Mediated Modeling

Excerpt from the draft SAB Committee report, *Valuing the Protection of Ecological Systems and Services*. *Two specific types of deliberative processes of potential use to EPA in particular valuation efforts are mediated modeling and constructed value processes. In mediated modeling, analysts work with members of the public to develop a model representing a particular environmental system of interest, ranging from watersheds or local ecosystems to large regions or even the globe (for example, Higgins et al., 1997; Cowling and Costanza, 1997; van den Belt, 2004). Members of the public participate in all stages of the modeling process, from initial problem scoping to model development, implementation, and use. The resulting model can be used for multiple purposes, including determining the ecosystem services that are potentially important to the public and evaluating alternative scenarios or options of interest. If the model is to be used to consider tradeoffs, the model must incorporate values drawn from methods described in chapter 4. Because of public involvement in the modeling process, the model and any results derived from it are likely to enjoy buy-in and reflect group consensus.*[*]

Brief description of the method. Computer models of complex systems are frequently used to support decisions concerning environmental problems. To effectively use these models, (i.e. to foster consensus about the appropriateness of their assumptions and results and thus to promote a high degree of compliance with the policies derived from the models) it is not enough for groups of academic "experts" to build and run the models. What is required is a different role for modeling - as a tool in building a broad consensus not only across academic disciplines, but also between science and policy.

Mediated modeling is process of involving stakeholders (parties interested in or affected by the decisions the model addresses) as active participants in all stages of the modeling, from initial problem scoping to model development, implementation and use (Costanza and Ruth 1998; van den Belt 2004). Integrated modeling of large systems, from individual companies to

[*] People using models may sometimes find that the implications of their models are surprising and unacceptable to them. For example, Slovic et al. (1982) found that people preferred a convex function (their general model) to express the value of varying numbers of lives lost, yet made choices in violation of this abstract model. They had not

industries to entire economies or from watersheds to continental scale systems and ultimately to the global scale, requires input from a very broad range of people. We need to see the modeling process as one that involves not only the technical aspects, but also the sociological aspects involved with using the process to help build consensus about the way the system works and which management options are most effective. This consensus needs to extend both across the gulf separating the relevant academic disciplines and across the even broader gulf separating the science and policy communities, and the public. Appropriately designed and appropriately used mediated modeling exercises can help to bridge these gulfs. The process of mediated modeling can help to build mutual understanding, solicit input from a broad range of stakeholder groups, and maintain a substantive dialogue between members of these groups. Mediated modeling and consensus building are also essential components in the process of adaptive management (Gunderson, Holling, and Light 1995, van den Belt, 2004).

Example of how the method could be used as part of the C-VPESS expanded and integrated framework. As described above, the method is fairly general and could be used to assess any value that a group of stakeholders could identify and build into a model. Any decision context that requires the estimation of the values of ecosystem goods or services could employ this method, although to the committee's knowledge no EPA decisions have as yet employed this technique. The method covers all elements of the diagram representing the C-VPESS framework for valuation after the initial identification of EPA needs, and could be used in conjunction with the full range of decision models. Prior applications have been at a broad range of scales, from watersheds or specific ecosystems to large regions and the global scale. The method is in principle broadly applicable to the full range of time and space scales.

- The method is inherently dynamic – that is what it does best
- The results can be aggregated to get a single benefits number as needed.
- Participants in the mediated modeling process gain deep understanding of the process and products, if the process is done well. Those who have not participated can easily view

realized that the abstract model implied choices that were unacceptable to them. In the view of Slovic and others, modeling needs to be interactive and mixed with examples of the model's specific implications.

and understand the results if they invest the effort. Usually the results can (with some additional effort) be made accessible to a broad audience.

- Since the method explicitly discusses and incorporates subjective or "framing" issues, it is at least open and transparent to users.

Status as a method. As mentioned above, mediated models can contain explicit valuation components. In fact, if the goal of the modeling exercise is to consider trade-offs, then valuation of some kind becomes an essential ingredient. How these trade-offs and valuations are incorporated into the model, varies, of course, from exercise to exercise. Perhaps the best way to describe this process is with an example. The South African fynbos ecological economic model described by Higgins et al. (1997) is an illustrative example.

The area of study for this example was the Cape Floristic Region—one of the world's smallest and, for its size, richest floral kingdoms. This tiny area, occupying a mere 90,000 km2, supports 8,500 plant species of which 68% are endemic, 193 endemic genera and six endemic families (Bond and Goldblatt 1984). Because of the many threats to this region's spectacular flora, it has earned the distinction of being the world's "hottest" hot-spot of biodiversity (Myers 1990).

The predominant vegetation in the Cape Floristic Region is fynbos, a hard-leafed and fire-prone shrubland which grows on the highly infertile soils associated with the ancient, quartzitic mountains (mountain fynbos) and the wind-blown sands of the coastal margin (lowland fynbos) (Cowling 1992). Owing to the prevalent climate of cool, wet winters and warm, dry summers, fynbos is superficially similar to California chaparral and other Mediterranean climate shrublands of the world (Hobbs, Richardson, and Davis 1995). Fynbos landscapes are extremely rich in plant species (the Cape Peninsula has 2,554 species in 470 km2) and plant species endemism ranks amongst the highest in the world (Cowling 1992).

In order to adequately manage these ecosystems several questions had to be answered, including, what services do these species-rich fynbos ecosystems provide and what is their value to society? A two-week workshop was held at the University of Cape Town (UCT) with a group of faculty and students from different disciplines along with parks managers, business people, and environmentalists. The primary goal of the workshop was to produce a series of consensus-based research papers that critically assessed the practical and theoretical issues surrounding ecosystem valuation as well as assessing the value of services derived by local and regional communities from fynbos systems.

To achieve these goals, an 'atelier' (or combined workshop/short course) approach was used to form multidisciplinary, multicultural teams, breaking down the traditional hierarchical approach to problem solving. Open space (Rao 1994) techniques were used to identify critical questions and allow participants to form working groups to tackle those questions. Open space meetings are loosely organized efforts that give all participants an opportunity to raise issues and participate in finding solutions.

The working groups of this workshop met several times during the first week of the course and almost continuously during the second week. The groups convened together periodically to hear updates of group projects and to offer feedback to other groups. Some group members floated to other groups at times to offer specific knowledge or technical advice.

Despite some initial misgivings on the part of the group, the structure of the course was remarkably successful, and by the end of the two weeks, seven working groups had worked feverishly to draft papers. These papers were eventually published as a special issue of Ecological Economics (Cowling and Costanza 1997). One group focused on producing an initial scoping (or mediated) model of the fynbos. This modeling group produced perhaps the most developed and implementable product from the workshop: a general dynamic model integrating ecological and economic processes in fynbos ecosystems (Higgins et al. 1997). The model was developed in STELLA and designed to assess potential values of ecosystem services given ecosystem controls, management options, and feedbacks within and between the ecosystem and human sectors. The model helped to address questions about how the ecosystem services provided by the fynbos ecosystem at both a local and international scale are influenced by alien invasion and management strategies. The model consists of five interactive sub-models: a) hydrology; b) fire; c) plants; d) management; and (e) economic valuation. Parameter estimates for each sub-model were either derived from the published literature or established by workshop participants and consultants (they are described in detail in Higgins et al. 1997). The plant sub-model included both native and alien plants. Simulation of the model produced a realistic description of alien plant invasions and their impacts on river flow and runoff.

This model drew in part on the findings of the other working groups, and incorporates a broad range of research by workshop participants. Benefits and costs of management scenarios were addressed by estimating values for harvested products, tourism, water yield and biodiversity. Costs included direct management costs and indirect costs. The model showed that the ecosystem services derived from the Western Cape mountains are far more valuable when vegetated by fynbos than by alien trees (a result consistent with other studies in North America and the Canary Islands). The difference in water production alone was sufficient to favor spending significant amounts of money to maintain fynbos in mountain catchments.

The model was designed to be user-friendly and interactive, allowing the user to set such features as area of alien clearing, fire management strategy, levels of wildflower harvesting, and park visitation rates. The model has proven to be a valuable tool in demonstrating to decision makers the benefits of investing now in tackling the alien plant problem, since delays have serious cost implications. Parks managers have implemented many of the recommendations flowing from the model.

There are several other case studies in the literature of various applications of mediated modeling to environmental decision-making, including valuation. Van den Belt (2004) is the best recent summary and synthesis. Some additional examples of mediated modeling projects where ecosystem service values were integrated are:

- Participatory Energy Planning in Vermont, Department of Public Service in Vermont, http://www.publicservice.vermont.gov/planning/mediatedmodeling.html
- Mediated Modeling of the impacts of Enhanced UV-B Radiation on Ecosystem Services (van den Belt et al, 2006)
- Ria Formosa Coastal Wetlands, (a case study in van den Belt, 2004)
- Upper Fox River Basin, (a case study in van den Belt, 2004)
- A consensus-based simulation model for management of the Patagonian coastal zone, (van den Belt et al. 1998)

Models can be downloaded from: www.mediated-modeling.com

Strengths/Limitations. Resources needed to implement the method vary from application to application. The method can deal with a broad range of available data and resources, probably better that most other methods, since the model can adapt to the resources available across different levels of data, detail, scope and complexity. As a rule of thumb, one can produce a credible mediated model in 30-40 hours of workshops, requiring about 300-400 hours of organizing/modeling. Cost: about $40,000 - $100,000 depending on side activities.

The most serious obstacle seems to be the fact that this method is very different from the top-down approach most frequently used in government. It requires that consensus building be put at the center of the process, which can be very scary for institutions accustomed to controlling the outcome of decision processes. An institutional mandate is important, however, to motivate various stakeholders to volunteer their time, knowledge and energy to a mediated modeling process. The final outcome of this process cannot be predetermined.

Treatment of Uncertainty.

In terms of uncertainty, there are all the usual sources, but the difference is that the stakeholders are exposed to these sources as they go, and learn to understand and accommodate them as part of the process. The method is compatible with formal or informal characterizing of uncertainty, producing probability distributions in addition to point estimates.

Research needs. No research has yet been done on whether application of the process to exactly the same problem by multiple independent groups would yield “consistent and invariant” results. One would expect general consistency, but some variation between applications. This is an area for further research.

To evaluate the impact of a mediated modeling process, surveys have been used before and after a process in the past and this research would deepen the understanding about exactly what elements of a mediated modeling process contribute to the success of failure of these processes.

Key References

Bond, P. and Goldblatt , P. 1984. Plants of the Cape Flora. Journal of South African Botany Supp. 13:1-455.

Checkland, P. 1989. Soft Systems Methodology, in J. Rosenhead (ed.) Rational Analysis for a Problematic World, John Wiley and Sons, Chichester, England.

Costanza, R. 1987. Simulation Modeling on the Macintosh Using STELLA, BioScience, Vol. 37, pp. 129 - 132.

Costanza, R., F. H. Sklar, and M. L. White. 1990. Modeling Coastal Landscape Dynamics. BioScience 40:91-107

Costanza, R. and M. Ruth. 1998. Using dynamic modeling to scope environmental problems and build consensus. Environmental Management 22:183-195.

Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, and H. Voinov. 2002. Integrated ecological economic modeling of the Patuxent River watershed, Maryland. Ecological Monographs 72:203-231.

Cowling, R.M. (ed.). 1992. The ecology of fynbos. Nutrients, fire and diversity. Oxford University Press, Cape Town.

Cowling, R. and R. Costanza (eds). 1997. Valuation and Management of Fynbos Ecosystems. Special section of Ecological Economics vol 22, pp 103-155.

Ford, A. 1999. Modeling the Environment: An Introduction to System Dynamics Models of Environmental Systems. Island Press, Washington, DC

Gunderson, L. C. S. Holling, and S. Light (eds). 1995. Barriers and bridges to the renewal of ecosystems and institutions. Columbia University Press, New York. 593 pp.

Hannon, B. and M. Ruth. 1994. Dynamic Modeling, Springer-Verlag, New York.

Hannon, B. and M. Ruth. 1997. Modeling Dynamic Biological Systems, Springer-Verlag, New York.

Higgins, S. I., J. K. Turpie, R. Costanza, R. M. Cowling, D. C. le Maitre, C. Marais, and G. Midgley. 1997. An ecological economic simulation model of mountain fynbos ecosystems: dynamics, valuation, and management. Ecological Economics 22:155-169.

Hobbs, R.J., Richardson, D.M. and Davis, G.W. 1995. Mediterranean-type ecosystems: opportunities and constraints for studying the function of biodiversity. In: Mediterranean-type ecosystems. The function of biodiversity. G.W. Davis and D.M. Richardson (eds), pp 1-42. Springer, Berlin.

Kahnemann, D. and A. Tversky. 1974. Judgment Under Uncertainty, Science, Vol. 185, pp. 1124 - 1131.

Kahnemann, D., P. Slovic, and A. Tversky. 1982. Judgment Under Uncertainty: Heuristics and Biasis, Cambridge University Press, Cambridge.

Lyneis, J.M. 1980. Corporate Planning and Policy Design: A System Dynamics Approach, Pugh-Roberts Associates, Cambridge, Massachusetts.

Morecroft, J.D.W. 1994. Executive Knowledge, Models, and Learning, in J.D.W. Morecroft, and J.D. Sterman (eds.) Modeling for Learning Organizations, Productivity Press, Portland, Oregon, pp. 3 - 28.

Morecroft, J.D.W., D.C. Lane and P.S. Viita. 1991. Modelling Growth Strategy in a Biotechnology Startup Firm, System Dynamics Review, No. 7, pp. 93-116.

Morecroft, and J.D. Sterman (eds.) 1994. Modeling for Learning Organizations, Productivity Press, Portland, Oregon

Myers, N. 1990. The biodiversity challenge: expanded hot-spots analysis. The Environmentalist 10: 243-255.

Peterson, S. 1994. Software for Model Building and Simulation: An Illustration of Design Philosophy, in J.D.W. Morecroft, and J.D. Sterman (eds.) Modeling for Learning Organizations, Productivity Press, Portland, Oregon, pp. 291 - 300.

Phillips, L.D. 1990. Decision Analysis for Group Decision Support, in C. Eden and J. Radford (eds.) Tackling Strategic Problems: The Role of Group Decision Support, Sage Publishers, London.

Rao, S.S. 1994. Welcome to open space. Training (April): 52-55.

Richmond, B. and S. Peterson. 1994. STELLA II Documentation, High Performance Systems, Inc., Hanover, New Hampshire.

Roberts, E.B. 1978. Managerial Applications of System Dynamics, Productivity Press, Portland, Oregon.

Rosenhead, J. (ed.) 1989. Rational Analysis of a Problematic World, John Wiley and Sons, Chichester, England.

Senge, P.M. 1990. The Fifth Discipline, Doubleday, New York.

Simon, H.A. 1956. Administrative Behavior, Wiley and Sons, New York.

Simon, H.A. 1979. Rational Decision-Making in Business Organizations, American Economic Review, Vol. 69, pp. 493 - 513.

Van den Belt, M. 2004. Mediated Modeling: a systems dynamics approach to environmental consensus building. Island Press, Washington, DC.

Van den Belt, Marjan, Oscar Bianciotto, Robert Costanza, Serge Demers, Susana Diaz, Gustavo Ferryra, Evamaria Koch, Fernando Momo, Maria Vernet. 2006. Mediated Modeling of the impacts of Enhanced UV-B Radiation on Ecosystem Services. Photochemistry and Photobiology, 82: 865-877

Van den Belt, M.J., L.Deutch, Å.Jansson, 1998. A consensus-based simulation model for management in the Patagonia coastal zone, Ecological Modeling, 110:79-103Vennix, J. A. M. 1996. Group Model Building : Facilitating Team Learning Using System Dynamics. Wiley, NY.

Vennix, J.A.M. and J.W. Gubbels. 1994. Knowledge Elicitation in Conceptual Model Building: A Case Study in Modeling a Regional Dutch Health Care System, in J.D.W. Morecroft, and J.D. Sterman (eds.) Modeling for Learning Organizations, Productivity Press, Portland, Oregon, pp. 121 - 146.

Westenholme, E.F. 1990. System Inquiry: A System Dynamics Approach, John Wiley and Sons, Chichester, England.

Westenholme, E.F. 1994. A Systematic Approach to Model Creation, in J.D.W. Morecroft, and J.D. Sterman (eds.) Modeling for Learning Organizations, Productivity Press, Portland, Oregon, pp. 175 - 194.