

# Restoring Legitimacy to the Systems Approach



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**T**he systems approach is a mainstay of engineering theory and practice, but it has been misapplied in the public policy arena and it is now viewed skeptically. This article briefly analyzes the problems that have been encountered with certain prescriptive applications of system concepts in the field of public policy. It then suggests steps that could restore credibility and legitimacy to policy-related applications of the systems approach.

## **SYSTEMS APPROACH: BROAD VIEW**

The systems approach is one general way of going about tackling

a problem; some others include the experimental, political, moral, religious, and aesthetic approaches [1, p. 5], [2]. The systems approach to a problem tends to take a broad view, tries to take all aspects into account, accepts the basic propositions of science, assumes that the world contains structured wholes, and concentrates on interactions between different parts of the whole [1, pp. 5-6].

Within engineering, the systems approach probably dominates professional practice. Most engineering design is largely system design. Relatively few engineers design devices; the majority of engineers connect “boxes” together to create systems. Thinking in

systemic terms is second nature to most engineers — otherwise the wonderful and complex things they create wouldn’t function.

Elements of the systems approach have long been in widespread use. Astronomers and physicists have analyzed dynamic systems for many centuries, and more

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recently ecologists have studied ecosystems, meteorologists have studied atmospheric systems, and political scientists have studied governmental systems, to name a few. Most of these users have had only descriptive aspirations, and they have merely wanted to show how things fit together and related to one another.

However, others with more ambition have wanted to prescribe changes — they have wanted to act like engineers. They have wanted to redesign landscapes, cities, economies, governments, and even Earth systems. When they have tried, they have often come to grief, and in so doing they have given the systems approach a bad name [3]- [7].

Engineers should care about this because it tarnishes the field's image. Non-engineers should care because the world we live in could be vastly improved, and we need more effective prescriptive thinkers in many fields. But the prescriptions need to be credible and legitimate.

Credible prescriptions are those that are implementable and technically defensible. Control systems engineers often measure implementation success using performance measures that characterize rates of response and tracking, and robustness, which is the ability of a controller to cope with the inevitable uncertainty associated with imperfect models of complex systems. Moreover, they may consider implementation complexity and cost to be important issues. System properties such as controllability, observability, and stability limit their ability to achieve effective designs. Some policy-relevant systems are difficult to analyze and control, making implementation of prescriptions problematic. The difficulties are often due to poor system controllability and observability properties, as well as problems with measuring factors such as performance and cost.

A prescription is technically defensible if one is able to predict its outcome with confidence and responsibility. Good engineers are particular about staying within their areas of expertise, and they avoid extending their analytical methods to cases where the information they require is not available. Some with the engineering impulse are not always so circumspect, and defensibility has become a second major credibility problem in the public policy context.

Also important in policy applications of the systems approach is the problem of ascribing purpose, as discussed below. This raises concerns about legitimacy.

## TYPES OF SYSTEMS

System characteristics profoundly influence the feasibility of prescriptions. Compare these definitions:

- Engineers typically define a system as a group or set of objects united by some form of regular interaction or interdependence to perform a specified function [8, pg. 15].
- Scientists traditionally define a system as a group of interacting, interrelated, or interdependent elements forming or regarded as forming a collective entity [9].

Both definitions mention bounded sets of objects and interactions. But an engineered system has a purpose, whereas a non-engineered system does not. One can optimize a system that has a purpose, whereas one can only influence other system types. People who have the engineering impulse will try to analyze and change any system they don't like, even if it was not originally an engineered system. Consider four vignettes:

My first job out of college was to design the mechanical systems in semiconductor manufacturing plants. I assembled standard components from catalogs and linked them together into heating, ventilating, air conditioning, plumbing, and process piping systems that maintained comfort, air purity, sanitation, and plant operations. These systems were reasonably control-

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lable, observable, and stable, so that we usually did a credible design job. These were optimizable systems, and the boss gave me grief if a design looked sub-optimal. As designed systems, everyone agreed on their purposes and on measures of their optimality.

I now teach in an urban planning department, and one of the early lessons the students learn is that planners lack robust instruments of control and operate with inadequate knowledge of complex, open urban systems. Also, while I can describe an urban system, it seems nonsensical to talk about its purpose, which lies mostly in the eye of the beholder. Some call it an economic engine that achieves efficiency through agglomeration economies; others think it is a geographic feature that imposes a transshipment requirement on the transportation network; for others it is a cultural cauldron that integrates ethnicities into a national identity; for most it is just where they live. Cities are human artifacts but they are not really

designed systems, and there is little agreement on their most important purposes or measures of optimality. Their mayors are frequently embroiled in controversy over such seemingly universal goals as adequate security and well being for residents.

Credible analysis and control of ecosystems and atmospheric systems remains elusive. Models of agricultural, forestry, fishing, and fossil fuel combustion impacts are improving but behavior change in these sectors comes slowly. Most of us would consider it silly to talk about the intrinsic purpose of such systems, except during theological speculation. However, we influence such systems every day for purposes of our own. Many of these influences — such as pollution — are unintended, but both resource extraction and environ-

goals are not widely shared.

Humans have long controlled living organisms in agriculture and in hierarchical human institutions such as slavery, the military, the university, and the corporation. Models of living systems have been crude and the means of control often have been both brutal and ineffective. Liberal democracies now limit the extent of such control and, for humans, emphasize self-determination. Although some biologists claim that the purpose of living organisms is to propagate their DNA, others find nobler purposes in life, human and otherwise. Ascribing purpose to autonomous, living agents is a sure way to generate controversy at the deepest philosophical level.

These four system examples vary in terms of complexity, controllability, observability, and stability. All but the first lack definitive endpoints and hence they cannot be optimized. Would-be controllers can do no more than establish satisfying processes, such as adaptive management [10], that keep the system within an “acceptable” performance range. Also, they need permission from others to perform the control function.

My point here is that means and ends that are taken as given in engineered systems must be invented and argued about for other systems. Analysis and control may not be feasible. There is no exogenous client, boss, or command hierarchy; the decisions instead are endogenous and shared by many parties. How the argument takes place becomes important — within which institutions, following what procedures, according to which methods, involving which people. The systems approach gains both substantive and proce-

dural dimensions that can place its credibility and legitimacy at risk, as its history illustrates.

## EVOLUTION OF THE SYSTEMS APPROACH

The intellectual history of the systems approach shows two transitions, first from science into engineering, and then out of it to other fields. Only the second transition has been problematic.

### *From description to control*

Descriptive modeling of systems (such as orbiting planets) predates Christianity [11]. With the development, first of calculus, and later, of numerical computation techniques, it has become possible to model increasingly complex systems. These modeling tools have greatly enriched scientific understanding of phenomena ranging from the behavior of elementary particles to that of the business cycle.

The engineering definition of systems branched off from others with the development of control systems engineering, a widely influential body of knowledge. Concepts such as feedback, difference measurement, and error correction were behind advances in electronics, robotics, space flight, air and rail transportation, numerous military technologies, biomedical devices, and many other applications [12].

The same concepts contributed to the development of systems engineering, which brought a quantitative, scientific perspective to the management and engineering of complex projects. This field took the best practices of the early Cold War missile projects and codified them into a coherent, teachable toolkit. Allied disciplines included operations research, which applied these methods to operational problems, and systems analysis, which evaluated the strengths and weaknesses of alternative planned projects [5, pp. 8-9]. Together, this package of techniques defined the

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mental laws are very purposeful. It remains difficult to establish measures of optimality, because there is little agreement on what we want. Either we establish an arbitrary goal —restoring the pre-industrial state, for example — or we resort to arguments that place broadly shared goals such as better human health at the end of a long causal chain with links back to environmental conditions. Controversy persists when links are tenuous or scientifically unproven, or

systems approach in engineering, and it established a formidable basis for managing technological complexity.

### *From technological to social systems*

When something works well in one context, there is a natural temptation to apply it elsewhere. The missile builders of the 1950s had successfully added organizational variables to the technological core of the systems approach. It seemed reasonable in the 1960s to expand the realm of application to non-military projects. U.S. President Johnson in 1965 issued an executive order requiring all federal agencies to adopt the Pentagon's systems approach (part of Robert McNamara's planning, programming, and budgeting system); and systems engineers were put to work on a variety of complex public problems ranging from water resources management to urban redevelopment [5, pp. 141-195].

Other disciplines also adopted aspects of the engineering systems approach. Sometimes the usage was metaphorical, as when the phrase "cybernetic federalism" was used to describe the dynamic and self-regulating system of intergovernmental relations in the United States [13]. Often there was more literal borrowing: environmental regulation [14] and macroeconomic stability [15] are illustrative of the many social, political, and economic phenomena that were explicitly modeled as controls engineering problems. The creation of a standard system dynamics modeling framework broadened the range of applications even further [16].

### *From hubris to timidity*

Like many Great Society programs, the spread of the systems approach encountered unexpected obstacles and failed to deliver on its high expectations. A historian of the systems approach observes that "engineers, scientists, and managers

who proved competent, even expert, in the 1950s as system builders in the context of military-funded projects found coping with the political aspects of 1960s civil projects bafflingly difficult" [5, p. 197].

Calling something a system did not make it controllable or even analyzable. One observer wryly noted that "the purpose of analysis is to connect knowledge with power, not ignorance with weakness" [6, p. 9]. The aggressive systems analysts of the 1960s overreached in their attempts at comprehensive policy planning, even as governments found that they had little influence over public problems rooted in individual behavior. In reaction to the embarrassing failure of "macro-macho" analysis [6, p. xxv], policy analysis has since become timid, emphasizing incremental rather than radical change, small solutions to small problems, and decentralized decision-making [7].

There were numerous analytical concerns. One influential critique identified seven sins of most system modeling efforts: hyper-comprehensiveness (unmanageable scope), grossness (inadequate detail to inform decisions), hungeriness (budget-busting data needs), wrongheadedness (inappropriate implicit assumptions), complicatedness (impossible to validate), mechanicalness (vulnerability to rounding errors and effects of calculation order), and expensiveness (costly relative to benefits) [17].

More broadly, there was concern that the power of experts was growing while the power of citizens was shrinking. This led to worry over the pursuit of substantive rationality ("the optimal solution") at the expense of procedural rationality ("the legitimate decision"). Critics argued that any purely instrumental ("optimizing") rationality enforced in a social context must come at the expense of both individual liberty and democracy [18]. Liberty would

suffer because individuals would be coerced into serving a dubiously defined public good. Democracy would suffer because individuals would relinquish decision-making power to the optimizers. Discourse would become thinner and alienation would set in.

Faced with these challenges and a dearth of funding, many advocates of the systems approach retreated to places they were more welcomed, including the Pentagon, business organizations, and universities. They had been found guilty of advocating "social engineering," a derogatory term associated with previously discredited movements favoring "a rule by a comprehensive knowledge of social facts," "the conscious, deliberate organization of society," "scientific socialism," and the "depoliticization of social problem solving" [19]. The systems approach — apparently just another form of antidemocratic elitism — skulked out of the limelight.

## **FUNDAMENTAL PROBLEMS**

The rise and fall of the systems approach in public policy illustrates two fundamental problems of analysis in support of decision-making:

- appropriate simplification of reality — choosing a model specification that has credible inputs and functional relationships, as well as outputs of interest to decision-makers; and
- successful communication — ensuring that information flows freely and interactively along three key pathways, between analysts and decision-makers, between analysts and the general public, and among analysts with different specialties.

These problems require that analysis be tailored to its context, and that the method be applicable in that context. Adopting engineering tools without adequate consideration of their applicability led to

embarrassing failures.

In public settings, analysis also needs legitimacy to be effective. Legitimacy in this context may have two sources [20]:

- a status-based, numinous, “authoritative” legitimacy such as that enjoyed by god-kings, charismatic leaders, and respected scientists; or
- a consent-based “civil” legitimacy that is granted to experts by the public in return for following constitutional rules and open, democratic procedures.

Credibility, which I earlier introduced as a separate concern, can now be subsumed into status-based legitimacy. Early users of the systems approach in public settings relied solely on their authoritativeness and found it inadequate to the task.

## THE ROAD TO REHABILITATION

A boisterous partisanship dominates most real democracies, and when it becomes excessive, people see that substituting politics for informed decision-making carries a cost. Think of the careless public execution of the Office of Technology Assessment by a belligerent 104th U.S. Congress in 1995. There is a permanent tension between knowledge and power, expertise and pluralism, in democratic societies [21]. Deep down, we know that both are crucial ingredients of governance, but striking a balance is difficult.

Reflecting on the retreat of the systems approach in public life, one of its leading advocates has noted: “Engineering is intellectually dangerous. One works beyond the edge of reliable information...” [22]. Implicit in this comment is concern that society’s problems will not be solved if there are no risk takers: the world needs social engineers after all. Or at least it needs the engineering impulse. Needed are more acceptable and useful ways to

apply the systems approach to public problems.

A few advocates of the systems approach have overcome both analytical hubris and timidity by redefining the problem as one of appropriate balance. They have internalized the lessons learned to date, becoming reflective practitioners [23] who have explicitly acknowledged the potential for bias, bounded rationality, and other limitations. Some have worked self-consciously — but not timidly — to earn public credibility and trust. These humble analysts have accepted that there is sometimes legitimate skepticism regarding authoritative knowledge claims and they have acted accordingly [2]. While they reject the postmodernist idea of “no privileged discourses” (who would drive a car designed by Foucault?), they nonetheless accept the reality of today’s multicultural world [24].

Here I describe a few of the advances that are bringing the systems approach back into public life.

### *From hard to soft*

System models such as the famous Limits to Growth effort substituted elaborate causal structures for missing data, and the models were criticized for their lack of empirical validity [25]. Many policy modelers subsequently took an empirical turn and relied primarily on econometric formulations that kept them close to their data [26]. This strategy precluded investigation of many important topics because adequate data were lacking.

A subset of modelers instead has embraced a “soft” systems approach that uses the field’s concepts and structures to organize qualitative investigations of problems [1]. This approach enjoys use mostly in the management consulting context where managers must solve organizational problems regardless of data availability, and

hence they are willing to lean on mental models rooted in personal experience [27].<sup>1</sup>

### *From macro to micro*

Rather than focusing only on macro-level phenomena such as Gross Domestic Product or global population, some analytical efforts now use the individual decision-maker as their unit of analysis. Game theory helps explain major events such as wars, treaties, and distorted markets by modeling the strategic interactions of individuals as they compete and cooperate [28], [29]. Agent-based modeling within a cellular automata framework produces realistic macro-level patterns in a variety of human systems [30], [31]. Such approaches let analysts move away from mechanistic, hydraulics-style system models with fixed structures, towards tools that capture elements of decentralized decision-making and evolution, and allow a focus on decision rules and individual behavior. These tools help those with the engineering impulse to intervene in ways that respect the individual decision-maker and take advantage of the adaptability of systems.

### *From control back to description*

It may sound like a step backwards, but system simulation — modeling for understanding — has become a valuable tool in both the original research context and to support decision making [8, pp. 10-14]. In a public setting, simulation can indicate the strengths and weaknesses of various policy alternatives while also exploring the effects of uncertainty. In a pluralistic society with decentralized decision-making power, the investigation of tradeoffs among alternatives is often more valuable than a black-box optimization exercise that opaquely provides “the solution”

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<sup>1</sup>Such work is frequently published in the Plenum journal *Systemic Practice and Action Research*.

[32]. Individuals with diverse preferences take better information about tradeoffs back to their own decision-making domains, so that the analysis improves the quality of democratic discourse rather than making it thinner.

### ***From comprehensive to holistic***

Comprehensiveness is a desirable but unachievable goal for policy analysis. No system analysis or project evaluation really includes all costs and benefits, even though the decision criterion — net benefit — assumes a comprehensive enumeration. Users of the systems approach invariably struggle with boundary questions as a result. Yet the seductive force of reductionism encourages analysts to study whatever they can measure, leads decision-makers to manage only what can be measured, and eventually deprives both parties of a holistic view of the forest for having focused so intently on the trees [33].

Qualitative holism is the unappetizing fallback position to which some policy analysts retreat, as in: “Like wow, man! Everything is interconnected, so we do systems thinking here at the Center for Holistic Analysis.” A more useful approach entering practice is to employ methods (such as multicriteria analysis) and processes (such as joint fact finding) that handle data of variable quality while still providing a credible basis for decision making [34].

There is another kind of big-picture thinking that is pleasingly rigorous, and it instead adopts a multi-level perspective. Careful holistic thinkers ask what level of detail is appropriate for analyzing each particular question. The world is made up of systems within systems (e.g., engines within automobiles within transportation systems), and each higher level can be defined by both its components and its emergent properties. In the research context, multi-level analysis is a standard

approach [35], and now it is finding greater use in the practice of policy analysis [36].

### ***From self-sufficient to interactive***

One way to characterize the division of labor between decision-makers and analysts is that the former decide upon reasonable decision rules, while the latter strive to apply those rules rationally. “Reasonable” decision rules are internally consistent and are the outcome of moral argumentation. “Rational” application is logical, valid, reliable, and empirically tested.

Analysts get into trouble when they adopt decision rules independently of decision makers. For example, is a “net social benefit” decision rule used to justify the displacement of local residents for a hydroelectric dam reasonable? Secondly, is the method used for estimating the costs and benefits rational? A rational analysis is of no use if it is based on an unreasonable decision rule. Given that there are many possible decision rules, analysts should ask.

The interactive planning movement [37] addresses such issues. Some analysts now specialize in building complex computer models directly with groups during participatory workshops. This approach works well in managerial and administrative contexts where few data are available and models codify experience in a causal structure. Examples include modeling the flow of children needing foster care in New York State, homelessness in New York City, and Medicaid expenditures in Vermont [38].

Those engaged in group model building processes have identified distinct roles for analysts, including facilitator (the person in front of the room eliciting knowledge), modeler/reflector (critically evaluates the model being built), process coach (observes and guides facilitator’s interventions in group dynamics), recorder (tracks the groups ideas

and decisions), and gatekeeper (represents the client’s interests) [39]. Others instead arrange iterative exchanges between analysts and decision-makers to design, validate, and exercise models in more public settings [32].

### ***From substantive to procedural***

In a public context, technical expertise is a necessary but not a sufficient condition for effectiveness as an analyst. Public policy curricula also include training in critical thinking, moral reasoning, and effective interpersonal relations [40]. That has not been the case in fields such as engineering, economics, ecology, and physics, whose graduates are the most vocal advocates of the systems approach in public affairs. An increasing amount of cross-training now occurs [41], and more analysts are bringing a sophisticated understanding of both substantive and procedural matters to their jobs.

Rational analysis is a fragile endeavor that flourishes only when those with power permit it to do so. The institutions of both science and democracy are only a few centuries old, and the notion that the “force of the better argument” should prevail in public debates has particularly shallow roots in the human experience [42].

Some savvy analysts therefore build “boundary” organizations that carve out a neutral space for performing technical analysis on an ongoing basis by balancing the relative influence of competing interests [43]. The former U.S. Congressional Office of Technology Assessment (OTA, 1972-1995) was one example, another is the Health Effects Institute, which is co-funded by the automobile industry and the U.S. Environmental Protection Agency to perform toxicological research that directly informs regulatory decision-making. Since funding comes in equal portions from both parties to the regulatory debate, research findings are more

readily accepted. The OTA's study process was very open and interactive, it invited both experts and interested parties to help set the scope of their studies and to review the draft products.

## RESTORING CREDIBILITY AND LEGITIMACY

In conclusion, I suggest that some with the engineering impulse have misapplied the systems approach in the public sphere, so that past work has lacked substantive rationality — credibility — as well as procedural rationality — legitimacy. I argue that the more successful current advocates of the systems approach work carefully to do two things:

- Interact frequently with decision-makers, other analysts, interested parties, and the lay public, from initial scoping through external review of analytical work. Open communication is crucial because it helps analysts build models that appropriately and credibly simplify reality for their specific context.
- Have the humility to seek both status-based and consent-based sources of legitimacy for analytical work. Consciously balancing those sources helps to restore both credibility and legitimacy to the systems approach in public policy.

## REFERENCES

[1] P. Checkland, *Systems Thinking, Systems Practice*. Chichester, UK: Wiley, 1981.  
 [2] C.W. Churchman, *The Systems Approach and Its Enemies*. New York, NY: Basic, 1979.  
 [3] I. Hoos, *Systems Analysis in Public Policy: A Critique*. Berkeley, CA: Univ. of California Press, 1972.  
 [4] L.H. Tribe, "Technology assessment and the fourth discontinuity: The limits of instrumental rationality," *Southern Califor-*

*nia Law Review*, vol. 46, pp. 617-660, 1973.  
 [5] T.P. Hughes, *Rescuing Prometheus*. New York, NY: Pantheon, 1998.  
 [6] A. Wildavsky, *Speaking Truth to Power: The Art and Craft of Policy Analysis*, rev. ed. New Brunswick, NJ: Transaction, 1987.  
 [7] S.S. Fainstein and N. Fainstein, "City planning and political values: An updated view," S. Campbell and S.S. Fainstein, Eds. *Readings in Planning Theory*. Oxford, UK: Blackwell, 1996, pp. 265-287.  
 [8] R.E. Shannon, *Systems Simulation: The Art and Science*. Englewood Cliffs, NJ: Prentice Hall, 1975.  
 [9] *American Heritage Dictionary of the English Language*. New College Edition, Boston, MA: HoughtonMifflin, 1981.  
 [10] C. S. Holling, Ed., *Adaptive Environmental Assessment and Management*. New York: Wiley, 1978.  
 [11] F. Morrison, *The Art of Modeling Dynamic Systems: Forecasting for Chaos, Randomness, and Determinism*. New York, NY: Wiley, 1991, p. 10.  
 [12] S.M. Shinnars, *Modern Control System Theory and Design*. New York, NY: Wiley, pp. 1-21, 1992.  
 [13] D.J. Elazar, "American federalism today: Practice versus principle," *American Federalism: A New Partnership for the Republic*, R.B. Hawkins, Jr., Ed., New Brunswick, NJ: Transaction, pp. 37-58, 1982.  
 [14] R. Bennett and R. Chorley, *Environmental Systems: Philosophy, Analysis, and Control*. London, U.K.: Methuen, 1978.  
 [15] A.H. Pacher, *Models of Economic Systems*. Cambridge, MA: M.I.T. Press, 1972.  
 [16] J.W. Forrester, *Principles of Systems*, Cambridge, MA: M.I.T. Press, 1968.  
 [17] D.B. Lee, Jr., "Requiem for large-scale models," *American Institute of Planners J.*, vol. 39, no. 3, pp. 163-178, May 1973.  
 [18] J. Habermas, trans. T. McCarthy, *Legitimation Crisis*. Boston, MA: Beacon, 1975.  
 [19] C.E. Lindblom, *Inquiry and Change*. New Haven, CT: Yale Univ. Press, 1990, pp. 214-215.  
 [20] M. Weber, *The Theory of Social and Economic Organization*. New York, NY: Free Press, 1922; 1957.  
 [21] D.W. Guston, "The essential tension in science and democracy," *Social Epistemology*, vol. 7, no. 1, pp. 3-23, 1993.  
 [22] J.W. Forrester, "System dynamics — Future opportunities," A.A. Legasto Jr., J.W. Forrester, and J.M. Lyneis, Eds., *System Dynamics*, Amsterdam, The Netherlands: North Holland, 1980, p. 14. Cited in Hughes [5], p. 184.  
 [23] D.A. Schön, *The Reflective Practitioner: How Professionals Think In Action*. New York, NY: Basic, 1983.  
 [24] B.R. Allenby, personal communication, Sept. 6, 2000.  
 [25] B. Commoner, "Alternative approach-

es to the environmental crisis," *American Institute of Planners J.*, vol. 39, no. 3, pp. 147-162, May 1973.  
 [26] J.M. Griffin, "Methodological advances in energy modeling: 1970-1990," *Energy J.*, vol. 14, no. 1, pp. 111-124, 1993.  
 [27] P. Checkland and J. Scholes, *Soft Systems Methodology in Action*. Chichester, U.K.: Wiley, 1990.  
 [28] T.C. Schelling, *Micromotives and Macrobehavior*. New York: Norton, 1978.  
 [29] R. Axelrod, *The Evolution of Cooperation*. New York, NY: Basic, 1984.  
 [30] M. Resnick, Turtles, Termites, and Traffic Jams: *Explorations in Massively Parallel Microworlds*. Cambridge, MA: M.I.T. Press, 1994.  
 [31] J. Epstein and R. Axtell, *Growing Artificial Societies: Social Science from the Bottom Up*. Washington, DC: Brookings Institution/M.I.T. Press, 1996.  
 [32] C.J. Andrews, "Spurring inventiveness by analyzing tradeoffs," *Environmental Impact Assessment Rev.*, vol. 12, no. 1, pp. 209-234, 1992.  
 [33] J.C. Scott, *Seeing Like A State*. New Haven, CT: Yale Univ. Press, pp. 11-22, 1998.  
 [34] C.J. Andrews, "Sorting out a consensus: Analysis in support of multi-party decisions," *Environment and Planning B: Planning and Design*, vol. 19, no. 2, pp. 189-204, Spr. 1992.  
 [35] D.M. Rousseau, "Issues of level in organizational research: Multi-level and cross-level perspectives," *Research in Organizational Behavior*, vol. 7, pp. 1-37, 1985.  
 [36] F. Fischer, *Evaluating Public Policy*. Chicago, IL: Nelson-Hall, 1995.  
 [37] R.L. Ackoff, *Creating the Corporate Future*. New York, NY: Wiley, 1981.  
 [38] J.A.M. Vennix, G.P. Richardson, and D.F. Andersen, Eds., *Special Issue on Group Model Building, Systems Dynamics Rev.*, vol. 13, no. 2, Sum. 1997.  
 [39] G.P. Richardson and D.F. Anderson, "Teamwork in group model building," *System Dynamics Rev.*, vol. 11, no. 2, Sum. 1995.  
 [40] G.C. Lim, "Toward a synthesis of contemporary planning theories," *J. Planning Education and Research*, vol. 5, no. 2, pp. 75-85, 1986.  
 [41] American Association for the Advancement of Science, listing of science and technology policy programs at <http://www.aaas.org/spp/dspp/dspp.htm>. Sept. 4, 2000.  
 [42] B. Flyvbjerg (S. Sampson, trans.), *Rationality and Power: Democracy in Practice*. Chicago, IL: Univ. of Chicago Press, pp. 2, 131, 1998.  
 [43] D.H. Guston, *Between Politics and Science*. Cambridge, U.K.: Cambridge Univ. Press, 2000.