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The State-of-the-Art of Systems-Analysis: Proposed Outline for a Series and Handbook

Levien, R.E., Rakhmankulov, V. and Brown, K.

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THE STATE-OF-THE-ART OF SYSTEMS ANALYSIS: PROPOSED OUTLINE FOR A SERIES AND HANDBOOK

R. Levien
V. Rakhmankulov
K. Brown

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PREFACE

This Working Paper contains the text of a brochure sent to 250 scientists around the world through IIASA's 14 NMOs. It presents an outline of the proposed structure and content for IIASA's State-of-the-Art publications, a Series and Handbook.

The outline presented here is the result of several iterations, during which comments from IIASA scientists have been exceptionally helpful. We are distributing the outline in this Working Paper both to inform those who have helped us of how we have used their comments, and to solicit further contributions from IIASA scientists.

If you would like to participate in our current round of revision, please ask Karen Brown, extension 286, Schloss-13, for a copy of the questionnaire that accompanies this outline. Alternately, you may simply wish to annotate this Working Paper. In either event, return your comments before 30 June to us in Schloss-13.

CONTENTS

INTRODUCTION

STATE-OF-THE-ART SURVEY PROJECT

One important function of IIASA is to facilitate widespread international exchange of experience with the application of systems analysis. To fulfill this function, IIASA has established a Survey Project to produce timely publications whose purpose is to systematize and generalize the current state-of-the-art of systems analysis throughout the world.

AUDIENCE

The project's publications will be addressed to a wide audience, including practitioners of systems analysis in government, industry, and research institutions; managers at all levels in government and industry; scientists and engineers working at the frontiers of systems analysis; and instructors, graduate and undergraduate students.

IIASA is in a unique position through its National Member Organizations (NMOs) to identify and report worldwide activities in the application of systems analysis to timely international issues such as energy, ecology, water resources, urban planning and management, and food; and to report the latest developments in the principles and methodologies of systems analysis from research centers around the world. It is expected, therefore, that there will be a large audience for this project's publications.

PRODUCTS

The primary initial products will be publications of two kinds: a state-of-the-art *Series* and a *Handbook*.

Series

The Series will be addressed to one specific audience: *practitioners* of systems analysis. Volumes in the Series will describe the foundations, processes, and applications of systems analysis, including specifically chosen topics of interest and contemporary themes; there will also be reference materials such as glossaries. Each volume will be written by one or more experts in the subject of the volume and will be carefully reviewed and edited to assure the technical quality and completeness of

its contents. Volumes will be issued individually as they are completed, and will be revised or replaced periodically to assure that they remain current. The first Series volumes should be completed by the end of 1975 or the beginning of 1976, and they will continue to be published at the rate of eight to ten volumes per year.

The Series will be produced by the Survey Project Editorial Staff at IIASA, with the advice of an international Editorial Board; it will be published in English, with publication and distribution handled by John Wiley & Sons Limited, an international publisher. The NMOs may arrange for translation and publication of the Series in their countries.

A Series volume will consist of between 200 and 400 printed pages. There will probably be a wide variation in the size of the volumes, partly as a consequence of the differences in development of the individual topics. Monographs on similar topics might be bound together for convenience.

Handbook

The Handbook will be addressed to several audiences: practitioners, managers, scientists, and students and teachers of systems analysis. It will be an integral publication comprising a concise and structured presentation of the underlying principles, methodologies, and practical results of systems analysis. Thus, the scope of the Handbook will be similar to that of the Series, but it will be broader and less detailed, and the materials in the Handbook will emphasize the relatively unchanging aspects of systems analysis. Because of its nature, the Handbook will require more time to prepare than the Series and probably will not appear before the end of 1976. The Handbook will be produced by the same Editorial Staff and Board and will also be published by John Wiley and Sons. The same arrangements for translation and publication through the NMOs will apply.

EDITORIAL STAFF AND EDITORIAL BOARD

The products of the Survey Project are the responsibility of an Editorial Staff and an Editorial Board. The Editorial Staff consists of an Executive Editor (R. Levien, USA), a Deputy Executive Editor (V. Rakhmankulov, USSR), and a Technical Editor. The Editorial Board consists of a Chairman, who is the Chairman of the IIASA Council (J. Gvishiani, USSR), and 6 to 12 members from other countries. In addition to the formal members of this Board, the IIASA Director (H. Raiffa, USA) and the Executive Editor of the Survey Project may be ex officio members.

AUTHORS AND REVIEWERS

Because of the international character of the state-of-the-art publications, there is a need for contributions from a wide range of experts from many different countries. For this reason, authors for the most part will be chosen from outside IIASA. Prospective authors for the various products will be identified by one or more of four basic methods:

- o Recommendations by members of the Editorial Board, Liaison Committees of the NMOs (established specifically to work with the Survey Project), or IIASA staff.
- o Recommendations by experts in appropriate topic areas.
- o Responses to an announcement, widely disseminated, suggesting the topics on which products are to be published and requesting submission of a proposed outline and sample of the author's previous work.
- o Proposals received directly from prospective authors.

Authors will be chosen by the Editorial Staff, with the advice of the Editorial Board, after careful consideration of all proposals and recommendations from the NMOs. The Editors will prepare guidelines for the authors. These will include specifications of style, organization, and general content. The authors will be paid an honorarium and/or a portion of the royalty income.

In addition, there will be reviewers to evaluate all contributions. They will be selected by the Editorial Staff, insofar as possible to complement the author's experience, both nationally and substantively. The Editors will attempt to ensure that the reviewing process is carried out in at least two or three NMOs. Reviewers will also be paid an honorarium.

CONTENT AND STRUCTURE OF THE STATE-OF-THE-ART PROJECT PUBLICATIONS

Background: Questionnaire To Determine Structure

The Staff of the Survey Project is currently engaged in defining the structure and content of the Series and Handbook. The task is a difficult one, since systems analysis is a broad, but poorly defined activity, and it is essential that publications have a truly international perspective.

There are many ways in which the Survey Project Staff gathers information about systems analysis, including review of international literature, participation in conferences, analysis of results of IIASA projects, and direct contacts with non-IIASA scientists and visitors. Together with this, the staff would like to use an additional means to obtain the opinions of a broad range of international experts: a survey questionnaire. This questionnaire, and all other information received, can help the Staff to prepare a publications structure that covers all important aspects of systems analysis, including current practice and scientific findings in many different countries.

The Editorial Staff invites scientists in the NMOs to assist in development of this structure by responding to the questionnaire forwarded with this document. It requests scientists' reactions and suggestions for improving the enclosed outline of the structure. The outline is not a final version, but rather a preliminary draft outline of topics proposed for inclusion in the Survey Project publications; it takes into account the comments made on an experimental questionnaire distributed to a group of IIASA scientists several months ago.

Purpose

The final version of the structure, which incorporates the comments of scientists in each of the NMOs, will serve a twofold purpose: It will provide prospective authors with a general overview for developing individual monographs, and it will serve as a framework to guide the Editorial Staff in their selection of material.

GENERAL EXPLANATION OF THE PROCEDURE

This document is being distributed internationally through the NMOs to a number of experts in different aspects of systems analysis. We hope that the recipients will respond by providing their comments and suggestions for improvement, and by noting prospective authors who are specialists

in the various subject areas in the accompanying questionnaire. If this should prove to be infeasible or inappropriate, we would welcome comments in any other useful form.

There are several ways of returning responses:

- o Responses, in the form of questionnaires, can be mailed to the NMO Liaison Committees.
- o Responses can also be mailed directly to the IIASA Survey Project Staff.
- o If preferable, some other form of response can be provided to the NMO Liaison Committees.
- o Responses can be given to the Survey Project Staff when they visit the NMOs. A visit will be scheduled during April, May, or June; respondents may obtain the exact date of the visit from the NMO Liaison Committees in their respective countries.

When the responses to the questionnaire are received by the Survey Project Staff at IIASA, they will be processed, analyzed, and used to prepare the structure and content of the state-of-the-art publications.

The draft outline of the structure and contents is presented in detail in the following pages. The same outline is duplicated in the questionnaire; the only difference is that the questionnaire lacks the explanatory overview for the main divisions. Thus, it is preferable that you look over this outline to acquaint yourself with the overall structure and explanatory notes before filling in the questionnaire.

SYSTEMS ANALYSIS: AN OUTLINE STRUCTURE

This outline presents the proposed content and structure for publications covering the developing field of systems analysis. The proposed structure is hierarchical.

At the highest level the structure divides into four parts:

I. FOUNDATIONS OF SYSTEMS ANALYSIS

Historical, conceptual, and disciplinary roots of contemporary systems analysis. Philosophical, social, and human aspects of systems analysis.

II. PROCESSES OF SYSTEMS ANALYSIS

Theory, practical approaches, and tools of systems analysis. Further divided into:

A. Art of Systems Analysis

Common features of the approaches used by systems analysts in any application area.

B. Methodology of Systems Analysis

Formal bases for the use of analysis as an aid to decision-making.

C. Techniques of Systems Analysis

Specific mathematical, computational, and qualitative tools of wide applicability.

III. APPLICATIONS OF SYSTEMS ANALYSIS

The current states of application of systems analysis in a wide range of areas.

IV. REFERENCE MATERIALS

Background and reference materials such as glossaries, bibliographies, directories.

Each of these four parts divides at the next level into sections. In the following, each section of each part is displayed in full detail in order.

I. FOUNDATIONS OF SYSTEMS ANALYSIS

Systems analysis, although widely conducted throughout the world, is characterized by a number of difficulties: the variety of different approaches used in systems analysis; the absence of distinct boundaries, both among areas of systems analysis and between systems analysis and other disciplines; and the use of concepts and methodological tools from social science as well as from engineering science. For these reasons, publications on the state-of-the-art of systems analysis might include:

- o An historical evaluation of the development of systems analysis.
- o An indication of the key areas under study.
- o A critical examination of meanings and bases of systems analysis, with the aim of seeking an acceptable terminology that will facilitate communication by identifying equivalent ideas and considerations.
- o An expression of the pressing need to apply achievements in social science to enrich the development of systems analysis.

Consequently, the proposed outline of systems analysis contains the following five sections:

I.1. *Development of Systems Analysis*

Precursors, history, main themes, classical cases and typical procedures, current status, needs and future directions.

I.2. *Meanings of Systems Analysis*

Alternative definitions, practical capabilities and limitations, relationship to other disciplines.

I.3. *Bases of Systems Analysis*

Systems approach, systems analytic concepts, systems structural/functional concepts.

I.4. *Philosophical Aspects of Systems Analysis*

Theoretical capabilities and limitations, relationship to various philosophical systems and questions, role of the analyst in the decisionmaking process.

I.5. *Human and Social Aspects of Systems Analysis*

Human beings in systems, social groups and organizations in systems.

Each of these sections might correspond to a volume in the Series or a chapter in the Handbook. We describe each section in further detail in the following pages.

I.1. *Development of Systems Analysis*

- o Precursors
  - -- operations research
  - -- microeconomics
  - -- control engineering
- o History
  - -- post World War II evolution in various countries
- o Main themes
  - -- aid to decisionmaking
  - -- concern with whole systems
  - -- choice among alternatives
  - -- systems modeling
  - -- interdisciplinarity
  - -- performance assessment
  - -- evaluation of decisions
  - -- explicit treatment of uncertainty
  - -- concern for changes over time
- o Classical cases and typical procedures
  - -- cost-effectiveness analyses to select among system alternatives
  - -- cost-benefit analyses to evaluate major public investments
  - -- PERT (Program Evaluation and Review Technique) to plan and manage programs
  - -- PPBS (Planning-Programming-Budgeting System) as a framework for government management
  - -- large-scale simulations to test operational variants
  - -- formal R&D planning methods
  - -- use of gaming to study conflict situations
  - -- large-scale regional and economic models for planning
- o Current status
  - -- status in various countries
- o Needs and future directions

1.2. *Meanings of Systems Analysis*

- o Alternative definitions
  - -- rational analysis of complex problems
  - -- study of large-scale systems
  - -- formal techniques of decisionmaking
- o Capabilities and limitations of systems analysis--in practice (see also I.4)
- o Relationship to other disciplines
  - -- operations research
  - -- systems engineering
  - -- cybernetics
  - -- economics
  - -- control engineering
  - -- computer science

I.3. *Bases of Systems Analysis*

- o Systems approach
  - -- comprehensive
  - -- interdisciplinary
  - -- future-oriented
  - -- analytical
  - -- objectives-oriented
  - -- sensitive to the inherent complexity of problems
  - -- simultaneously qualitative and quantitative
- o Systems analytic concepts
  - -- specification of alternatives
  - -- evaluation in terms of criteria: cost, performance, risk
  - -- explicit treatment of uncertainty and temporal factors
- o Systems structural/functional concepts
  - -- structural: elements, subsystems, hierarchy, linkage; dynamic changes in structure
  - -- functional: flows of information, control, incentives, objects; assignment of goals, tasks, resources; dynamic changes in functions

I.4. *Philosophical Aspects of Systems Analysis*

- o Capabilities and limitations of systems analysis--in principle (see also I.2.)
- o Relationship to various philosophical systems and questions
- o Role of the analyst in the decisionmaking process

I.5. *Human and Social Aspects of Systems Analysis*

- o Human beings in systems: implications for systems analysis
- o Social groups and organizations in systems: implications for systems analysis

II. PROCESSES OF SYSTEMS ANALYSIS

There is not yet general agreement about what constitutes the appropriate practice of systems analysis, although much has been written about specific aspects of the subject. This outline attempts to bring together these various approaches in a unified structure.

It has been useful to distinguish among three aspects of the practice of systems analysis:

- o The general approach that characterizes all systems analyses, which, however, has many individual and subjective features and cannot be prescribed precisely--the art of systems analysis.
- o The formal bases for systems analysis and methods to aid decisionmakers, which both come from decisionmaking theory and from decisionmaking practice--the methodology of systems analysis.
- o The specific tools (both qualitative and quantitative), often coming from other disciplines (such as statistics, mathematics, computer science, economics), that are useful during the conduct of a systems analysis and should, therefore, be known to all systems analysts--the techniques of systems analysis.

Each of these aspects constitutes a subpart of the second major part of the outline--PROCESSES OF SYSTEMS ANALYSIS.

II.A. Art of Systems Analysis

Types and stages of systems analysis. Case studies. Guidelines.

II.B. Methodology of Systems Analysis

Methods and concepts of decisionmaking theory. Analytical frameworks for practical decisionmaking.

II.C. Techniques of Systems Analysis

Description, modeling, forecasting, measurement, synthesis, planning, management, and implementation techniques.

These in turn are divided into sections.

II.A. Art of Systems Analysis

While it is not possible to give precise prescriptions for the conduct of a systems analysis, the experience of the past 25 years reveals patterns and suggests generalizations that can be distilled and presented. The publications on the state-of-the-art of systems analysis might include:

- o A description of the principal features of systems analyses
- o A characterization of the principal types of systems analyses
- o A specification of the stages of a system analysis
- o A number of case studies, chosen to illustrate successful and unsuccessful systems analyses
- o Practical recommendations for the conduct of successful analyses

These topics have been included in the outline as five sections:

II.A.1. *Features of Systems Analysis*

Participants, inputs, modes of analysis, possible outputs.

II.A.2. *Types of Systems Analysis*

Simplest type. Most complex type.

II.A.3. *Stages of Systems Analysis*

Problem formulation and information gathering. System identification and specification of alternatives. Assessment of alternatives and presentation to decision-makers. Assistance in implementation. Evaluation of implemented alternative.

II.A.4. *Case Studies*

Individual systems analyses, successful and unsuccessful. Comparison of systems analyses.

II.A.5. *General Guidelines*

Pitfalls and common problems. Rules-of-thumb and tricks-of-the-trade.

Each of these sections might correspond to a volume in the Series or a chapter in the Handbook.

II.A.1. *Features of Systems Analysis*

- o Participants
  - -- decisionmakers
  - -- analysts
  - -- other interested parties (e.g., citizens)
- o Inputs
  - -- goals and objectives
  - -- perceptions of problems
  - -- system and contextual characteristics
  - -- decision environment
  - -- alternative decisions
- o Modes of analysis
  - -- mathematical and computational models
  - -- controlled experimentation
  - -- empirical data analysis
  - -- judgment by groups of experts
  - -- individual judgment
  - -- retrospective introspection
- o Possible outputs
  - -- goal statement
  - -- clarification of objectives
  - -- problem definition
  - -- system description
  - -- specification of alternatives
  - -- invention of new alternatives
  - -- comparison of alternatives
  - -- techniques for implementation
  - -- evaluation of performance of selected alternative

II.A.2. *Types of Systems Analysis*

- o Simplest type
  - -- participants: one decisionmaker, one analyst, few other interested parties
  - -- input: clear goals, one objective, well-specified problem, well-known system and context, specified alternatives
  - -- mode: employs a mathematical or computational model to assess clear alternatives according to a single objective
  - -- output: preference ranking of alternatives
- o Most complex type
  - -- participants: several (competing) decisionmakers, several (competing) analysts, many other interested parties
  - -- input: unspecified or unclear goals, multiple objectives, vague problem, poorly understood system and context, incomplete alternatives
  - -- mode: employs experimentation, empirical data analysis or expert judgment to construct and assess the performance of alternatives according to multiple objectives
  - -- outputs: improved statement of goals and objectives, clarification of problem, better description of system, design of improved alternatives, assessment of alternatives in multiple dimensions, assistance in implementation, evaluation of implemented alternative
- o Other types
  - -- most analyses lie between these two extreme types

II.A.3. *Stages of Systems Analysis*

- o Problem formulation and information gathering
  - -- isolation of issues
  - -- identification of decision framework
  - -- determination of global and local objectives
  - -- specification of problem for analysis
  - -- gathering information about problem, context, and system
- o System identification and specification of alternatives
  - -- definition of factors affecting objectives
  - -- specification of linkage among variables in system
  - -- construction of formal or informal model(s), including identification of system boundaries, subsystems, levels of aggregation, interrelationships, input/output functions, choice of analytical tools, validation of model(s)
  - -- identification of possible decisions and actions open to decisionmakers, including creative design of new actions
  - -- indication of the limits to the range of possible actions
- o Assessment of alternatives and presentation to decisionmakers
  - -- choice of outcomes to assess: costs, performance, risk
  - -- choice of methods of accounting for uncertainty and outcomes for various time streams
  - -- selection of a method to test consequences (in terms of outcome measures) of each alternative in a system context, under specified constraints
  - -- assessment of each alternative according to chosen methods
  - -- selection of a method to present the results of the analysis to decisionmakers
- o Assistance in implementation
  - -- adapting a selected alternative for implementation, including detailed design (e.g., scheduling, organization changes)
  - -- informing and training persons who must adopt the alternative
  - -- monitoring the performance of the adopted alternative
  - -- revising the alternative on the basis of performance

II.A.3. *Stages of Systems Analysis* (continued)

- o Evaluation of implemented alternative
  - -- determination of reason for evaluation
  - -- choice of performance outcomes to evaluate: costs, performance, risk
  - -- design of evaluation procedure
  - -- conduct of evaluation
  - -- report of results to decisionmaker/manager

II.A.4. *Case Studies*

- o Critical examinations of individual successful and unsuccessful systems analyses (emphasis on the process of analysis, rather than the specific findings)
- o Comparisons of different analyses of similar subjects

II.A.5. *General Guidelines*

- o Pitfalls and common problems
- o Rules-of-thumb and tricks-of-the-trade

II.B. Methodology of Systems Analysis

While the practice of systems analysis continues to be very much an art, attempts are being made to give it a solid scientific basis. One approach is through the systematic study of fundamental issues in decision-making theory. A second approach has been through the development, both theoretically and empirically, of analytical frameworks that can be used to give structure to the analysis of a practical decisionmaking problem. Both of these approaches might be explained in the publications on the state-of-the-art of systems analysis through:

- o A presentation of the basic concepts and methods of decisionmaking theory
- o A description of analytical frameworks useful in practical decisionmaking

This has led to inclusion in the proposed outline of systems analysis of two sections:

II.B.1. *Basic Concepts and Methods of Decisionmaking Theory*
General concepts based on systems principles and the systems approach. Methodological problems.

II.B.2. *Analytical Frameworks for Practical Decisionmaking*
Traditional investment analysis. Cost-benefit analysis. Cost-effectiveness analysis. Multiattribute impact assessment. Decision analysis. Possible new analytical frameworks. Comparison and evaluation of alternative frameworks.

Each of these sections might require several volumes in the Series or several chapters in the Handbook for proper exposition.

II.B.1. *Basic Concepts and Methods of Decisionmaking Theory*

- o General concepts of decisionmaking theory based on systems principles and the systems approach
  - -- determination of single- and multiple-objective functions and sets, multiattribute solutions and interrelationships
  - -- decision value measurement and decidability evaluation
  - -- explicit treatment of inherent complexity
  - -- extension of the time horizon
  - -- consideration of uncertainty and means of reducing its impact
  - -- risk-analysis and assessment of the consequences of risk
  - -- consideration of competitive aspects and the resolution of conflicts
- o Methodological problems in decisionmaking
  - -- methods to determine objectives, particularly structuring and constructing objectives trees and scenarios
  - -- choice methods dealing with different structures of preferences and stipulating a wide range of choice procedures, such as single- and multiple-dimensional scaling and quantifying, scalar and vector comparison, ordering and ranking, individual and collective choice, modal and multiattribute choice
  - -- methods for utility analysis based on different statements of utility or its specific features, such as single- and multiple-dimensionality, additiveness or nonlinearity
  - -- methods for analyzing sensitivity to determine a decision's sensitivity to errors, parameter deviation, structure variations, and external disturbances
  - -- aggregation and decomposition methods dealing with procedural issues of system divisibility and integrity
  - -- methods for analyzing decision efficiency and feasibility on the basis of different assumptions about feasible sets, alternatives, or solutions
  - -- heuristic decisionmaking methods using, for instance, psychoheuristic programming
  - -- searching and optimizing methods dealing with approaches to deterministic and random search, scalar and vector optimization
  - -- methods for analyzing the stability and equilibrium of decisions

II.B.2. *Analytical Frameworks for Practical Decisionmaking*

- o Traditional investment analysis
  - -- costs and returns calculated in pure monetary units
  - -- decision guided by relationship between cost and returns
- o Cost-benefit analysis
  - -- costs and benefits translated into monetary units (even when they are not monetary)
  - -- decision guided by relationship between costs and benefits
- o Cost-effectiveness analysis
  - -- effectiveness calculated in a "natural" unit
  - -- decision guided by relationship between costs and effectiveness
- o Multiattribute impact assessment
  - -- multiple costs and effects determined in many different "natural" units
  - -- decision guided by relationships among all effects
- o Decision analysis
  - -- outcomes calculated in terms of overall expected utility
  - -- decision guided by expected utility
- o Possible new analytical frameworks
- o Comparison and evaluation of alternative frameworks
  - -- limitations of traditional analytical frameworks
  - -- appropriate areas of use for each of the different analytical frameworks

II.C. Techniques of Systems Analysis

During the conduct of an analysis, the analyst must call upon a wide range of specific tools to assist in such tasks as data gathering and analysis, measuring, modeling, forecasting, synthesizing and optimizing, and so on. Some of these are unique to systems analysis, but generally they are drawn from other disciplines. Nevertheless, they form an important, in fact central, part of the process of systems analysis. For this reason, publications on the state-of-the-art of systems analysis might include:

- o A survey of system description techniques
- o A presentation of both general and special-purpose modeling techniques
- o A review of forecasting procedures
- o A description of techniques for measurement of cost and resource use, of performance, and of risk
- o A collection of useful system synthesis and optimization practices
- o A survey of planning and management techniques
- o A listing of techniques useful during program implementation

As a result, the proposed outline of systems analysis includes the following sections:

II.C.1. *Description Techniques*

Data gathering, data handling, data analysis.

II.C.2. *Modeling Techniques*

General model types, specific model types.

II.C.3. *Forecasting Techniques*

Qualitative, quantitative.

II.C.4. *Measurement Techniques*

Cost and resource use measurement. Performance measurement. Risk measurement. Common measurement issues.

II.C.5. *Synthesis, Design, and Optimization Techniques*

Qualitative, computational, optimization, experimental.

II.C.6. *Planning and Management Techniques*

Program-oriented planning and budgeting, event-oriented planning and scheduling, sectoral planning and management, regional planning and management.

II.C.7. *Implementation Techniques*

Program specification, program introduction, program monitoring and revision.

Each of these sections might correspond to several volumes in the Series or several chapters in the Handbook.

II.C.1. *Description Techniques*

- o Data gathering
  - -- sampling theory
  - -- survey methodology
  - -- experimental design
- o Data handling
  - -- data entry
  - -- data structures
  - -- data files/bases
  - -- data selection, manipulation, retrieval
  - -- data display
- o Data analysis
  - -- data screening
  - -- multivariate statistical techniques (including regression analysis)
  - -- time-series analysis
  - -- pattern recognition

II.C.2. *Modeling Techniques*

- o General model types
  - -- qualitative and manual models
  - -- structured data arrays
  - -- continuous mathematical models
  - -- discrete mathematical models
  - -- stochastic models
  - -- computer models (including simulations)
  - -- man-machine models
  - -- mixed models (e.g., continuous-discrete mathematical models)
- o Specific model types
  - -- economic models (e.g., interindustry models, production models, demand models)
  - -- engineering models (e.g., control system models, communication system models)
  - -- operations research/management science models (e.g., scheduling models, transportation models, queueing models)
  - -- competitive system models (e.g., game theory models, game simulations)
- o Systems of models

II.C.3. *Forecasting Techniques*

- o Qualitative
  - -- scenario writing
  - -- case analysis
  - -- objectives trees
  - -- expert opinion
- o Quantitative
  - -- trend interpolation and extrapolation
  - -- relevance trees
  - -- multivariate and structural models
  - -- cross-impact analysis

II.C.4. *Measurement Techniques*

- o Input--cost and resource use measurement
  - -- cost accounting
  - -- cost estimation
  - -- resource use accounting
  - -- resource use estimation
- o Output--performance measurement
  - -- effectiveness (measured in "natural" performance units)
  - -- benefits (measured in monetary units)
  - -- utility (measured in abstract units)
- o Risk measurement
  - -- absolute risk assessment
  - -- relative risk assessment
- o Common measurement issues
  - -- treatment of uncertainty
  - -- treatment of multidimensional system attributes
  - -- treatment of time-streams of attribute values

II.C.5. *Synthesis, Design, and Optimization Techniques*

- o Qualitative
  - -- individual and group creativity
  - -- use of expert judgment
  - -- use of manual gaming, scenario-writing
- o Computational
  - -- simulation
  - -- man-machine interaction
- o Optimization
  - -- mathematical programming
  - -- optimal control theory
  - -- combinatorial techniques
- o Experimental
  - -- small-scale experimentation
  - -- social (large-scale) experimentation

II.C.6. *Planning and Management Techniques*

- o Program-oriented planning and budgeting
- o Event-oriented planning and scheduling
- o Sectoral planning and management
- o Regional planning and management

II.C.7. *Implementation Techniques*

- o Program specification (in detail for implementation)
  - -- programmed selection of routine and repetitive tasks
  - -- design of group and individual incentives
  - -- scheduling
  - -- organizational analysis and development
  - -- partial and complete documentation
- o Program introduction
  - -- training procedures and programs
  - -- management procedures and programs
- o Program monitoring and revision
  - -- sampling, measuring, and testing
  - -- information feedback and program modification

III. APPLICATIONS OF SYSTEMS ANALYSIS

The application of systems analysis is characterized by the large variety of different areas in which systems analysis is applied, and the possible interrelatedness of some of those areas. Because of these features, applications of systems analysis could be divided into three groups:

- o Application to systems distinctly specialized by the characteristics of the system or by the objects within the system (e.g., water resources, industrial production, medical systems and health care)
- o Integrated applications, which include some or all of the above applications (e.g., energy-environment-industry, food-population-economics, global models)
- o Applications linked functionally (e.g., distribution systems, allocation systems)

This has led to the inclusion in the outline of eight sections: the first six cover topics within the first group, and the last two cover integrated and functional systems, respectively:

III.1. *Resources and Environment*
III.2. *Human and Societal Systems*
III.3. *Economic Systems*
III.4. *Industrial Systems*
III.5. *Biological and Medical Systems*
III.6. *Information Systems and Computers*
III.7. *Integrated Systems*
III.8. *Functional Systems*

In contrast to the sections included in the first two parts of the outline, less detail is provided about each of the subtopics in this section. There are two reasons for this. First, the meaning of each of the subtopics is, in general, self-evident and, for the basic purpose of the outline, does not usually require further explanation (through double-dashed entries of the kind employed elsewhere). Second, however, a truly

satisfactory elaboration of the content of each subtopic requires the knowledge of experts in the area.

Depending on the state of development of the application area, volumes of the Series or chapters of the Handbook might correspond either to the subtopics of the outline (e.g., education), or to sub-subtopics within them (e.g., analysis of river basins within water resources).

III.1. *Resources and Environment*

- o Mineral resources, including energy resources
- o Water resources, including energy uses of water resources
- o Climate
- o Environment
- o Ecology
- o Agriculture, including forestry and animal husbandry

III.2. *Human and Societal Systems*

- o Population
- o Urban and regional planning, development, and management
- o Housing
- o Transportation
- o Communications
- o Education
- o Research and development (basic; not applied to specific sectors)
- o Health services: planning, organization, and management of health care

III.3. *Economic Systems*

- o International trade and economics
- o National economic planning, development, and management
- o Sectoral and industrial economic planning, development, and management
- o Planning, development, and management of economic organizations

III.4. *Industrial Systems*

- o Functions
  - -- research and development (including new technologies)
  - -- planning and management
  - -- production and distribution
- o Sectors
  - -- energy
  - -- structural materials (e.g., steel, nonferrous metals)
  - -- petrochemicals
  - -- electrical machinery
  - -- electronics
  - -- transportation vehicle construction (e.g., automobiles, aircraft)
  - -- construction
  - -- food
  - -- textiles and clothing

III.5. *Biological and Medical Systems*

- o Elementary biological systems
- o Human biology and psychology
- o Medical systems and health care: diagnostic and treatment techniques for the individual
- o Bionics: modeling of human and other biological functions
- o Artificial intelligence: modeling of psychological functions

III.6. *Information Systems and Computers*

- o Telecommunications systems and computer networks
- o Information storage and retrieval
- o Computer systems: software and hardware design and choice
- o Management information systems

III.7. *Integrated Systems*

- o Food and agriculture-population-economics
- o Energy-environment-industry
- o Industry-environment-health care
- o Territorial-industrial complexes
- o Global modeling

III.8. *Functional Systems*

- o Distribution systems
- o Allocation systems
- o Monitoring systems
- o Supply systems

IV. REFERENCE MATERIALS

The international exchange of information on systems analysis can be facilitated by the provision of information about the "system" through which systems analysis itself is conducted and about the specialized language of systems analysis. This has led to the inclusion in the outline of three sections:

IV.1. *Glossaries*

Definitions of key terms used in various areas of systems analysis, both single language and multiple language.

IV.2. *Bibliographies*

Indexed listings of international publications in various areas of systems analysis.

IV.3. *Directories*

Indexed listings of individuals and organizations active in various areas of systems analysis.