; Clymer, H.A., "Investment Model for R & D Project Evaluation and Selection", I.E.E.E. Transactions on Engineering Management, vol. EM-18, no. 3, August 1971. (1)
4. Gear, A.E., Lockett, A.G., and Pearson, A.W., "Analysis of Some Portfolio Models for R & D", I.E.E.E. Transactions on Engineering Management, vol. EM-18, no. 2, May 1971. (1)
5. Hamilton, Carl W., "Optimal Control of Research and Development Expenditures", M.I.T. Cambridge Operations Research Centre, Report No. TR-48 AROD-968:57-M, December 1969. (2)
6. Krasnican, M.J., "Managing the Development of an Experimental Computer-Aided Technology Planning System (PLANET)", I.E.E.E. Transactions on Engineering Management, vol. EM-18, no. 2, May 1971. (1)
7. Rizvi, M. Haseeb, "Non-Parametric Ranking and Selection Procedures", Ohio State University, Dept. of Mathematics, 1971. (2)
8. Roy, B., "Ranking and Choice in Presence of Multiple Points of View", (Electra Program), Revue Française D'Information et de Recherche Opérationnelle, vol. 2, no. 8, 1968. (2)
9. Rubenstein, Albert H.; Baker, Norman R.; Forster, R. Patrick; Hurter, Arthur P. Jr.; Keagan, Daniel L., "A Series of Studies on the Design Requirements for a Real-Time Information and Computational System to Assist R and D Management in their Project Selection Decision-Making", Northwestern University, Evanston, Ill., Report no. 70-33, July 1970. (2)

D. Systems Analysis and Planning, Programming, Budgeting Systems

1. Archibald, K.A., "Three Views of the Expert's Role in Policy-Making: Systems Analysis, Incrementalism and the Clinical Approach", Rand Corp., Jan. 1970. (3)
2. Barro, S.M., "An Exploratory Study of Science Resource Allocation", Prepared for the National Science Foundation by the Rand Corp., March 1969. (1)

3. Drury, C.M., "Planning, Programming Budgeting Guide", Government of Canada Treasury Board, September 1969. (1)
4. Dror, Yehezkel, "Systems Analysis for Development Decisions: Applicability, Feasibility, Effectiveness, and Efficiency", Rand Corp., August 1969. (2)
5. Martino, Joseph P., "A Classification System For Military Functions, Technologies, and Sciences", I.E.E.E. Transactions on Engineering Management, vol. EM-14, no. 1, March 1967. (2)

E. Miscellaneous Methodologies

1. Allen, D.H., "Credibility Forecasts and Their Application to the Economic Assessment of Novel Research and Development Projects", Operations Research Quarterly, vol. 19, no. 1, March 1968. (2)
2. Allen, D.H., "Two New Tools for Project Evaluation", Chemical Engineering, vol. 74, no. 14, July 1967. (1)
3. Bliamptis, Emmanuel E., "A Tetrahedron Model for Research", Physics Today, vol. 2, no. 12, December 1968. (2)
4. Cook, Leslie G., "How to Make R & D More Productive", General Electric, Schenectady, N.Y., from Harvard Business Review, vol. 44, no. 4, July/August 1966. (3)
5. Defense Documentation Center, Alexandria, Va., "Rationale for Making Decisions", Report Bibliography, Jan-Dec. '70, April 1971.
6. Gerardin, L., "Relevance Trees", Compagnie Française Thomson Houston-Hotchkiss Brandt, Paris, 28 May 1970. (2)
7. Hartle, D.G., "The Evaluation of Effectiveness in Terms of Ultimate Objectives", unpublished paper, November 26, 1968 (2)
8. Jones, P.M.S., "Technological Forecasting as a Management Tool, presented at Lecture to Polytechnic School of Management Studies Course, 19-23 May 1969, PAU-M-10, October 1969. (2)
9. Levine, R.A. and Williams Jr., A.P. "Making Evaluation Effective - A Guide", Report prepared for Dept. of Health, Education and Welfare by Rand Corp., R-799-HEW/CMU, May 1971. (3)

F. Review Articles

1. Bezed-dov, Aharan G., and Klein, Thomas A., "Research Methodology in the Management Sciences: Formalism or Empiricism", Operations Research Quarterly, vol. 21, no. 3, September 1970. (3)

2. Heide, Cynthia, "Bibliography on Technological Forecasting and Long Range Planning", Defence Research Board, Ottawa, Plans Report 69-1, December 1969.
3. Jantsch, Eric (ed), Perspectives in Planning, O.E.C.D., 1969. (1)
4. Jones, P.M.S., "Project Evaluation - Decisions on Levels of Investment in Research, Feasibility Studies and Market Surveys", Programmes Analysis Unit, U.K., 1969. (1)
5. Jones, P.M.S., and Hunt, H., "An Outline of Evaluation as Practised by the Programmes Analysis Unit with Three Case Studies", PAU M-12, Programmes Analysis Unit, U.K., 1969. (1)
6. Laue, H.J., "Efficient Models for the Allocation of Resources in Project Networks", Unternehmensforschung, vol. 12, no. 2, 1968. (2)
7. Marsden, P.S.S.F., "Operational Research in Research and Development", Programmes Analysis Unit, U.K., PAU M 13, 1969. (2)
8. Nicholson, R.L.R., "Programme Evaluation in the Programmes Analysis Unit", Programmes Analysis Unit, U.K., PAU M 5/67, 1967. (2)
9. Rea, Robert H., "The Design of Integrated Technological Forecasting and Planning Systems for the Allocation of Resources", Perspectives of Planning, Proceedings of the O.E.C.D. Working Symposium on Long Range Forecasting and Planning, Bellagio, Italy, 1968. (1)

G. Bibliography of Fundamental Literature

This section of the bibliography contains a short list of references which I feel would be of interest to those looking for introductory information on the subject of project evaluation and operations research. They have already been cited in the main bibliography, but are set apart here because of their simplified approach in dealing with the fundamental principles of the subject.

1. Allen, D.H., "Two New Tools for Project Evaluation", Chemical Engineering, vol. 74, no. 14, July 1967.
2. Bliamptis, E.E., "A Tetrahedral Model for Research", Physics Today, vol. 2, no. 12, Dec. 1968.
3. Cetron, Marvin J., "QUEST Status Report", I.E.E.E. Transactions on Engineering Management, vol. EM-14, no. 1, March 1967.
4. de l'Estoile, H., "La Programmation de la Recherche Appliquée - Méthode et Critères", Le progrès Scientifique, no. 108, May 1967.

5. Galloway, E.C., "Evaluating R & D - Keep it Simple", Research Management, vol. 14, no. 2, March 1971.
6. Jantsch, Eric (ed), Perspectives in Planning, O.E.C.D., 1969.
7. Jones, P.M.S., "Project Evaluation - Decisions on Levels of Investment in Research, Feasibility Studies and Market Surveys", Programmes Analysis Unit, U.K. 1969.
8. Jones, P.M.S., and Hunt, H., "An Outline of Evaluation as Practised by the Programmes Analysis Unit with Three Case Studies", PAU M-12, Programmes Analysis Unit, U.K., 1969.
9. Reader, R.D., and Beattie, C.J., "The Evaluation and Selection of Research Projects", British Steel Corporation, U.K., 1967.

VI. Footnotes

1. Baker, N.R., and Pound, W.H., "R & D Project Selection: Where we Stand", I.E.E.E. Transactions on Engineering Management, vol. EM-11, no. 4, 1964.
2. Ibid.
3. Quade, E.S., and Boucher, W.I., (eds), "Systems Analysis and Policy Planning: Applications in Defense", Report prepared by the Rand Corp. for the United States Air Force Project Rand, p. 2, June 1968.
4. The Programmes Analysis Unit is a joint venture of the Ministry of Technology and the United Kingdom Atomic Energy Authority formed to try and solve the problems in the evaluation and selection of R & D projects.