Analyzing Public Policy Decisions

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Abstract

An introduction to the contents of the book that focus on the art of building and using various optimization and simulation modeling methods for analyzing public systems planning and management issues. Emphasized is on the use of models for informing policy makers and for assisting in decision making processes.

1.1 Introduction

This book introduces the art of building and using models for analyzing public systems planning and management issues. These deterministic and probabilistic optimization and simulation models provide a means of identifying possible ways of addressing various policy problems and evaluating them based on their physical, economic, environmental, and social impacts. While the problems we address to illustrate the application of various mathematical modeling tools will likely differ from the ones you may have to deal with in your future jobs, they serve to help develop your skills in applied systems analysis. Such skills should help you analyze and identify solutions to both well and poorly defined public systems planning and management problems. Typically, such problems have many possible solutions and the best ones, especially given multiple goals and uncertain data, are not obvious.

The purpose of the quantitative and qualitative methods for managing data discussed in this book is to inform those responsible for decision-making. They can help decision-makers estimate the potential impacts of the decisions they might make. These methods cannot determine what decisions are best, but they may help in determining which are better than others. What is best will depend on many factors, including those not considered in any mathematical modeling exercise. Different assumptions can lead to different preferred policy decisions. These

D. P. Loucks, *Public Systems Modeling*, International Series in Operations Research & Management Science 318, https://doi.org/10.1007/978-3-030-93986-1_1

assumptions can range from just what is to be accomplished by a proposed decision and how those impacted will react, to details such as what interest rate may have to be paid on loans 20 years from now. It is the decision-maker who must decide which goals or objectives to consider and which assumptions about how a system functions are most reasonable. The aim of all of this ‘systems analysis technology’ is to help us generate and communicate ‘what if’ information to decision-makers in ways that result in more informed decision-making.

Working in the public sector, including non-governmental organizations, can offer many benefits: a sense of purpose and the opportunity to serve the public and improve the quality of the lives of those of us living in this world. For those having this opportunity, it will undoubtedly involve participation in decision-making processes. Decision-making by public officials establishes programs and policies that can have a significant impact on our lives and on our environment. Governments make decisions. That is what they are supposed to do. From local decisions to federal or international decisions, the impact of public sector decision-making on the lives of people can be significant. Many organizations in the private sector have been benefiting from the use of systems analysis tools for over 5 decades, the military for over 8 decades. Public sector uses have been more recent, but no less useful.

Public sector decisions just like those in other sectors, and indeed the decisions we make in our own lives, are influenced by many factors. Many are made without the benefit of any mathematical modeling. But such models can contribute useful insights on what is technically possible and on what is economically, or environmentally, or ecologically, or socially preferred based on various performance criteria. The use of models as aids to decision-making has been growing in the environmental, natural resources, agriculture, energy, urban planning, and public health decision-making areas, to mention only a few. As more become familiar with both the advantages as well as limitations of systems analysis methods applied by competent analysts to public sector issues, its use will continue to spread and lead to more informed decision-making throughout the public sector.

1.1.1 Historical and Other Perspectives

Systems modeling approaches have existed for well over a half a century with early applications in the biological and ecological disciplines (von Bertalanffy, 1950, 1968). Development and use of systems modeling approaches during the Second World War advanced the fields of systems analysis, systems engineering, and operations research, all of which involve developing and applying optimization, simulation, and statistical models of multicomponent systems. Operations Research (OR) is the name given to a discipline that focuses on the use of mathematical modeling and statistical analysis of decisions on the deployment of the resources under an organization’s control. Systems analysis was developed by RAND Corporation in 1948. It broadened and extended OR. In 1961, the Kennedy Administration in the US decreed that systems modeling methods, combining OR with cost–benefit and cost-effectiveness analyses, should be used throughout the government to provide a quantitative basis for broad decision-making (Enthoven, 2021).

At the international level, the International Institute for Applied Systems Analysis (IIASA) has been successfully providing policy-relevant analysis tools and information pertaining to the management of food and forests, energy, ecosystems and the environment, population growth, and water resources management among other issues since its founding in 1972. Systems analysis tools are commonly used in all the UN organizations and the World Bank. Mostly at the national level, RAND Corporation has been doing the same, but their reach and impact have been at the international level as well. Since 1948 RAND has been developing and using systems analysis methods to meet its goal of identifying solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier, and more prosperous.

The increase in computing power following the War along with advances in algorithms (mathematical procedures) for solving models has made it possible to design and analyze increasingly larger systems, often involving thousands of variables and equations. The availability of computers and software programs that can solve models allows us in the application disciplines to focus on the art of model development and use. Just like painters and musicians and actors, the only way to develop skills in the art of modeling is to practice. This book has been prepared to assist readers in doing that. But even if one doesn't become a systems analyst or modeler, being exposed to the material in this book will help give one an appreciation of the benefits and limitations of using models to better understand and manage systems. They will be better able to understand and work with those who do.

Quantitative models of systems generally rely on predefined goals and causal relationships. Since the late 1970s, soft systems approaches have emerged in response to the challenges faced by modelers in the social world (Checkland, 1999a, 1999b). Soft systems methodology is more qualitative. It is used to gain insight into the decision-making and planning processes and in defining conceptual system diagrams before introducing the mathematics. Soft systems methodology begins by asking what the objectives are, which of course can change over time. Hard systems approaches analyze the system in search of alternatives that satisfy the desired objectives. These approaches can include qualitative as well as quantitative modeling approaches. Chapter 17 of this book presents one way to convert qualitative statements to quantitative expressions suitable for incorporating into models.

To be clear, these modeling approaches are not problem-free. They are all based on assumptions, and they cannot distinguish between good assumptions and bad or incorrect ones. They synthesize but fail to innovate. They fail to suggest new ideas that may not have been considered when creating a conceptual model of a system. The solution of models cannot identify what to include in a system or in what detail. This is one reason why modeling is an art, not a science. Even when modeling physical or biological processes—the science—it is a matter of judgment as to what detail is needed to inform the decisions being considered. Again, modeling is an art and different analysts can differ on what they consider to be the best modeling approach. As stated by George E. P. Box:

> All models are approximations. All models are wrong but some are useful. However, the approximate nature of the model must always be borne in mind.

If models cannot innovate, the question is how can they help humans innovate. One approach is to incorporate models within an interactive participatory modeling framework. Using participatory systems methods that include humans in the modeling loop, innovation may be possible. Models can generate scenarios that may suggest new ideas, i.e., motivate human innovation. Such models have been increasingly applied in the field of natural resources (van den Belt et al., 2010; Voinov et al. 2018).

In practice, most systems analysts use a multitude of methods. For example, different optimization models may be employed to narrow down the number of alternative plans or policies to be examined in greater detail using simulation models. You will be introduced to both types of modeling approaches in the chapters that follow. You will learn that each type of model has its strengths and limitations. There is no single best modeling approach for all analyses and problems. Each modeling approach or type has its advantages and limitations. This will become evident as you are introduced to the different types of models and computer software (e.g., in Excel) used to solve the modeling problems presented in this book.

1.2 Modeling Policy Issues

Modeling and model outputs can help focus policy-making debates. This does not imply that the decision-making processes mimic best accepted modeling procedures. A decision-making framework, where first data are collected, next policy objectives are defined, then alternative policies that meet these objectives are identified, analyzed, and evaluated, perhaps using some of the methods introduced in this book, and finally, a choice that maximizes some combination of social welfare (or minimizes political risk) indicators is made, rarely works in practice. For various reasons, this logical systematic modeling framework does not represent the reality of most policy-making processes (Fig. 1.1).

Policy problems not only have an analytical dimension but also a normative value-based one. Public policymakers need to find acceptable practical compromise solutions to problems or issues that are acceptable to all participants. Often there may be no such obvious solutions. These so-called ‘wicked’ problems are hard to define, let alone address using models. Thus, inevitably their resolution is temporary, tentative, and dependent on political judgments possibly informed by the results of models of those aspects of the problem that can be modeled. This distinction between the analytical approach to the discovery of knowledge and policy-making does not make it impossible for analysts and policymakers to work together to better inform the policy-making process. But it is not always easy. While policy decisions can certainly be made without being informed by any analyses of alternatives, the added value of policy informed by such analyses suggests they are worth performing.

There are a variety of modeling approaches that can be useful tools for informing policymakers. Models used to inform policy are built and solved to provide information that can help policymakers develop insights on which they can base, at least in part, their policy decisions. The usefulness of such 'policy modeling' is judged not by how accurately it reflects the real world, but by how well it is able to provide information that enables a policymaker to make knowledgeable choices among policy options—i.e., how well the modeling can help construct and defend arguments about the relative pros and cons of alternative policy options. A relatively crude model that can clearly demonstrate that alternative 'A' performs better than alternative 'B' under both favorable and unfavorable assumptions will probably lead to a better decision than a complex model that can perform only a detailed expected-value estimation.

Policy models trade off rigor for relevance. In some cases, they can be used for screening large numbers of alternative policy options, comparing the outcomes of the alternatives, and/or designing strategies considering a wide range of factors (e.g., technical, financial, or social), but not a lot of detail about each factor. The outcomes are generally intended for comparative analysis (i.e., relative rankings) of policy alternatives. Approximate results are often sufficient to map out the decision space—the ranges of values of the various input parameter values for which each of the various policy options would be preferred.

1.3 Complexity

In today's highly interconnected societies and economies, policymakers addressing one issue must consider the impacts of their decisions not only on the issue being addressed but also if and how those decisions may impact other aspects of society over time. We are all living in a multicomponent environment and dealing with multicomponent systems, as illustrated in Fig. 1.2. Hence, taking a systems approach to managing them makes sense. A systems approach focuses on the performance of the system as a whole, not of each component separately. How one component of a system is designed and managed may impact the performance of one or more other components of that system or even of other systems. These possibilities are worth being identified and evaluated, ideally before policy decisions are made. Better to prevent major problems or crises than to deal with their consequences although politicians, and indeed most of us, probably get more credit and fame from solving crises than from preventing them.

The more complex the issue is, the more likely some application of systems analysis methods may be helpful when considering ways of addressing the

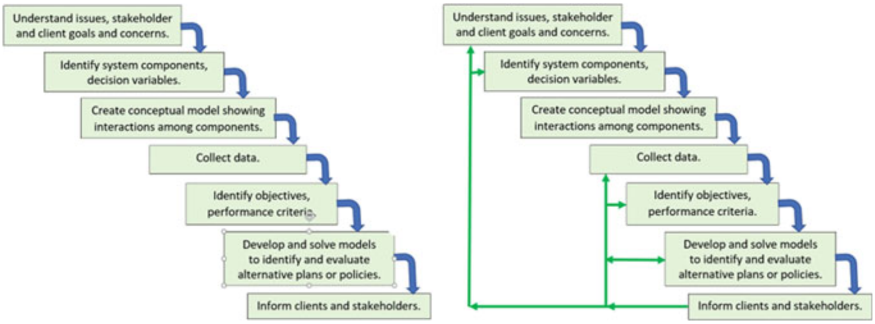
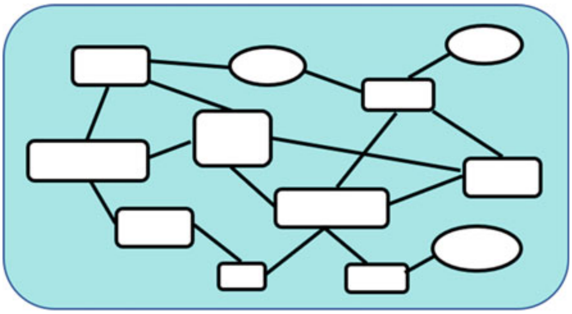


Fig. 1.1 A theoretical sequential modeling process on the left looks like a water cascade. The modeling process in practice on the right has many possible feedbacks requiring model modifications or even having to begin parts of the process over again

Fig. 1.2 Conceptual model of an interdependent interacting multicomponent system



issue. What is a complex issue? Factors characterizing complex issues include the following:

- existence of multiple criteria (outcomes you want any decision to achieve);
- many possible alternative decisions and the 'best' is not obvious;
- significant uncertainty in the outcome of any decision;
- competing viewpoints or goals among decision-makers and/or stakeholders;
- conflicting criteria (e.g., improving one outcome worsens another);
- significant (size or time frame) impacts associated with any decision; and
- decision outcomes that will impact many people and are
- hard to modify or adapt to changing criteria or conditions over time.

Certainly, there are many public policy decisions that have these characteristics. For example, consider the fossil fuel industry's argument that production and pipeline transport contributes to job creation and economic benefits. Positioning themselves as friends of working people, they counter those concerned about potential environmental damage and global warming by arguing that they are protecting oil and gas workers' livelihoods. It happens often. A company proposes some big project, environmentalists oppose it. Or a government agency proposes new regulations intended to reduce air pollution. Public health experts say it will improve human health and reduce premature deaths, but unions say it will destroy jobs. These are examples of conflict of criteria.

Decisions that have multiple conflicting criteria and many alternatives are difficult to make. These are examples of public policy issues for which systems analysis methods can help identify and evaluate the consequences of alternative policy decisions that could be taken to address them.

1.4 Are You Ready?

Decision sciences are typically taught in engineering, mathematics, and economics departments including business schools. Because of their wide applicability, they are increasingly being offered in public affairs programs as well. To reassure those who may not have quantitative backgrounds, you do not need a mathematics or engineering or economics background to learn how to use the tools presented in this introductory text. All that is expected and assumed is some proficiency in algebra. The emphasis in this book is on learning the art of developing and solving models that address particular public policy issues. Having these skills can only benefit you as an employee in a public service organization. What public organization does not need to analyze data, make decisions, and interact with those having a large diversity of backgrounds and expertise in law, engineering, the natural sciences, the social sciences, and in communications, to mention a few?

1.5 Book Outline

Chapter 2 offers some insights into public systems and how models of such systems may help inform those responsible for their design and operation. The advice offered in Chap. 2 is backed up with some case studies involving the application of modeling and factors that contributed to their success or failure. Chapters 3 and 4 begin the introduction to developing and solving models applied to some simple policy and infrastructure design problems.

Many of the models used to address policy and infrastructure issues include economic functions that define benefits and costs over time. Chapter 5 reviews the methods used to compute present and future and annual benefits and costs, and the influence of inflation and taxes on how we manage our personal as well as public investments. Those who develop models do so in part because they assume they can be solved. Many of the modeling examples used in this book to illustrate different modeling approaches can be solved on a computer using Excel. Chapter 6 reviews how to apply the Solver component of Excel to solve a wide variety of optimization models.

Chapters 7, 8, and 9 focus on constrained optimization modeling, again using policy and infrastructure issues as example problems to model and solve. Chapters 10 and 11 introduce ways calculus can be used to analyze problems that are characterized by continuous non-linear functions. These chapters are written for those not yet familiar with calculus and how slopes (marginal values) of functions are derived and used to find optimal solutions. Issues such as the privatization of public utilities and the impacts that may follow such decisions are addressed using these calculus-based methods.

Chapters 12 and 13 introduce ways of dealing with uncertainty when developing optimization or simulation models. They review the basics of probability and statistics and introduce stochastic processes and how such processes can be included within models applied to various public policy issues. Chapter 14 describes how reliabilities associated with relationships within systems can be considered and introduces methods for generating values of random variables and how they can be applied in simulation models.

Simulation modeling is introduced in Chap. 15, again through its application to policy and infrastructure planning problems, taking advantage of the information presented in previous chapters. The chapter serves to reinforce many of the modeling and solution approaches covered throughout the book. Chapter 16 addresses situations where multiple system performance criteria or goals exist, and some of them may conflict with others. In such cases, tradeoffs among the values of multiple performance measures can be identified using various modeling and other analysis approaches reviewed in this chapter, thereby informing the political negotiation process as it attempts to identify the most preferred policy or plan.

The book concludes with an introduction on how to include qualitative expressions of goals or constraints in optimization and simulation models. Chapter 17 explains how qualitative expressions of economic, environmental, and social concerns can be considered along with the system conditions that can be expressed quantitatively. Final Chap. 18 briefly summarizes the role this modeling plays in the political decision-making process where public policies and infrastructure plans are approved and implemented.

1.6 Conclusion

'Data-driven decision-making' and 'evidence-based decision-making' are popular topics these days, especially as a counterweight to the misinformation that seems to influence many aspects of today's public sector decision-making. The terms refer to the analyses of observed scientific data to inform decision-making processes. The keyword is 'to inform'. Experienced decision analysts addressing public policy challenges recognize that no analysis, including their own, can by itself tell one what the best decision is pertaining to a particular public issue. Analyses are always limited in what they include or consider.

Nevertheless, analyses can provide insights about potential outcomes and uncertainties and clarify what the implications may be of any decision or action taken regarding a particular issue or problem. Applying these tools could very well increase the probability of achieving agreements among stakeholders, or at least elucidate the causes of disagreements that may exist. As mentioned earlier, they may also help identify new, preferred alternatives. These tools can also be used to help people outside of the decision process better understand why an alternative policy was selected. In sum, modeling approaches can provide structure, consistency, transparency, and understanding about public sector decisions, which would benefit the public as well as the decision-makers.

Exercises

1. Why develop and use models?
2. Under what conditions is modeling potentially useful to managers (decision-makers)?
3. Develop a conceptual network representation of the interdependence among our water, land, energy, climate, and socio-economic systems.

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