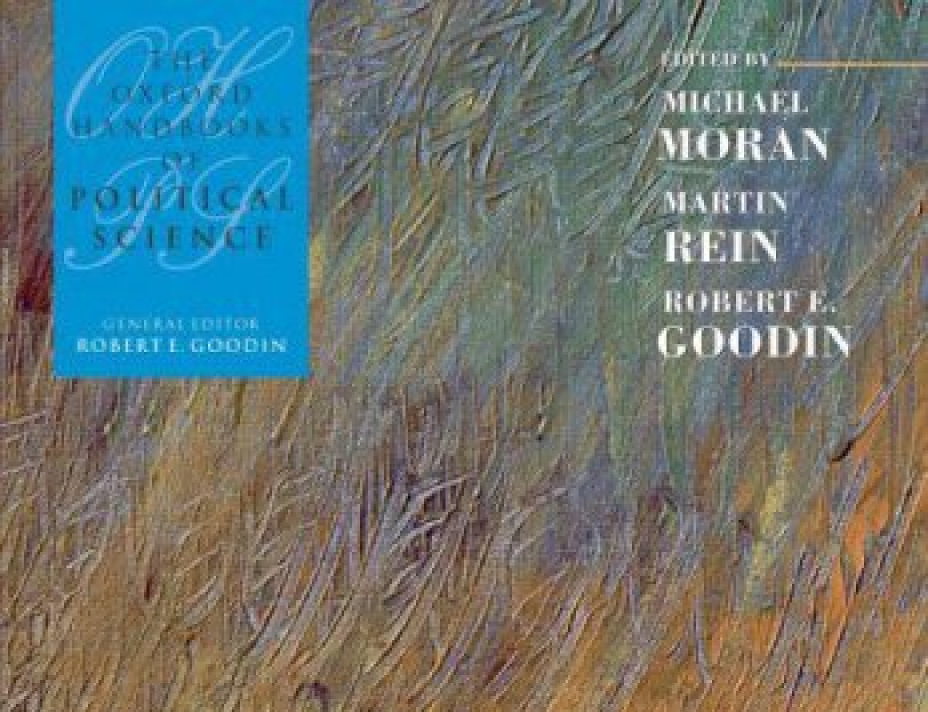

THE OXFORD HANDBOOKS OF POLITICAL SCIENCE

GENERAL EDITOR ROBERT E. GOODIN

EDITED BY

MICHAEL MORAN

MARTIN REIN

ROBERT E. GOODIN

The Oxford Handbook *of* PUBLIC POLICY

goal, such as decreasing mortality. What it cannot do is to give an indication *how much* should be spent to achieve a policy outcome. Neither can CEA give guidance whether a policy intervention is worth doing at all, for it tacitly assumes that the objective has been deemed worth meeting beforehand. It therefore does not specify how far a program's ratio of effects to costs can fall before it is no longer worth doing. To determine whether resources have been allocated in such a way that benefits to society have been maximized is not possible with CEA.

What neither CBA, CUA, nor CEA can solve, however, is the intrinsic value problem that we addressed in Section 5. Intrinsic values are not merely not commensurable, they are more fundamentally, also not comparable with other benefits and costs. All too often, they are therefore "forgotten" in economic evaluations although they should be allowed to restrict the projects that government may permissibly carry out. In policy practice, such side constraints can be feasibly implemented by giving a veto power to the individuals impacted by the proposed policy. It does not follow, of course, that such rights automatically override any possible net benefits of a proposed policy, but neither are they morally irrelevant.

7. Conclusion

In concluding, economic tools are very general techniques that have very stringent information requirements not all of which can always be met. They can therefore not function as a fundamental standard of choice among policy options. This is not a reason to reject economic evaluations per se as they do provide us with information that is morally relevant and thus possibly uncovers hitherto concealed judgements by policy makers eager to cater to special interests. It is, we have argued, both unethical and irrational in general to ignore the cost and benefits of a pending policy decision. Yet, it is a reason to acknowledge that economic evaluations should be understood as an input into, rather than a substitute for political deliberation and judgement (Sunstein 2002). Not all situations call on us to maximize value. Some simply compel us to respect it. Economic evaluations should be seen as a useful heuristic to raise red flags about policy proposals and identify the economic factors involved. Whether economic factors are, in fact, the dominant concern at all in a given situation is a judgement that will have to remain within the realm of responsibility of the policy maker.

References

Adler, M. D., and Posner, E. A. (eds.) 2001. *Cost Benefit Analysis: Legal, Economic, and Philosophical Perspectives.* Chicago: University of Chicago Press.

Arrow, K. J. 1963. Uncertainty and the welfare economics of medical care. *American Economic Review*, 53(5): 941 73.

Solow, R., Learner, E., Portney, P., and Schuman, H. 1992. *Report of the NOAA Panel on Contingent Valuation.* Washington, DC: National Oceanic and Atmospheric Ad ministration.
Bentham, J. 1970. *An Introduction to the Principles of Morals and Legislation*, ed. J. Burns and H. L. A. Hart. London: Athlone Press.
Bleichrodt, H., and Johannesson, M. 1997. An experimental test of the theoretical foundation for rating scale valuations. *Medical Decision Making*, 17(2): 208 17.
Bossert, W. 1991. On intra and inter personal utility comparisons. *Social Choice and Welfare*, 8: 207 20.
Chang, R. (ed.) 1997. *Incommensurability, Incomparability, and Practical Reason.* Cambridge, Mass.: Harvard University Press.
Costanza, R., et al. 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387: 253 61.
Coudouel , A., and Hentschel , J. 2000. *Poverty Data and Measurement.* Washington, DC: World Bank; available at: www.worldbank.org/poverty/strategies.
Diamond, P. A., and Hausman, J. 1993. On contingent valuation measurement of non use values. Pp. 170 90 in *Contingent Valuation: A Critical Assessment*, ed. J. Hausman. New York: North Holland.
Drummond, M. F., Brien, B., Stoddart, G. L., and Torrance, G. W. 1997. *Methods for the Economic Evaluation of Health Care Programmes*, 2nd edn. Oxford: Oxford University Press.
Dworkin, R. 1977. *Taking Rights Seriously.* Cambridge, Mass.: Harvard University Press.
Elster, J. 1983. *Sour Grapes.* Cambridge: Cambridge University Press.
and Roemer, J. (eds.) 1991. *Interpersonal Comparisons of Well Being.* Cambridge: Cambridge University Press.
Glover, J. (ed.) 1990. *Utilitarianism and its Critics.* New York: Macmillan.
Gramsci, A. 1971. *Selections from the Prison Notebooks of Antonio Gramsci*, ed. Q. Hoare and G. N. Smith. New York: International.
Hanley, N., and Spash, C. 1993. *Cost Benefit Analysis and the Environment.* Aldershot: Edward Elgar.
Hardin, R. 1982. *Collective Action.* Baltimore: Johns Hopkins University Press.
Harris, J. 1975. The survival lottery. *Philosophy*, 50: 81 7.
Hayek, F. 1975. *Collectivist Economic Planning: Critical Studies on the Possibilities of Socialism.* London: Routledge.
Henderson, H. 1996. Fighting economism. *Futures*, 28: 580 4.
HM Treasury 1997. *Appraisal and Evaluation in Central Government: Treasury Guidance.* London: HMSO.
Holland, A. 1995. Cost benefit analysis: a philosopher's view. Pp. 21 38 in *Environmental Valuation: New Perspectives*, ed. K. G. Willis and J. T. Corkindale. Wallingford: CAB.
Kahneman, D. 2003. A psychological perspective on economics. *American Economic Review*, 93: 162 8.
Kneese, A. 1984. *Measuring the Benefits of Clean Air and Water.* Washington, DC: Resources for the Future.
Kopp, R. 1993. Environmental economics: not dead but thriving. *Resources*, 111: 7 12.
Krupnik, A. J., and Toman, M. 1997. *Cost Benefit Analysis and Regulatory Reform: An Assessment of the Science and the Art.* Discussion Paper 97 19. Washington, DC: Resources for the Future.
Kornai, J. 1986. The soft budget constraint. *Kyklos*, 39: 3 30.
Krutilla, J. 1967. Conservation reconsidered. *American Economic Review*, 57(5): 777 86.

Kymlicka, W. 2001. *Contemporary Political Philosophy: An Introduction.* Oxford: Oxford University Press.
Layard, R., and Glaister, S. (eds.) 2001. *Cost Benefit Analysis*, 2nd edn. Cambridge: Cambridge University Press.
and Walters, A. A. 2001. Income distribution. In Layard and Glaister 2001, 179 98.
Le Grand, J. 1991. *Equity and Choice.* London: HarperCollins.
Leibenstein, H. 1966. Allocative efficiency vs. "X efficiency." *American Economic Review*, 56: 392 415.
Lenin, V. I. 1964. A caricature of Marxism and imperialist economism. Pp. 28 76 in V. I. Lenin, *Collected Works*, vol. xxiii, 5th edn. Moscow: Progress.
Lipsey, R. G., and Chrystal , K. A. 1999. *Principles of Economics*, 9th edn. Oxford: Oxford University Press.
McLellan, D. 2000. *Karl Marx: Selected Writings.* Oxford: Oxford University Press.
Marx, K. 1964. *Economic and Philosophic Manuscripts.* New York: International.
Mishan, E. J. 1972. *Cost Benefit Analysis.* New York: Praeger.
Mooney, G. 1992. *Economics, Medicine, and Health Care.* London: Harvester Wheatsheaf.
Murray, C. J. 1996. Rethinking DALYs. Pp. 1 98 in *The Global Burden of Disease*, ed. C. J. Murray and A. D. Lopez. Cambridge, Mass.: Harvard School of Public Health.
von Neumann, J., and Morgenstern, O. 1947. *Theories of Games and Economic Behavior.* Princeton, NJ: Princeton University Press.
Nord, E. 1999. *Cost Value Analysis in Health Care: Making Sense of QALYs.* Cambridge: Cambridge University Press.
Okun, A. 1975. *Equality and Efficiency: The Big Trade Off.* Washington, DC: Brookings Institution.
Pearce, D. 1993. *Economic Values and the Natural World.* London: Earthscan.
Presidential/Congressional Commission on Risk Assessment and Risk Management (PCCRA) 1997. *Framework for Environmental Health Risk Management*, 2 vols. Washington, DC: PCCRA.
Radin, M. J. 1996. *Contested Commodities: The Trouble with the Trade in Sex, Children, and Body Parts.* Cambridge, Mass.: Harvard University Press.
Rhoads, S. E. 1999. *The Economist's View of the World.* Cambridge: Cambridge University Press.
Richardson, H. S. 2001. The stupidity of the cost benefit standard. In Adler and Posner 2001, 135 68.
Robbins, L. 1932. *The Nature and Significance of Economic Science.* London: Macmillan.
Sagoff, M. 1988. *The Economy of the Earth.* Cambridge: Cambridge University Press.
Samuelson, P. A. 1948. *Foundations of Economic Analysis.* Cambridge, Mass.: Harvard University Press.
Scanlon, M. 1991. The moral basis of interpersonal comparison. In Elster and Roemer 1991, 17 44.
Sen, A. 1987. *On Ethics and Economics..* Oxford: Basil Blackwell.
Shrader Frechette, K. 1991. *Risk and Rationality: Philosophical Foundations for Populist Reforms.* Berkeley: University of California Press.
Smith, A. 1979. *The Wealth of Nations: Books I III.* London: Penguin.
Smith, V. (ed.) 1984. *Environmental Policy under Reagan's Executive Order: The Role of Benefit Cost Analysis.* Chapel Hill: University of North Carolina Press.
Sunstein, C. 1997. Incommensurability and kinds of valuation: some applications in law. Pp. 34 54 in *Incommensurability, Incomparability, and Practical Reason*, ed. R. Chang. Cam bridge, Mass.: Harvard University Press.
2002. *Risk and Reason: Safety, Law, and the Environment.* Cambridge: Cambridge University Press.

Torrance, G., Thomas, W. H., and Sackett, D. L. 1972. A utility maximization model for evaluation of health care programmes. *Health Services Research*, 7: 118 33.

Turner, R. K., Pearce, D., and Bateman, I. 1994. *Environmental Economics*. Hemel Hemp stead: Harvester Wheatsheaf.

Tversky, A., Slovic, P., and Kahneman, D. 1990. The causes of preference reversals. *American Economic Review*, 80(1): 205 18.

Woods, N. 2000. Order, globalization, and inequality in world politics. Pp. 8 35 in *Inequality, Globalization, and World Politics*, ed. A. Hurrell and N. Woods. Oxford: Oxford University Press.

World Health Organization (WHO). 2000. *The World Health Report 2000: Health Systems: Improving Performance*. Geneva: World Health Organization.

Zeckhauser, R., and Schaefer, E. 1968. Public policy and normative economic theory. Pp. 27 102 in *The Study of Policy Formation*, ed. R. A. Bauer and K. J. Gergen. New York: Free Press.

and Shephard, D. 1976. Where now for saving lives? *Law and Contemporary Problems*, 40 (4): 5 45.

CHAPTER 38

POLICY MODELING

NETA C. CRAWFORD

> [A] "decision" is only a part of a decisional process that began long before the specific decision was made. . . . The momentary act of decision, on which so much of the literature of "decision making" focuses, may be little more than *pro forma*. (Green 1966, 205)

> Systems analysis takes a complex problem and sorts out the tangle of significant factors so that each can be studied by the method most appro priate to it. Questions of fact can be tested against the available factual evidence; logical propositions can be tested logically; matters of value and uncertainty can be exposed so that decision makers can know exactly where to apply their judgment. (Enthoven and Smith 1971 61)

From the days when generals used miniature battlefields and maps to analyze, plan, and predict the outcome of battles, to the contemporary use of computer simulations and war gaming, modeling has played a crucial part in the equipment, planning, and conduct of war. Policy modeling is intended to help decision makers and observers make "rational" judgements about complex and technical public policy questions. It uses a variety of techniques ranging from scenarios and simulations to operations research and game theory, but all policy modeling relies on similar inputs: more or less hard data derived from experience or experiments, assumptions about unknown variables, and rules of thumb or formulas for handling data. Climate modelers use a combination of real-world measurement, assumptions about the growth and effects of certain "greenhouse" gases, and computer simulation to predict the effects of human behavior on the climate. Those who prepare for conventional war can rely on thousands of years of experience; modeling nuclear war is necessarily more abstract.

Responding to the charge that the US military was ill prepared for war in Iraq, US Secretary of Defense Donald Rumsfeld said, "As you know, you go to war with the Army you have. They're not the Army you might want or wish to have at a later time"

(Ricks 2004: A1). In other times, the USA has been more than well prepared for "overkill;" at the end of the cold war in 1989, the United States deployed a "triad" of 14,530 strategic nuclear weapons on land-based intercontinental ballistic missiles (ICBMs),[1] submarine-launched ballistic missiles (SLBMs),[2] and long-range bombers.[3] The USA also had tens of thousands of medium-range (theater) and short-range (tactical) nuclear weapons for use in "less than all-out nuclear war" scenarios. From 1940 to 1995 the USA spent over $4 trillion in 1995 dollars making nuclear weapons and preparing for nuclear war (Schwartz 1995). How did the United States come to have these particular weapons, and in numbers that were well in excess of the ability to destroy the other side, the Soviet Union, as a functioning society? How did US cold war nuclear planners answer the question of "how much is enough?"

The reason for the exact number, composition, and quality of United States nuclear weapons during the cold war was overdetermined and could be explained by several theories.[4] But one often overlooked factor was the formal logic of nuclear discourse—known in the nuclear weapons planning community as "operations research" or "systems analysis."[5] Although its methods are not widely known and understood, the practice and assumptions of nuclear systems analysis helped determine the size and capabilities of the US nuclear weapons arsenal. The Pentagon's Systems Analysis Office established in 1961 (renamed Program Analysis and Evaluation in 1973), was just one site of nuclear operations research and systems analysis. Operations research and systems analysis were widely practiced and became

[1] On Minuteman II, Minuteman III, and MX (Peacekeeper) missiles.

[2] On Poseidon C 3 and Trident C 4 missiles.

[3] On B 52 and B 1B bombers, which carried both gravity bombs and in some cases, air launched cruise missiles (ALCM).

[4] On nuclear weapons procurement and the arms race see Brown 1994; Evangelista 1988; Greenwood 1975; Sapolsky 1972; Spinardi 1990; Francis 1995. Rational planning by one state could lead to "action reaction" phenomena of quantitative and/or qualitative arms racing driven by security dilemma dynam ics. "Action reaction phenomena, stimulated in most cases by uncertainty about an adversary's inten tions and capabilities, characterizes the dynamics of the arms race" (Rathjens 1969, 42). Inter service rivalry among branches of the US military led to a duplication of effort as each service allocated nuclear weapons for targets that had also been identified as targets by other services. Organizational interests within services also led to what critics called "bootstrapping," where "growth of the stockpile was linked to expansion of the target lists, and both were used to justify expansion of SAC [Strategic Air Com mand]" (Rosenberg 1986, 42). Domestic politics and economics also helped to determine whether or not a nuclear weapons system was purchased: Congressional support sometimes depended more on the clout of a particular Congressperson whose district or state made the weapon than on whether it could efficiently perform its mission. For example, Senator Alan Cranston's (D CA) support of the B 1 strategic nuclear bomber (manufactured in California) grew during the early 1980s with his presidential aspir ations. A "technological imperative" to make nuclear weapons more complex and advanced may also have affected the growth of the arsenal (e.g. Thee 1986; Zuckerman 1983).

[5] "Operations research uses mathematical models to plan real systems that either function optimally or meet some defined performance criterion. . . . Systems analysis emphasizes a rigorous statement of the goals of the project and a listing of different policies and their consequences. It can handle broader messier problems than operations research, and has often helped in the design and procurement of weapons systems" (O'Neill 1993, 2567 8).

embedded in organizational routines and the work of individual analysts within government and non-government policy organizations.[6] To the extent that the Soviets responded to US weapons developments, systems analysis helped determine the character of the Soviet arsenal as well.[7] Though game theory was used, operations research, or operations research supplemented by game theory, was one of the primary tools, if not the primary technique for nuclear policy modeling.[8] Moreover, operations research and nuclear systems analysis are still used in the post-cold war era by policy analysts inside and outside government (see Wilkening 1994; Larson and Kent 1994; Cimbala 1995; Batcher 2004). According to one analyst who worked in the Pentagon's office from 1969, with the end of the cold war, the techniques of operations research and systems analysis and their importance in the policy process "haven't changed" although because the world has changed, "nuclear things are less important and there is more emphasis on general purpose conventional forces," and counter-terrorism (Yengling 1997). Indeed systems analysis may return to prominence if all the elements of the Bush administration Nuclear Posture Review are implemented.[9] Hence, it is still vital to understand how systems analysis works.

The specific practices of nuclear systems analysis vary depending on the problem at hand. These modeling techniques can be used to estimate the effects of nuclear weapons on particular targets, to estimate the cost of a specific weapons system over time, to assess the cost effectiveness of targeting strategies, to compare the effectiveness of different weapons, to decide how many of which weapons systems to build, to determine the likely number of casualties resulting from a nuclear war, to assess the effectiveness of civilian defense, and to decide how to use nuclear forces in the event of war. The analysis itself can be done with relatively simple formulas on "the back of an envelope," using spreadsheets, or using fairly complex classified or unclassified versions of computer codes such as FAS/CIVIC (Fallout Assessment System/Civilian Vulnerability Indicator Code) and PDCALC (Batcher 2004; Scouras and Nissen 1994).

Operations research and systems analysis techniques are thus knowledge-making processes that underpinned, rationalized, and to a surprising degree determined the

[6] Other institutions and individuals, such as air force Strategic Air Command (SAC), the Congres sional Budget Office, analysts at universities, the Brookings Institution, the RAND Corporation, and other private think tanks, used nuclear modeling.

[7] The Soviet Union had 12,403 strategic nuclear warheads, distributed between missiles and aircraft. Totals, using SALT II counting rules, are from IISS 1989, 212. After the cold war, the United States found out that it had underestimated the total number of Soviet nuclear weapons (Broad 1993).

[8] As O'Neill suggests, "One myth about game models and deterrence is worth refuting in detail. It is that in the late 1940s and 1950s thinking on nuclear strategy was molded by game theory. By the end of the Cold War this claim was so widely believed that no evidence was needed to support it.... In fact, with a couple of exceptions, substantial game modeling of international strategy started only in the later 1960s, after the tenets of nuclear strategy had already developed" (1994, 1010 11).

[9] Including deployment of an anti ballistic missile system; the introduction of "capabilities based" and "adaptive planning" to allow for limited nuclear strikes; the upgrading of its nuclear weapons (DOD 2002; Woolf 2002).

choice of United States strategic nuclear weapons after 1961. The equations and procedures of systems analysis exemplify instrumental beliefs (causal understandings of how nuclear weapons and nuclear strategy work) and what Eden (2004) calls "organizational frames"—ways of understanding the world. The strategists who use systems analysis constitute an epistemic community of government and private nuclear analysts, with systems analysis constituting a core element of the cultural practices of that community. Being able to use systems analysis, or at least understanding its formal logic is one of the criteria for membership in this epistemic community understood as "a network of professionals with recognized expertise and competence in a particular domain and authoritative claim to policy relevant knowledge within that domain or issue area." Epistemic communities have "(1) a shared set of normative and principled beliefs . . . (2) shared causal beliefs . . . (3) shared notions of validity . . . (4) a common policy enterprise" (Haas 1992, 3; also see Adler 1992). This epistemic community, above all, sought ways to deal rationally with uncertainty in the scientific-technical-political context created by the development and deployment of nuclear weapons. Policy modeling in the form of systems analysis became a taken-for-granted part of the Pentagon's organizational culture. Yet as Litfin suggests, "Epistemic community approaches downplay . . . the ways in which scientific information simply rationalizes or reinforces existing political conflicts" (1994, 12). In other words, scientists have politics too and in any case, their analysis may not be used by neutral observers.

The point of using operations research and systems analysis was and is to make the decision-making process more "rational." The models and the math are supposed to abstract from nuclear reality and to predict the unknowns of nuclear war in order better to represent and understand it. The conclusions might ultimately be distorted in the policy process, but the numbers themselves should be neutral and hard. On the one hand, in some respects the policy modelers failed *by their own criteria* to do an adequate job. Indeed, others have criticized poor applications of nuclear systems analysis techniques and some of those criticisms are discussed below.[10] The logical conclusion of those critiques is to urge more rigorous specification and application of mathematical models.[11] Yet the aim here is not so much a critique of shoddy practices, the provision of remedies, or alternatives, as it is to understand some of the consequences of using this sort of modeling. An examination of nuclear discourse at its most formal, abstract level illustrates unexpected and even frightening aspects and consequences of policy modeling—whether or not the modeling is well executed.

As much as policy modelers were analyzing, describing, or indeed sometimes simply rationalizing the decisions actors wanted to take for other reasons, systems

[10] See, for examples, Green 1966, 15 93; Brewer and Shubik 1979; Postol 1987; Salman, Sullivan, and Van Evera 1989.

[11] Davis and Schilling (1973) is one of the best open source discussions of the analytical techniques of systems analysis, including the formulas. They critique the application of systems analytical techniques, while accepting the logic of systems analytical practices.

analysts also made the nuclear world through their analysis. The ways they did so are uncovered not so much by an attention to the levers through which the systems analysis community influenced policy (which it certainly did) but by attention to the content of the discourse of systems analysis. Thus, I focus on the instrumental beliefs and logic of systems analysis and show how those beliefs and models helped structure the emerging nuclear world and were used in arguments within the US foreign policy decision-making community to develop the strategic nuclear arsenal. Systems analysis was intended to clarify and model the nuclear reality; instead it mystified nuclear reality *among the experts* and led to technically rational, though profoundly unreasonable consequences.

Nuclear operations research and systems analysis was and is a knowledge-making process that began to make its own "reality" more than the reality that was uncovered through the techniques of nuclear modeling. Despite all its pretensions of rationality, the formal discourse is neither rational nor irrational. Systems analysis is a "belief system" (Little and Smith 1988) that depends on and functions within larger foreign policy and scientific belief systems.[12] Others, e.g. E. P. Thompson (1981), Carol Cohn (1987), and Paul Chilton (1985), have shown how nuclear language was mystifying. My focus here is on the supposedly neutral and objective practice of mathematical modeling. Indeed, just as Cohn argues that "learning the language [of nuclear strategy] is transformative" (1987, 716), then engaging in the formal part of strategic nuclear discourse is even more so. The linguistic and mathematical abstractions used by weapons planners remove them from the reality of their plans and practices and thus allow them to "think the unthinkable" and perhaps do the unthinkable (Chilton 1985; Thompson 1981). Thus, the instrumental consequences of the weapons—what the weapons do to bodies, how the weapons help shape our understanding of and relations to others, and how making and preparing to use the weapons structures our ways of organizing ourselves, economically, politically, and militarily—is more often obscured, not revealed by systems analysis.[13]

But the formal mathematical and logical abstractions of nuclear modeling do more than remove planners from realities that are patently ghastly. The abstractions of systems analysis lead to the creation of new material "realities" which in turn demand new conceptual and linguistic abstractions. The way that this formal reasoning, nuclear rationality, begins to make its own cognitive and real world is obscured by the analysis. In other words, when analysts talk and reason abstractly about nuclear weapons through their nuclear models, they are not simply reporting in a precise way, the realities of the nuclear world as they find it. Nor are they simply using abstraction and models as a veil to hide the nuclear world from plain view by non-experts, though that might be a consequence of their discourse. Nor are they simply using abstraction, metaphor, models, and math psychologically to

[12] On belief systems, see Little and Smith 1988.

[13] Lifton and Markuson (1990) have argued that living in a world of nuclear weapons and potential nuclear holocaust has important psychological consequences. Systems analysis may inadvertently help planners deal with the psychological stress of planning for mass death.

insulate themselves from realities that they would rather not examine too closely, though this might also be the case. Nor was modeling simply a rationalization for decisions already taken for political or other reason, though this also happened.

Abstractions and forms of reasoning that become embodied in knowledge-making practices, organizational routines, the acquisition of capabilities, the plans for conducting operations, and the criteria for judging the reasonableness of arguments do not simply model the world. They make it. The formal, abstract, and ultimately incomplete models of systems analysis became more complex and simultaneously divorced from political context even as the political context was in part shaped by the practice of policy modeling. Indeed, there was as Freedman argued, "a tendency, which gradually became more acute, to place an extremely sophisticated technical analysis within a crude political framework" (2003, 169). At the same time the decisions based on systems analysis began to shape the arsenals and thus the political world. As Adler (1992, 108) argues, "the science of nuclear strategy has an input in creating the reality it is supposed to explain and predict." The use of systems analysis by US nuclear strategists, arms control analysts, and their critics illustrates the way that particular rationalities and the process of argument work in foreign policy decision making and how abstractions can make a world.[14] Understanding the abstractions, the models, helps explain how the USA acquired the capability to utterly destroy the Soviet Union, not just once, but almost inconceivably, several times, and why nuclear weapons remain in sizeable numbers despite the end of the cold war.

In what follows, I first briefly summarize some of the main strategic nuclear beliefs and arguments held in the USA during the cold war that constituted the taken-for-granted assumptions that underpinned nuclear arguments and systems analysis as a policy-modeling process. Second, I review the origins of systems analysis and summarize the core beliefs that underpin the practice. Third, I explore the abstract and formal world of systems analysis by "walking" through some of its basic techniques. Fourth, I discuss the "scientific seduction" of operations research and systems analysis and review some of the problems of this analytical tool and its relation to the material reality of nuclear weapons. Finally, I return to the question of the consequences of systems analysis—how nuclear abstractions made the world.[15]

[14] The consequences of the systems analysis discourse for non experts are profound but anticipatable, similar to the consequences or effects of technical discourse in other areas of life, for instance in the ability of non physicians to understand and participate in choices about their medical care. Non experts may then defer to the experts, trusting in their rationality and their conscious manipulation of the nuclear forces and planning for either good or ill. Alternatively, non initiates may claim that the system is completely mad, insane, and illogical, that there is some underlying pathology at work in the community. Still some critics of US nuclear policy understood it and nuclear modeling quite well. Even those who criticized nuclear policy using systems analysis, or who charged that nuclear modeling was little more than a rationalization for decisions that were already made, appear to have believed in the legitimacy of this form of rationality.

[15] One could, of course, make similar arguments about conventional force modeling.

1. The Context: Nuclear Weapons and US Strategic Nuclear Beliefs

The policy process can be conceived of as a flow where US nuclear weapons policy and forces are determined in broad outline by presidential, National Security Council, and Defense Secretary directives. The president and NSC also direct policy analysts to study alternative options. Presidential and NSC directives are then fleshed out and implemented by planners and analysts within the Defense Department and the military services. In both official and public discourse, the lingua franca of nuclear arguments was of course deterrence theory, but arguments rested on nuclear modeling—operations research and systems analysis techniques. United States strategic nuclear policy ranged from war fighting to deterrence (Freedman 2003; Glaser 1990; Eden and Miller 1989). The dominant logic of deterrence theory is based on the idea of keeping someone from acting by threatening them with painful punishment if they do act. The Soviet Union, it was supposed, would be deterred from attacking the United States, or its more distant interests, if they knew the United States would attack them in return. The belief was that decision makers would *not* be deterred if they thought they could get away with an attack without being punished or if the punishment were very light. Success in deterring an attack depended on one ensuring that the other side knew that they would, most likely, receive unacceptable damage as retaliation for an attack.

This logic of deterrence and credibility is embedded in other intersubjectively held philosophical, instrumental, normative, and identity beliefs. The core beliefs of nuclear "rationality"—that the Soviets were the enemy, that the best way to deal with them was through threats, that the utility of threats depends on an ability to carry them out, and so on—were rarely challenged. At the beginning of the cold war, the idea of killing tens of millions of the other's populations was acceptable, considered necessary to ensure the survival of one's own state and population—though by the mid-1970s the US government argued that it was not targeting civilian population per se (Ball 1986*a*, 27). In addition to these core beliefs there were many more context-specific beliefs about how deterrence worked and how to structure nuclear forces so that threats were credible, and so that if war came the mission of destroying the other side could be accomplished (Jervis 1984; Kull 1988). The project of constructing a nuclear arsenal for the United States in part consisted of meeting the "requirements" of deterrence in a nuclear world. Part of the requirement for deterrence during the cold war was to acquire a secure second strike capability—that is, to build enough weapons that could survive a Soviet first strike nuclear attack, and that would be able to retaliate against their cities or remaining nuclear weapons to inflict unacceptable damage.

There were also those who pushed for the United States to develop a nuclear war fighting capability. Indeed, early US nuclear strategy was explicitly focused on developing a capability for pre-emptive nuclear war fighting, targeting Soviet and Chinese conventional military forces and their industrial infrastructure (Rosenberg