shaping the Next One Hundred Years

New Methods for Quantitative, Long-Term Policy Analysis

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SUMMARY

New analytic methods enabled by the capabilities of modern computers may radically transform human ability to reason systematically about the long-term future. This opportunity may be fortuitous because our world confronts rapid and potentially profound transitions driven by social, economic, environmental, and technological change. Intentionally or not, actions taken today will influence global economic development, the world's trading system, environmental protection, the spread of such epidemics as AIDS, the fight against terrorism, and the handling of new biological and genetic technologies. These actions may have far-reaching effects on whether the twenty-first century offers peace and prosperity or crisis and collapse.

In many areas of human endeavor, it would be derelict to make important decisions without a systematic analysis of available options. Powerful analytic tools now exist to help assess risks and improve decisionmaking in business, government, and private life. But almost universally, systematic quantitative analysis rarely extends more than a few decades into the future. Analysts and decisionmakers are neither ignorant of nor indifferent to the importance of considering the long term. However, well-publicized failures of prediction—from the Club of Rome's "Limits to Growth" study to the unexpected, sudden, and peaceful end of the Cold War—have done much to discourage this pursuit. Systematic assessments of the long-term future are rare because few people believe that they can be conducted credibly.

A PROSTHESIS FOR THE IMAGINATION

This report describes and demonstrates a new, quantitative approach to long-term policy analysis (LTPA). These robust decisionmaking methods aim to greatly enhance and support humans' innate decisionmaking capabilities with powerful quantitative analytic tools similar to those that have demonstrated unparalleled effectiveness when applied to more circumscribed decision problems. By reframing the question "What will the long-term future bring?" as "How can we choose actions today that will be consistent with our long-term interests?" robust decisionmaking can harness the heretofore unavailable capabilities of modern computers to grapple directly with the inherent difficulty of accurate long-term prediction that has bedeviled previous approaches to LTPA.

This report views long-term policy analysis as a way to help policymakers whose actions may have significant implications decades into the future make systematic, well-informed decisions. In the past, such decisionmakers, using experience, a variety of heuristics, rules of thumb, and perhaps some luck, have occasionally met with impressive success, for example, in establishing the West's Cold War containment strategy or in promoting the first U.S. transcontinental railroads to forge a continent-sized industrial economy. Providing analytic support to improve such decisionmaking must contend with a key defining feature of the long term—that it will unavoidably and significantly be influenced by decisions made by people who live in that future. **Thus, this study defines the aim of LTPA as identifying, assessing and choosing among near-term actions that shape options available to future generations.**

LTPA is an important example of a class of problems requiring decisionmaking under conditions of *deep uncertainty*—that is, where analysts do not know, or the parties to a decision cannot agree on, (1) the appropriate conceptual models that describe the relationships among the key driving forces that will shape the long-term future, (2) the probability distributions used to represent uncertainty about key variables and parameters in the mathematical representations of these conceptual models, and/or (3) how to value the desirability of alternative outcomes. In particular, the long-term future may be dominated by factors that are very different from the current drivers and hard to imagine based on today's experiences. Meaningful LTPA must confront this potential for surprise.

Advances in LTPA rest on solid foundations. Over the centuries, humans have used many means to consider both the long-term future and how their actions might affect it. Narratives about the future, whether fictional or historical, are unmatched in their ability to help humans viscerally imagine a future different from the present. Such group methods as Delphi and Foresight exploit the valuable information often best gathered through discussions among groups of individuals. Analytic methods—e.g., simulation models and formal decision analyses—help correct the numerous fallacies to which human reasoning is prone. Scenario planning provides a framework for *what if–ing* that stresses the importance of multiple views of the future in exchanging information about uncertainty among parties to a decision. Despite this rich legacy, all these traditional methods founder on the same shoals. The long-term future presents a vast multiplicity of plausible futures. Any one or small number of stories about the future is bound to be wrong. Any policy carefully optimized to address a "best guess" forecast or well-understood risks may fail in the face of inevitable surprise.

This study proposes four key elements of successful LTPA:

- Consider large *ensembles* (hundreds to millions) of scenarios.
- Seek *robust,* not optimal, strategies.
- Achieve robustness with *adaptivity.*
- Design analysis for *interactive exploration* of the multiplicity of plausible futures.

These elements are implemented through an iterative process in which the computer helps humans create a large ensemble of plausible scenarios, where each scenario represents one guess about how the world works (a future state of the world) and one choice of many alternative strategies that might be adopted to influence outcomes. Ideally, such ensembles will contain a sufficiently wide range of plausible futures that one will match whatever future, surprising or not, does occur—at least close enough for the purposes of crafting policies robust against it. Robust decisionmaking then exploits the interplay between interactive, computer-generated visualizations called "landscapes of plausible futures" that help humans form hypotheses about appropriate strategies and computer searches across the ensemble that systematically test these hypothesis.

In particular, rather than seeking strategies that are optimal for some set of expectations about the long-term future, this approach seeks near-term strategies that are robust—i.e., that perform reasonably well compared to the alternatives across a wide range of plausible scenarios evaluated using the many value systems held by different parties to the decision. In practice, robust strategies are often adaptive; that is, they evolve over time in response to new information. Adaptivity is central to the notion that, when policymakers consider the long term, they seek to shape the options available to future generations. Robustness reflects both the normative choice and the criterion many decisionmakers actually use under conditions of deep uncertainty. In addition, the robustness criterion is admirably suited to the computer-assisted discovery and testing of policy arguments that will prove valid over a multiplicity of plausible futures.

At its root, robust decisionmaking combines the best capabilities of humans and computers to address decision problems under conditions of deep uncertainty. Humans have unparalleled ability to recognize potential patterns, draw inferences, formulate new hypotheses, and intuit potential solutions to seemingly intractable problems. Humans also possess various sources of knowledge—tacit, qualitative, experiential, and pragmatic—that are not easily represented in traditional quantitative formalisms. Humans also excel, however, at neglecting inconvenient facts and at convincing themselves to accept arguments that are demonstrably false. In contrast, computers excel at handling large amounts of quantitative data. They can project without error or bias the implications of those assumptions no matter how long or complex the causal chains, and they can search without prejudice for counterexamples to cherished hypotheses. Working interactively with computers, humans can discover and test hypotheses about the most robust strategies. Thus, computer-guided exploration of scenario and decision spaces can provide a prosthesis for the imagination, helping humans, working individually or in groups, to discover adaptive near-term strategies that are robust over large ensembles of plausible futures.

DEMONSTRATING ROBUST DECISIONMAKING

This study demonstrates new robust decision methods on an archetypal problem in long-term policy analysis—that of global sustainable development. This topic is likely to be crucially important in the twenty-first century. It is fraught with deep uncertainty. It incorporates an almost unmanageably wide range of issues, and it engages an equally wide range of stakeholders with diverse values and beliefs. This sustainable-development example demonstrates the potential of robust decisionmaking to help humans reason systematically about the long-term implications of near-term actions, to exploit available information efficiently, and to craft potentially implementable policy options that take into account the values and beliefs of a wide variety of stakeholders.

The project team began by reviewing and organizing the relevant background information, particularly from the extensive literature on sustainability. The team also assembled a group of RAND experts to act as surrogate stakeholders representing a range of opinions in the sustainability debate. To help guide the process of elicitation and discovery and to serve as an intellectual bookkeeping mechanism, the study employed an "XLRM" framework often used in this type of analysis The key terms are defined below.[1]

- Policy levers ("L") are near-term actions that, in various combinations, comprise the alternative strategies decisionmakers want to explore.
- Exogenous uncertainties ("X") are factors outside the control of decisionmakers that may nonetheless prove important in determining the success of their strategies.
- Measures ("M") are the performance standards that decisionmakers and other interested communities would use to rank the desirability of various scenarios.
- Relationships ("R") are potential ways in which the future, and in particular those attributes addressed by the measures, evolve

[1]This discussion continues the long-standing practice of ordering the letters XLRM. However, in this instance, a clearer exposition was achieved by presenting the factors in a different order.

over time based on the decisionmakers' choices of levers and the manifestation of the uncertainties. A particular choice of Rs and Xs represents a future state of the world.

In the approach described in this report, the first three factors—near-term actions (L), uncertainties (X), and performance measures (M)—are tied together by the fourth (R), which represents the possible relationships among them. This decision-support system thus becomes a tool for producing interactive visual displays (i.e., landscapes of plausible futures) of the high-dimensional decision spaces inherent in LTPA problems. The system employs two distinct types of software:

- *Exploratory modeling software* enables users to navigate through the large numbers of scenarios required to make up a scenario ensemble and to formulate rigorous arguments about policy choices based on these explorations.
- *A scenario generator* uses the relationship among the variables to create members of scenario ensembles. In contrast to a traditional model that is typically designed to produce a comparatively small number of predictive conclusions, a scenario generator should yield a full range of plausible alternatives .

In combination, these two types of software enable humans to work interactively with computers to discover and test hypotheses about robust strategies.

The robust decision analysis reported in this study begins with a diverse scenario ensemble based on XLRM information. A modified version of the "Wonderland" system dynamics model functions as the scenario generator. The analysis examines and rejects a series of candidate robust strategies and, by appropriate use of near-term adaptivity, it eventually arrives at a promising near-term policy option. The robust strategy sets near-term (10-year) milestones for environmental performance and adjusts policies annually to reach such milestones, contingent on cost constraints. Compared to the alternatives, it performs well over a wide range of plausible futures, using four different value systems for ranking desirable futures.

A steering group of surrogate stakeholders was then challenged to imagine surprises representing distinct breaks with current trends or expectations. These surprises were added to the scenario generator and the policy options stress-tested against them. The analysis concludes by characterizing the wager decisionmakers would make if they choose not to hedge against those few futures for which the proposed robust strategy is not an adequate response. This iterative process thus provides a template for designing and testing robust strategies and characterizing the remaining "imponderable" uncertainties to which they may be vulnerable.

SEIZING THE NEW OPPORTUNITIES FOR LTPA

This report does not provide specific policy recommendations for the challenge of sustainable development. The analysis involves neither the level of detail nor the level of stakeholder participation necessary for policy results that can be acted on. Rather, the study aims to describe the new analytic capabilities that have become available to support long-term decisionmaking. The report concludes with a description of how future work might improve on the robust decision approach to LTPA as well as some of the challenges and potential suggested by this limited demonstration. In particular, policy-relevant LTPA will require improved scenario generators, better algorithms to support navigation through large scenario ensembles, improved treatment of measures of the future human condition, and refined protocols for engaging the parties in a decision in a robust policymaking exercise and widely disseminating the results.

The lack of systematic, quantitative tools to assess how today's actions affect the long-term future represents a significant missed opportunity. It creates a social context where values relating to long-term consequences cannot be voiced easily because they cannot be connected to any practical action. Across society, near-term results are often emphasized at the expense of long-term goals. However, our greatest potential influence for shaping the future may often be precisely over those time scales where our gaze is most dim. By its nature, where the short term is predictable and subject to forces we can quantify, we may have little effect. Where the future is ill-defined, hardest to see, and pregnant with possibilities, our actions may well have their largest influence in shaping it.

Only in the last few years have computers acquired the power to support directly the patterns of thought and reason humans traditionally and successfully use to create strategies in the face of unpredictable, deeply uncertain futures. In today's era of radical and rapid change, immense possibilities, and great dangers, it is time to harness these new capabilities to help shape the long-term future.