THE ANALYSIS, DESIGN, AND IMPLEMENTATION OF INFORMATION SYSTEMS

THIRD EDITION

Henry C. Lucas, Jr.

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PREFACE

The purpose of this text is to provide students with an understanding of information systems, management, and the operation of the computer department in an organization. The text emphasizes both the tasks involved in system analysis and design and the relationship between the designers and the users of a system The book is divided into four parts.

In Part One, system analysis, the nature of the organization, the role of management, and the role of computer-based systems in the organization are discussed. The purpose of this first section is to furnish perspective on information systems and on the approach to systems design advocated in the next section.

Part Two is an overview of system analysis and design and approaches to this task. This section is extremely important; it presents a number of alternative approaches to building a system

Part Three goes into depth on systems analysis and design, one of the major creative tasks undertaken in a modern organization. Here we follow the systems life cycle and illustrate our approach with a case. Part Four of the book discusses some of the problems of managing the computer department to prepare the student to undertake information systems-related activities in an organization.

The book is designed for students who plan to become programmers, systems analysts, and/or managers in the information systems area. The text assumes that the student has completed a course on a higher-level procedural programming language such as COBOL, PL/I, ALGOL, etc. The text should fit the needs of a second or third course on computers or data processing at the undergraduate level Although the book assumes no further background than a good programming course, some prior preparation on hardware, software, and data base technology will make individual topics more meaningful.

For schools with a limited number of information systems courses, the text is intended to follow an introductory programming course. For schools which are able to offer a variety of information systems courses, certain topics in the book can be used as either a review of a prior course (for example, Chapter 8 on files) or an introduction to a more specialized elective (for example, Chapter 22 on the management of the computer department.) The book encompasses almost all the topics for the ACM Curriculum Recommendation for Undergraduate Programs in Information systems course UD9, Systems Design and Implementation, and about 70 percent of the topics in UA8, Systems Concepts and Implications.

The book attempts to cover the broad field of systems analysis and design. The instructor can go into depth on the topics introduced here or additional courses may be taken. One of the best ways to appreciate the nature of systems analysis and design is to complete a course using the text and then to participate in an actual systems analysis and design project.

For the instructor who wishes to use the text in a class on systems analysis and design, there are several features of the text and supplementary materials that may prove helpful. First, there is an Instructors Manual available from McGraw-Hill. In addition, *The Casebook for Managment Information Systems* by Lucas and Gibson contains a number of substantial case studies that can be assigned for class or as term projects to an individual or group of students. (The *Casebook* is also published by McGraw-Hill.)

The text itself contains a series of Discussion Questions, File Problems and Systems Design Exercises. The Systems Problems are very important and the student should be encouraged to read and solve them. These problems are discussed in the Instructor's Manual; they either make a point to supplement the text or require the student to solve a problem by applying the material in the book. The Discussion Questions and File Problems can usually be answered with a few sentences. The Systems Design Exercises are major assignments; here the student reads about a situation and is asked to design some part of an information system. All of this material is intended to better prepare the student for a role in systems analysis and design activities.

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I acknowledge the permission of Columbia University Press to reproduce Tables 7-1 and 7-2 from my 1974 book *Toward Creative Systems Design*, and Figure 4-1 from my 1975 book *Why Information Systems Fail*. McGraw-Hill has also given permission to use parts of *Information Systems Concepts for Management* in this text. *The IBM System Journal* granted permission to reprint Figures 16-3, 16-4, 16-5 and *Management Science* granted permission to reprint Figure 16-6.

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Henry C. Lucas, Jr.

CONTENTS

PART 4 THE MANAGEMENT OF INFORMATION SYSTEMS

PART ONE

INTRODUCTION

CHAPTER 1

THE INFORMATION SYSTEMS ENVIRONMENT

INTRODUCTION

In the past three decades, a new and dynamic activity has developed in organizations the design, operation, and management of computer-based information systems While many organizational activities and resources have long been devoted to the acquisition and processing of information, the advent of electronic computers has greatly extended our information processing capabilities Computer-based information systems have influenced organizations of all types and sizes Many organizations own or lease computers; others obtain computer time from commercial service bureaus.

Organizations with their own computer equipment constitute the majority of computer users, and most of these organizations have established a computer department to design, operate, and manage computer-based information systems In this text, we explore all the activities associated with a computer department except programming (We assume the reader has been exposed to and written at least one program in a higher-level computer language such as COBOL, FORTRAN, PL/1, PASCAL, or BASIC.) In this first chapter we examine general systems theory and organizations that provide the environment for information systems. However, before we discuss systems theory and organizations, it is helpful to present an overview of computer department activities and of the remainder of the book

OVERVIEW

What is an information system? For our purposes, we define an information system as a set of organized procedures that, when executed, provide information for decision making and/or control of the organization Information is some tangible or intangible entity that reduces uncertainty about a state or event For example, information that the weather will be good tomorrow reduces our uncertainty about whether or not a baseball game will be played

We are surrounded by information systems, as we shall see in the examples in later chapters. Organizations use information systems to process transactions, reduce costs, and generate revenue as a part of their products or services. Banks use information systems to process customer checks and produce statements Many firms use computer-based systems to maintain inventories at the lowest level consistent with the kind of service they want to provide in terms of available items There are many services firms that sell particular programs or data to various users In the rest of the text, we shall examine some of the characteristics of these information systems and learn how to design them.

Who uses information systems? There are many examples of information systems and many different types of users In this text, we are primarily interested in computer-based information systems because of the special requirements necessary to develop and manage these systems There are many non-computer-based information systems. However, these systems can be highly flexible, since manual processing procedures are relatively simple and easy to change Computer-based systems are complex and are often seen as rigid and difficult to change. The presence of computer technology also occasionally intimidates users. For these reasons we are primarily interested in systems analysis and design for computer-based information systems

Most computer-based information systems exist within an organization of some type. Members of the organization are the users of the information produced by the system. Because the organization furnishes the overall environment for systems, we discuss organizations in a later section of this chapter. Many users of information systems are managers, and managers are also responsible for allocating resources for the development and operation of information systems. Therefore, in the next chapter we discuss the role of management in the organization.

One of the most important activities of the computer department is the design of information systems. The systems designer works with users to create procedures, file contents and structures, and processing algorithms and conversion steps. The analyst and others manage the programming and implementation of a new system and prepare documentation describing the system. Because the design of a system is so central to the organization and the computer department, the second part of this text is devoted to it.

The entire collection of computer-based information systems in the organization is operated on a regular basis. In addition, both the systems design and operations function in a computer department must be managed. In the fourth part of the book, we explore these activities as they relate to a computer professional At the completion of the text, the reader who has had some programming experience should have a good understanding of the activities and responsibilities of a modern computer department.

SYSTEMS THEORY

General Systems

The field of systems analysis and design for information systems has its foundations in general systems theory General systems theory emphasizes the need to examine all parts of a system. Too often the analyst focuses only on one component of a system, he or she takes action that may be ineffective because important components were ignored

As an example, the federal government mandated certain bumper strength standards for automobiles to reduce damage from slow-speed accidents However, the system in this case was too narrowly defined, the attention of the regulators was on repair costs for slow-speed accidents When the system is enlarged to include the automobile as a consumer of scarce fuels and to include accidents occuring at high speeds, the wisdom of the standards becomes less obvious The impact-resistant bumpers are more complex and heavier than their weaker predecessors. Therefore the automobile consumes more fuel to carry the heavier bumpers. The bumpers are more expensive than their predecessors to repair or replace if damaged in a high-speed accident. Partly as a result of this analysis, bumper requirements were reduced

In addition to focusing on all the parts of a system, general systems theory helps communications among specialists in different fields One field closely associated with general systems theory is cybernetics, the field of communications and control in man-machine systems (including computer systems) Cybernetics represents a combination of the fields of physics, biology, electrical engineering, etc

In the analysis and design of information systems, we also have to apply knowledge from diverse fields. An information system involves people at different levels of an organization, computers, programs, procedures, and personnel to operate the system Fields such as management, organizational behavior, industrial engineering, computer science, electrical engineering, communications, psychology, and others all have important contributions to make to the study and design of information systems. For these reasons we shall briefly review the main elements of general systems theory to prepare for our study of the analysis and design of information systems.

A system is an organized, interacting, interdependent, and integrated set of components or variables. Churchman has defined basic considerations in systems thinking (Schroderbek, 1971) A system has objectives or goals, and often these goals are hard to observe. The goals of a machine are clear, but what are the goals of a social system? What are the goals of a group of interacting individuals?

The environment is external to the system; it encompasses everything that is outside the system's control. The environment also determines in some part the performance of the system, so the system and its environment are interrelated and interdependent. Resources are all the means available to the system to execute activities necessary for goal attainment In contrast to the environment, resources are inside the system and are under its control.

A system is made up of components that are the jobs, activities, missions, or parts of the system that are performed to realize objectives One should not look necessarily at the traditional components of a system such as a department, rather, one's focus should be on thinking of the entire system A focus on missions or activities makes it easier to understand a system

The management of the system consists of activities aimed at planning and control Planning encompasses setting goals, the utilization of resources, and the development of a program for undertaking different activities and of a strategy for dealing with the environment Control deals with the execution of plans Associated with control is the flow of information and feedback so that a system can evaluate its plans For example, a thermostat is a feedback control for a heating system

The following list has been suggested by various theorists as the basics of general systems theory (Schroderbek, 1971)

1 The components of a system are interrelated and interdependent, unrelated and independent components do not constitute a system. In fact, one of the important tasks in studying a system is to determine the relationships among components

2 A system is viewed as a whole, we do not necessarily break it down into constituent parts, particularly if it means that we lose sight of the entire system In many instances we shall concentrate on subsystems that constitute a large system, but we do not want to ignore the overall framework provided by the larger system

3 Systems are goal-seeking in some way, the interacting components reach some final state or goal, an equilibrium position of goal attainment

4 Systems have inputs and outputs, they are dependent on some set of inputs to process to attain the system's goals All systems produce some output needed by other systems.

5 All systems transform inputs into outputs; usually the form of the output differs from that of the input

6 Systems exhibit entropy, a term borrowed from thermodynamics. Entropy describes the state of a closed system (no inputs from outside the system) where all elements move toward disorganization and the inability to obtain and process inputs so the system is unable to produce outputs. Information processing is critical to the survival of systems

7 The system must have a way to regulate its interacting components so that its objectives will be realized. Planning, control, and feedback are associated with this regulatory function

8 Systems usually consist of smaller subsystems The nesting of smaller systems within larger ones forms a hierarchy that is a characteristic of systems theory

9 We usually find differentiation in complex systems, that is, specialized units perform specialized tasks

10 Systems generally exhibit equifinality: some final state that can be reached from several different paths or starting points In other words, there are multiple ways to achieve the goals of the system

Systems Analysis and Design

Systems analysis draws heavily on general systems theory as a conceptual background (see Table 1-1) The many approaches to systems analysis are all aimed at basically the same objective understanding a complex system and modifying it in some way. The modifications may be a new subsystem, new components, a new set of transformations, etc The objective is to improve the internal functioning of the system to make it more efficient, modify the goals of the system, change the outputs, achieve the same goals with a different set of inputs, or make some similar improvement

Normally we will follow a number of steps including

1 Define the problem What is it about the system that is not satisfactory? Have inputs changed in form, cost, or availability? Is the output unsatisfactory for some reason? What is the objective of the systems analysis effort?
2 Understand the system and define it. Because systems are hierarchical (subsystems exist within larger systems) and are interrelated with their environments, it can be very difficult to define exactly what constitutes the system under study This activity can be further subdivided; we ask the following questions to

TABLE 1-1
GENERAL SYSTEMS THEORY AND INFORMATION SYSTEMS DESIGN

	General systems theory	Importance for information systems design
1	Components of a system interact	Delineate components and their interrelation during analysis.
2	A system is a whole	*Be sure to define the entire system before examining subsystems.*
3	Systems are goal seeking	What is the goal of an information system?
4	Systems have input and output.	A major design task is to specify input and output.
5	Systems transform input to yield output	A major design task is to specify processing to produce output from inputs.
6	Systems exhibit entropy.	Information processing is critical to an organization's success.
7	Systems must be controlled.	Information systems help control the organization, information systems have to have feedback on their own performance and be controlled
8	Systems form a hierarchy	Information systems design is a hierarchical task, systems consist of hierarchies of subsystems.
9	*Systems exhibit differentiation*	*Information systems have many specialized parts.*
10	Systems exhibit equifinality	There are many ways to design a system to achieve desired goals

develop an understanding of the system:
  a What are the variables (components) of the system?
  b How are these variables related to each other and the environment?
  c What are the boundaries of the system of interest; that is, where does the system stop and what defines its extent?
3 What alternatives exist to achieve our objectives with respect to modifying the system? What choices are there to improve the system, what is their cost, and can they be implemented?
4 Choose one of the alternatives defined in the previous step.
5 Implement the alternative
6 If possible, we should try to evaluate the impact of the changes we have made in the system

An Example

In a highly readable and entertaining paper, Savas presents an example of systems analysis applied in a highly charged political environment (Savas, 1973). This example will help to show how the systems approach works and how it can be used with a minimum of mathematical sophistication

The Problem The problem that led to this systems analysis effort arose in New York City on a February Sunday in 1969; 15 inches of snow fell though none had been forecast As one might expect, only a skeleton crew was on duty in the sanitation department, which is responsible for snow removal. By the time the reserves were called, they could not get to work. Those who managed to report to work found that the equipment could not cope with the drifts or that abandoned cars blocked plow paths. Some workers ended up plowing out isolated street segments because complementary plow routes could not be completed.

The mayor, facing reelection soon, was soundly booed at his public appearances shortly after the storm because of snow-removal problems Many individuals representing special interest groups offered solutions to the problem. The sanitation workers felt that by having sufficient workers on overtime around the clock during the winter, the problem could be solved. Manufacturers of snow-removal equipment thought that the city should buy more equipment from them.

The mayor turned to the systems analysis unit in his office to undertake a thorough study of the city's snow-fighting capability. The purpose of the analysis was not to find a scapegoat or place blame; the objective was to find out what went wrong and prevent it from happening in the future.

Approach The systems analysis group studied the literature and city snow-removal procedures. After a great deal of thought, they developed a series of questions that would help define the system and its variables. Their questions were:

1 How much snow falls on New York City; snowfall is the input to the system in terms of demand.