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Andrew P. Sage, Series Editor

HOW TO DO SYSTEMS ANALYSIS

PRIMER AND CASEBOOK

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How to Do Systems Analysis
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Preface

The *systems approach*, *systems analysis*, *systems engineering*, or *systems thinking*, whatever one calls the concept, is more likely to be caught than taught. Asking the right questions is often more important than knowing the right answers. The collective experience of the authors in teaching and practicing systems engineering in academia and in the public and private sectors exceeds a combined 100 years. This experience leads us to conclude that the best way for students and practitioners to master the systems concepts is to face realistic, often unstructured, and typically ambiguous problems that require much more than reciting answers or applying methods from the text. Moreover, we have observed that students discover that what they learn from the material presented in Part One of this text becomes integrated into the way they think, as they gain more experience applying the principles and methods through cases such as those provided in Part Two. These cases, developed by instructors based on their professional experience, are situations that students and practitioners face in their own lives, from finding places to live while in school, evaluating employment opportunities, reading about current events and issues, or making other major life decisions.

The unique approach in this book is to motivate systems thinking, or as we like to say: "See the world with new eyes—that of a systems thinker." Throughout the book are examples from the past and from today's pressing issues, which illustrate these concepts, along with case studies in Part Two to give the reader exposure to the practice of systems analysis and systems engineering. The resulting book is appropriate for numerous fields and professionals that need the perspective and tools of systems analysis, including anyone working in the analysis of complex systems, such as in business consulting, financial services, healthcare, telecommunications, and so on.

The goal of the book is to assist in creating the active learning experience such that both students and practitioners internalize systems thinking and the systems approach as they become more effective systems engineering practitioners, including greater proficiency in both technical and professional competencies. We measure the success of this approach by observing the extent to which students demonstrate good systems thinking in the way they approach cases, conduct analysis, communicate findings and recommendations to clients and other stakeholders, and demonstrate professionalism in their ability to both collaborate with others and conduct themselves within ethical standards of practice.

We believe that present books in the area of systems analysis and engineering are excellent; however, many fail to emphasize the art of systems problem-solving

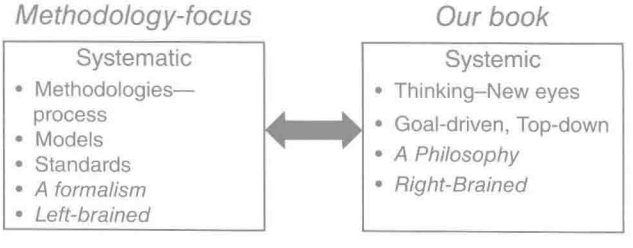
(systems analysis) by focusing instead on operations research methods (mathematical models, such as linear programming) or on the formal systems engineering processes (as stressed by INCOSE: The International Council on Systems Engineering). This book focuses on systems analysis, broadly defined also to include problem formulation and interpretation of proposed alternatives in terms of the value systems of stakeholders. Therefore, this book is a *complement*, not a substitute, to the other "traditional" books when teaching systems engineering and systems analysis. However, the nature of problem-solving discussed in this book is appropriate to a wide range of systems analyses—thus, it can be used as a stand-alone book for teaching the analysis of systems.

Numerous other books describe the processes of systems engineering, including systems engineering handbooks developed by NASA, DOD, Boeing, and so on.

Currently, there is also considerable discussion on the concept of system-of-systems—that is, systems that are of significant complexity and order that they require methodologies beyond the classic systems methodologies that are all basically derivatives of MIL-499B, a classic systems engineering military standard. The emphasis of this book, however, is not on the formal process of systems engineering eloquently described in the referenced books, but on the systems analysis component and the associated thought processes.

The design of this book is such that it can be used at different educational levels. Undergraduates, for example, focus on the basic problem-solving ideas, and the expected depth in their analyses and cases would be significantly less than expected from graduate students. How the book is used, that is, as a primary text or supplemental/complementary text, also depends on the student level. Experience at both levels has shown that experienced students (such as our Accelerated Master's Degrees students—working professionals in an executive degree format program) clearly understand (from their experiences) the issues addressed in the book and can relate the material directly to their work experiences, especially from what we call the systemic perspective; thus, for them the book is a required and a primary source. Undergraduates, typically without the benefit of significant work experience, see the value in a general problem-solving method that applies to many situations, with more focus on the systematic aspects of the material. For them, we use the book as supplemental.

Fundamentally, we see two worlds typical in systems engineering (both are necessary!):



By systemic, we mean affecting the entire system or holistic.[1] By systematic, we mean a formal step-by-step process (in the most direct form, computer code is an example). This book makes a unique contribution by addressing the right-hand side, the systemic side. An analogy could be made to the left-brain (logical; often engineers) and right-brain (artistic) thinkers. The book focuses on problem definition, which is in our opinion a very difficult part of the systems process and an often neglected (or failed) part in practice (and books).

So, we have *How to Do Systems Analysis: Primer and Casebook*. This book is not intended to be an instructional guide to systems engineering (such as practiced in industry or government), but a book that engages one in beginning or enhancing their journey toward becoming a systems thinker—a requisite skill for systems engineers and all problem solvers. *Trends come and go, but quality Systems Analysis thinking abides*. Throughout the book are pointers and references to excellent books and articles that provide detailed techniques, research, and think pieces on the disparate aspects of systems analysis. We have deliberately left much of Jack Gibson's original material alone. We feel strongly that there is considerable wisdom in these words and that this wisdom is timeless. Unfortunately, systems thinking and good systems engineering remain elusive, as evidenced by the fairly recent (Summer 2006) experiences with the Big Dig in Boston and the current U.S. healthcare system debates. Many of Jack's examples and experiences, some dating back to the 1950s, add considerable insight to the realm of systems thinking. We have used draft parts of this book in graduate and undergraduate courses that introduced systems engineering concepts since the early 1990s; then the first book of this nature was based largely on Jack Gibson's contribution, *How to Do Systems Analysis*, published in 2007. The material uniformly received excellent reviews from students for its unique perspective on problem-solving in all types of domains. It is particularly relevant for students with some professional experience who appreciate its practical and accessible concepts.

How would we read this book? Top-down of course. One might start with reading in Part One, beginning by reading Chapter 6 completely, followed by Chapter 1, then reading the first several pages of Chapters 2–5, using the cases in Part Two to reinforce and practice the concepts presented in Part One. For undergraduate students, Chapters 2–4 form the core concepts of a general systems analysis

[1] A wide-reaching term designating views in which the individual elements of a system are determined by their relations to all other elements of that system. Being highly relational, holistic theories do not see the sum of the parts as adding up to the whole. In addition to the individual parts of a system, there are "emergent," or "arising," properties that add to or transform the individual parts. As such, holistic theories claim that no element of a system can exist apart from the system in which it is a part. Holistic theories can be found in philosophical, religious, social, or scientific doctrines. (*Source*: Public Broadcasting Systems.)

methodology. Chapter 6 is, in effect, an executive summary of systems analysis and can basically stand on its own.

We encourage you to engage in and enjoy the material.

William T. Scherer
William F. Gibson
Michael C. Smith
Charlottesville, Virginia
January 2016

Original Preface from Jack Gibson

There appear to be three generic points of view one may take in writing a textbook. These are . . . the *problem-centered* viewpoint, the *technique-centered* viewpoint, and the *reader-centered* viewpoint. Of course, it is also possible to write a book with no consistent point of view at all, one probably need not add. The problem-centered view is not common in general texts but is an acceptable approach for advanced texts on focused, narrow topics. My text, *Designing the New City*, Wiley, 1977, was written from this perspective. However, if the author has an introductory, general purpose in mind, this approach leads to difficulties. In such a situation, problem-centering usually leads to a book of recipes. That is, the author is led to saying for a series of instances, "given this problem, here is how to handle it." One becomes bogged down in specifics, and it is difficult to achieve a general perspective of the topic. This is a severe limitation in itself, and, furthermore, it is unappealing to the academic mind. The technique-centered approach is more common in basic introductory texts.

Generally speaking, technique-centered texts typically provide a chapter or two of introduction and then launch into a survey of the main topics and techniques in the field. It is assumed that the reader will be able to select the appropriate tools to solve his or her specific problem. If one is faced with a problem similar to the type of problems used to illustrate the technique under discussion in the text, this is a good approach. But what it gains in general perspective and an overall viewpoint, it may lose in usefulness in applicability. The technique-centered approach seems to be popular with academics, since we generally have a mind bent that seeks general understanding and we are less interested in problem-solving and specifics. I have written several texts with this perspective, among them being *Introduction to Engineering Design*, Holt, Rinehart & Winston, 1968, and *Nonlinear Automatic Control*, McGraw-Hill, 1963.

The reader-centered point of view has initial appeal as a guide to the perplexed, but in practice it sometimes descends to pontification and anecdotal generalities—that is, retelling of old and possibly irrelevant personal "war stories." This approach assumes a common starting point for its readers, and, as in the present text, this starting point is usually an assumption of a reader's unfamiliarity with the topic. *Scientific American* magazine practices this approach in a masterly way. The first paragraph or two of each of its articles is couched at a simple, obvious level and then acceleration is smooth and gradual.

For better or worse, the reader-centered approach is the one taken in this text. I will assume you are a systems analyst faced with a problem situation. We will go through a step-by-step approach to the application of the systems approach to the

situation, using techniques as the need arises. We will not focus on the details of the analytic techniques to be used; it is assumed that you will learn the details of these (mostly mathematical) techniques elsewhere. From the present text, I hope you will learn just what "systems analysis" (SA) is and what the "systems approach" means. You will see from examining the cases, which are based on actual practice, how the need for mathematical techniques develops, and how to apply them. Moreover, I hope that you will develop a sense of the pitfalls and difficulties in practicing SA. This is a tall order, especially for readers without professional work experience.

Unless you are able to provide a "reality check" from your own work experience, you may be tempted to accept the suggestions herein for analyzing problems as simple and obvious. In reality they are neither, but unlike advanced mathematics, which is obviously difficult going in, SA appears almost trivial on first observation. We will discuss this trap as we go on.

JACK GIBSON
Ivy, Virginia
January 1991

Acknowledgments

Many people have contributed to this book, but first and foremost is John "Jack" Egan Gibson, one of the most intelligent and insightful people I have met and a true systems thinker and cofounder of the modern systems approach. I've had the pleasure of working for 30 years in the premier systems engineering department in the world, a department cofounded by Jack and Andrew P. Sage. During those years, I've had the pleasure of working with giants in the field, including Gibson, Sage, Aleco Christakis, John Warfield, and Wil Thissen. I'd especially like to acknowledge my two mentors, Chip White and Doug White, for their wisdom and friendship.

I'd like to thank my coauthors, Will Gibson and Mike Smith, two outstanding colleagues and true disciples of the systems approach. Finally and most importantly, I'd like to acknowledge the considerable support and love from my wife, Amy, and my trio of daughters, Kendall, Merritt, and Linden, the lights of my life.

W.T.S.

This book is the culmination of the work of many individuals. The primary is John Egan Gibson. Over the years, I pleasantly continue to be surprised by the comments I receive from his students, colleagues, clients, and friends. His seminal ideas and insights continue to provide the framework by which individuals and groups analyze problems. And, I continually see the practical application of these ideas in the non-academic environment. Many of Jack's former graduate students and faculty members provided valuable comments and perspectives on this work.

Additionally, over many years working on the predecessor text and this one, I have enjoyed collaborating with Bill Scherer; we continually chide each other about how Jack's systems approach continues to prevail. And, an additional evangelist of this discipline is Mike Smith, from whom I continue to learn. Over the many years, I could not have completed this work without the help of two very important people. This book would not have been in your hands without the love, tolerance, and support of my wife, Hilary, and our son, Ted.

W.F.G.

"Systems thinking" is something that is observed, learned, and earned over the course of many years, through academic preparation, professional practice, and life experiences. As I look back over the past 30+ years of learning and practice, I see the thumbprints of many individuals – colleagues, clients, students, friends, and family – whose influence and encouragement gave me insights into "How to do systems analysis." I am grateful to my coauthors, Bill Scherer and Will Gibson, who invited me to participate and have embraced my contributions as helpful in

advancing systems thinking among young minds and older practitioners. I am also grateful for the experiences afforded to me throughout my professional career by clients who trusted my colleagues and me to provide thoughtful analysis based largely on the principles presented in this book. And, of course, my greatest appreciation goes to my family, especially my wife, Amanda, whose steadfast love and support exceeds what I deserve or ever expected; and our four children, Martha, Laura, David, and Elizabeth, whose ideas and perspectives always challenge me to think more systemically and recognize the importance of approaching problems with humility and grace.

M.C.S.

About the Companion Website

This book is accompanied by a companion website:
www.wiley.com/go/Gibson/HowtoDoSystemsAnalysis

The Student's website includes:

- Excel data sets associated with specific cases
- Other materials may be added to this website that complement the materials in the textbook and enhance the learning experience.

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Part I

Primer