Cooperative Modeling To Promote Systems Thinking In Applying The National Environmental Policy Act

By: **Kristan Cockerill**

Abstract

When the National Environmental Policy Act was passed in 1969, it presupposed that there were clear ways to identify and then address environmental impacts from federal actions. Since then, it has become evident that environmental issues are grounded in complex systems, which are often difficult to "see" in traditional venues for gathering public input and informing decision makers. To address this, practitioners have been exploring collaborative modeling using system dynamics as a method for promoting systems thinking in a variety of decision venues. Historically applied in the business world, system dynamics has expanded into other arenas, including natural resource management. Cooperative modeling combines principles of collaboration with system dynamics to link relevant physical and social systems. In this approach, a multidisciplinary team convenes to engage in dialogue, to identify key variables for a particular issue, to identify relevant data, and to construct a systems-based computer model that helps team members "see" the complexity inherent in the system. Results from these experiences suggest that participants develop a deeper level of understanding about the policy issue, increase their agreement about root problems, and generate sound information about the issue being addressed. This article suggests that cooperative modeling can be an effective tool to meet both the letter and the spirit of the National Environmental Policy Act.

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When the National Environmental Policy Act was passed in 1969, it presupposed that there were clear ways to identify and then address environmental impacts from federal actions. Since then, it has become evident that environmental issues are grounded in complex systems, which are often difficult to "see" in traditional venues for gathering public input and informing decision makers. To address this, practitioners have been exploring collaborative modeling using system dynamics as a method for promoting systems thinking in a variety of decision venues. Historically applied in the business world, system dynamics has expanded into other arenas, including natural resource management. Cooperative modeling combines principles of collaboration with system dynamics to link relevant physical and social systems. In this approach, a multidisciplinary team convenes to engage in dialogue, to identify key variables for a particular issue, to identify relevant data, and to construct a systems-based computer model that helps team members "see" the complexity inherent in the system. Results from these experiences suggest that participants develop a deeper level of understanding about the policy issue, increase their agreement about root problems, and generate sound information about the issue being addressed. This article suggests that cooperative modeling can be an effective tool to meet both the letter and the spirit of the National Environmental Policy Act.

The National Environmental Policy Act of 1969 (NEPA) was simultaneously progressive and naive when promulgated. Its fundamental premise was forward thinking: gather information regarding environmental impacts *before* making a decision and thereby increase attention to environmental issues. There is no doubt that NEPA has succeeded in raising the profile of environmental issues in federal decision making [Blumm, 1990; Council on Environmental Quality (CEQ), 1997; Eccleston, 2006]. Its global influence is evident as NEPA has been the model for developing environmental policy in many other countries. NEPA language linking social, economic, and environmental concerns in the present and into the future foreshadows sustainable development (CEQ, 1997; Thrower, 2006) and well fits contemporary ideas in systems thinking. This holistic view reflects public sentiment at the time with its attention to environmental degradation and social change. In fact, building on the tone that NEPA set, the first Environmental Protection Agency (EPA) administrator, William Ruckelshaus, initially intended the EPA to take a "systems approach" in regulating pollution (Lewis, 1985). In practice, however, the EPA soon devolved into media-specific "silos," and NEPA has become more procedural than substantive.

While progressive in intent, NEPA is a product of its formative years and reflects a naïveté and ignorance about decision making and ecosystems. Its language assumed that better information would lead directly to better decisions (Karkkainen, 2002). Like all environmental legislation passed in the early 1970s, NEPA presupposed a linear path to predict and then address environmental impacts and assumed that our level of knowledge and technology were sufficient to the task (Lewis, 1985). Early environmental legislation was premised on the *equilibrium paradigm*, which posited that there is a "balance of nature" and that, left to its own devices, nature will find an ordered equilibrium that is stable (Botkin, 1990; Thrower, 2006; Wu and Loucks, 1995). This paradigm has had profound effects on attempts to manage natural resources as it segregated humans from ecosystems, assumed that any environmental change would be negative, and therefore focused on avoiding disruption

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(Botkin, 1990; Thrower 2006). As NEPA began to be applied, it soon became apparent that many of the assumptions in its foundation were false: new or different information does not always lead to more environmentally focused decisions; the concept of predicting environmental impacts is fraught with problems; ecosystems are not necessarily stable; and disruption, whether human or otherwise induced, is part of the system. The equilibrium paradigm has given way to an appreciation that ecosystems are dynamic and complex and therefore not readily predictable and that humans are part of the complexity (Botkin, 1990; Molles, 1999; Thrower, 2006).

Because complex systems are not predictable, the NEPA requirement to identify impacts before taking action is problematic. In response, agencies have moved toward litigation avoidance with a process-over-product mentality that includes generating high quantities of information without regard to the quality of the information (CEQ, 1997; Karkkainen, 2002). Judicial decisions ruling that NEPA is a procedural statute have reinforced agency behavior. Lynton Caldwell, NEPA framer, declared in his 1998 testimony to Congress that NEPA was not designed to be procedural and its implementation as such reflects a lack of commitment across the federal government. I argue that it also reflects the difficulties in attempting to address complex systems within a framework that was based on assumptions of simple, linear processes. While understanding of the environment and the complex nature of interlocking human and physical systems has evolved, decision-making methods and behavior have not entirely embraced this knowledge. In fact, participants at the 1999 National Conference on Environmental Decision Making concluded that the top threat to the environmental future was a lack of attention to systems perspectives (Tonn, 2000). A decade later, there is still a need to find ways to pursue policy that recognizes complex systems and to meet the spirit and the intent embedded in NEPA to make decisions that explicitly integrate environmental impacts with economic and social priorities.

NEPA is about both process and product. The process for involving the public (and/or proxies in the form of interest groups) in federal decision making has been part of NEPA's success and should continue to be a focal point. In contributing to decision making, however, the public and decision makers need tools that can link physical and social systems to show relationships among variables and to identify feedback loops in how these variables interact over time. They need to be able to design scenarios to ask "what if" questions of a proposed project. Applying system dynamics within a cooperative-modeling framework offers the ability to do this.

Cooperative Modeling with System Dynamics

Cooperative modeling can help meet the spirit (and the letter) of NEPA to generate more thoughtful and ideally more sustainable decisions regarding the environment. This technique has evolved from theories on collaboration and system dynamics and is variously called mediated modeling, group modeling, participatory modeling, and collaborative or cooperative modeling. The approach has been applied to address diverse issues throughout the world, and there is a growing body of literature defining cooperative modeling and describing how it works (Nicolson et al., 2002; Renger, Kolfschoten, and de Vreede, 2008; van den Belt, 2004; Vennix, 1996). Rouwette, Vennix, and van Mullekom (2002) reviewed more than 100 examples of group modeling applied within organizational settings. Additionally, there are numerous documented case studies relevant to environmental management (Cockerill et al., 2007; Palmer, Keyes, and Fisher, 1993; Ruth, Davidsdottir, and Amato, 2004; Stave 2002; van Eeten, Loucks, and Roe, 2002; Winz, Brierley, and Trowsdale, 2009). Cooperative modeling using system dynamics can contribute to achieving the elements that a 1997 CEQ assessment indicated are necessary for NEPA's success: strategic planning, public information and input, interagency coordination, an interdisciplinary place-based approach to decision making, and science-based and flexible management approaches.

System dynamics relies on identifying causal relationships among variables and using these relationships in constructing computer models. Its roots are in the business world (Forrester, 1961), but it has been applied in diverse settings, including environmental management. Cooperative modeling employs system dynamics to address policy issues. In this approach, a policy need is the catalyst to convene a multidisciplinary team that engages in dialogue to identify key variables for that policy issue, to identify relevant data, and to construct a systems-based computer model. These models capture feedback, nonlinearities, and time lags in a particular system, which are too often ignored in assessing issues and in developing management approaches (Costanza and Ruth, 1998). The specific functionality of a system dynamics model makes it an ideal tool for strategic planning, as the systems-based approach enables people to "see" the complexity and thereby develop a common understanding of the patterns in a system over time: "System dynamics models are constructed to help us understand why these patterns occur. Our purpose is improved understanding, not point prediction" (Ford, 1999, p. 10). Because the goal is learning, system dynamics modeling is well suited to flexible management approaches that require monitoring and revising as appropriate. The models can be updated as necessary to reflect new information and/or new relationships in the system being studied. Modeling-team logistics are flexible and therefore responsive to the needs, desires, and resources available. Some modeling groups meet for a single day, whereas others meet for multiple years. The models themselves range from very simple (e.g., five variables) to quite comprehensive (e.g., hundreds of variables). Because the cooperative-modeling process is collaborative and focused on a specific policy need, modeling teams enable diverse stakeholders—including multiple federal agencies, content experts, interest groups, and the general public—to offer input. This approach generates multiple and diverse sources of information relevant to the system, including eliciting mental models from participants and capturing local, place-based knowledge about the system (den Exter, 2004; Forrester, 1992; Vennix, 1999). With this type of input, the output is interdisciplinary and information rich. This can help alleviate the critique that NEPA remains discipline bound and does not link physical and social systems in decision making (Bronstein et al., 2005).

The power of computer technology is crucial to identifying and addressing contemporary environmental concerns because humans are rather poorly equipped to assess complex systems. As Jay Forrester (1971), the founder of system dynamics has written, "Orderly processes in creating human judgment and intuition lead people to wrong decisions when faced with complex and highly interacting systems" (p. 1). Vennix (1999) well summarizes the literature indicating that *Homo sapiens* have limited capacity to process feedback loops and even extensive training may not alter this; and that preexisting perceptions and peer pressure heavily influence how humans interpret information and events. He therefore notes that cooperative model building and system dynamics can help individuals and groups uncover misperceptions "because the rigour of mapping and modeling forces participants to carefully and consistently make their mental models explicit and put their problem definitions to the test, by surfacing implicit (causal) assumptions" (p. 384).

Case studies of cooperative modeling show that the approach increases knowledge levels about the particular topic (Cockerill, Passell, and Tidwell, 2006; Rouwette, Vennix, and van Mullekom, 2002). Additionally, the case studies reveal that cooperative modeling often leads to increased consensus about the problem (Costanza and Ruth, 1998; Rouwette, Vennix, and van Mullekom, 2002; van den Belt, 2004). This is in part because, as Hellstrom and Jacob (1996) write, "In practice, most environmental negotiation processes are not about facts per se, but about whose value judgments are to be represented in making decisions" (p. 80). Cooperative modeling can help delineate what the group accepts as fact and where group members stand on the values being expressed through the modeling exercise. In my personal experience with cooperative modeling, participants have concluded that the process of identifying the relationships among variables helped to generate common ground that reduced the intensity of advocacy positions present at the outset of the project. The collaborative nature of these projects generated more, and more diverse, information than would have been gathered in a more traditional literature review. Additionally, participants have reported that model output showed unexpected results that generated new levels of discussion about "best" actions. For example, in one water management project, the model made clear that implementing low-flow appliances as a water conservation measure to reduce groundwater withdrawals had a negative effect on surface water flows. This was because much of the surface-water flows were returns from the wastewater treatment plant. So, by reducing the level of groundwater pumping, a perceived "good" policy, these conservation measures introduced lower surface flow with potentially "bad" ecological impacts. Because system dynamics models make explicit these counterintuitive results, the models contribute to a better understanding of the interrelationships within a system and ideally contribute to better decisions because the decision makers have considered these interrelationships.

Cooperative Modeling for NEPA

Cooperative modeling with system dynamics offers an opportunity to revisit the substantive portions of NEPA while maintaining the benefits of a sound public process. Shifting to a cooperative-modeling approach in conducting an environmental impact statement (EIS) could be fairly straightforward. Because the EIS process is currently time and resource intensive, agencies could convert those resources to employ a cooperative-modeling effort that engaged a modeler, agency personnel, content experts, interest groups, and the public. This would increase the level of interdisciplinarity, generate attention to complex systems, and offer a tool that could continue to be used in monitoring to adapt actions as appropriate.

To improve the participatory aspects of conducting an EIS [or an environmental assessment (EA)], cooperative modeling can be done using virtual meeting software. This well fits Turina's (2001) call to better utilize online computer technology in implementing NEPA. The computer technology allows geographically dispersed stakeholders to meet online and contribute to model development. It also enables people for whom attending a public meeting is a challenge (e.g., those with young children, health issues, or limited transportation options) to become more actively engaged in the EIS process.

Applying cooperative modeling to EAs requires more fundamental change from the status quo, but offers greater potential impact because there continues to be an increase in the number of EAs compared to EISs. The EA approach is criticized for not adequately integrating public input (Turina, 2001) and for being used to sidestep the more rigorous EIS (Karkkainen, 2002). Cooperative modeling could be readily used within the current EA process. As colleagues and I have written elsewhere, although cooperative modeling is intended to ensure a strongly participatory approach, the level of inclusivity in the participation can vary (Cockerill et al., 2009). For example, at the less inclusive end of the spectrum, agency personnel, content experts, and a modeler could gather in short modeling sessions to generate the basis of the assessment. This could be done in face-to-face or virtual meetings. Participants could design a fairly simple model to be used to develop mitigation scenarios that would actually improve a project and simultaneously offer more robust information to support a "finding of no significant impacts" if such a finding were warranted. This would improve the level of interdisciplinarity as individuals from different agencies and/or specialists would offer input to the process and this input would be integrated into the model. As den Exter (2004) found, system dynamics modeling can improve attempts to integrate science and management perspectives in making environmental decisions. The model development process would likely reveal unforeseen relationships that could be addressed through mitigation. The model itself could then be used to inform the public by offering systems-based ideas that highlight the various mitigation options and the trade-offs inherent in making project decisions. This approach maintains the existing benefits of developing an EA—namely, integrating environmental values in agency decisions and keeping the public informed (CEQ, 1997)—while adding additional benefits to the process and the product.

Ideally, an EA, like an EIS, would include interest-group and/or public input at the model development stage. Developing a model without such input does raise questions of limiting public participation in federal decisions. It also potentially limits the value of the model developed as the interest groups or public may not trust a tool developed without their input (Cockerill, Tidwell, and Passell, 2004). There is evidence that to best understand the complexity in a system and to gain confidence in a model's output, it is more effective to have a group help design the model than to employ an existing model (Rouwette, Vennix, and van Mullekom, 2002; Winz, Brierley, and Trowsdale, 2009). Although increased public input is desirable, the reality is that EAs are currently being developed without public input, without interdisciplinary thinking, and typically without any tools capable of addressing complex systems (Bronstein et al., 2005; Karkkainen, 2002). Therefore, even a less participatory cooperative-modeling effort that was interdisciplinary and actually influenced the decision-making process would be an improvement compared to the status quo.

Because complex systems are difficult for people to grapple with, cooperative modeling offers a learning opportunity for helping people to realize that they may not be considering the whole picture. This is a rationale for including interest groups and the public in the EA modeling process. As people (including agency personnel) better understand that, in a complex system, there are going to be nonlinearities and counterintuitive results, they will recognize that system dynamics offers benefits as an assistant to making policy decisions. In essence, when applying system dynamics, teams can utilize the idea that "information structure is an important feedback mechanism with high-leverage. If you make information go to places it did not go before, it may well cause people to behave differently" (Hjorth and Bagheri, 2006, p. 86). Ford (1999) and Vennix (1999) emphasize that modeling is a way to learn and this is key to applying cooperative modeling to NEPA. Because prediction is faulty, shifting the focus to learning about the relationships (social, economic, and ecological) inherent in a project is perhaps a more productive way forward. Applying system dynamics through cooperative modeling can help move the general understanding (for agency personnel and the public) away from the idea of *predicting* and then *solving* a problem to a more realistic notion of consistently managing issues. This approach is entirely congruous with other efforts being suggested to improve NEPA and environmental management, including calls to monitor outcomes from EA decisions (CEQ, 1997; Karkkainen, 2002) and to employ adaptive management under the NEPA rubric (CEQ, 1997; Thrower, 2006). In considering complex systems, the idea of solutions (implying that the issue has been addressed in its entirety) is problematic because the system is dynamic. As both Wildavsky (1979) and Cates (1979) suggested decades ago, better policy lies in asking better questions, not in finding better solutions. Cooperative modeling does help participants focus on questions.

Limitations

For all of its benefits, cooperative modeling is not being proposed as a panacea. Just as there is no "silver bullet" option in most NEPA decisions, cooperative modeling with system dynamics is not a silver bullet for improving NEPA or making better environmental decisions. Like all methods, this one faces challenges, and its use as a tool should be carefully considered. As Renger, Kolfschoten, and de Vreede (2008) highlight, this approach requires that someone experienced in system dynamics modeling be involved. This adds a layer of expertise required for agencies developing the EA or EIS. Depending on the level of inclusivity, it may add expenses to the current EA process. Additionally, using collaborative modeling will not reduce the number of competing interests or potential conflict in the decision-making process. Actually, in many collaborative efforts (multidisciplinary and otherwise), the initial level of conflict may be higher than in a noncollaborative effort as people explore their values relevant to the decision. If the process is not structured appropriately, especially in terms of who participates, cooperative-modeling efforts can be reduced to mere academic exercises that have little or no bearing on any actual decisions. Collaboration also does increase the amount of time required to move through the process. This can be especially true if holding virtual meetings. Because nonverbal cues are absent, communicating does take longer when it is not face to face.

Cooperative modeling with system dynamics will be new for many agency personnel, and there is resistance to pursuing the unknown, especially when the stakes (i.e., litigation) may be high. The historical artifact of the equilibrium paradigm is still present, and agency personnel may be quite familiar with linear, predictive models. Because the human mind is ill equipped to "see" complex systems, the linear approach seems more intuitive. It gives a sense of certainty to the outcome even though the certainty may be falsely based. Repenning (2003) concludes that the popularity of models based on "assumptions of equilibrium and mono-causality" makes it difficult for people to "develop intuition from system dynamics models" (p. 316). Overcoming these cognitive, historical barriers will not be easy.

Finally, there is always the potential for modeling output to be used irresponsibly to promote one viewpoint or another. Models have often been used as political tools (King and Kraemer, 1992) and policy makers, members of the public, and interest groups may not trust a model that produces counterintuitive results, even if they helped develop it. There will always be individuals or groups who are not satisfied with the process and/or the final decision. Therefore, in the short term, using cooperative, system dynamics modeling may not reduce the litigious atmosphere surrounding NEPA. It is interesting, however, that system dynamics is being employed as a tool in litigation (Howick, 2005).

Discussion and Conclusion

Although the limitations are significant, the potential for substantive change and improvement in the NEPA process is also significant. As evidenced by the citations in this article, numerous practitioners throughout the world are engaged in cooperative modeling using system dynamics, and therefore agency personnel do have a diverse array of expertise to tap if they choose to pursue cooperative modeling in a NEPA context. More promising, federal agencies in the United States (US) are embracing system dynamics and cooperative modeling in various venues. The Department of Energy commissioned an adaptation of an existing guide to system dynamics. The document, *An Introduction to System Dynamics*, covers the basic concept and features energy-relevant examples (US Department of Energy, 1997). A more extensive use of systems-based modeling is found in the US Army Corps of Engineers Institute for Water Resources (IWR, 2009). Their Shared Vision Planning program links traditional planning mechanisms with collaboration and systems modeling to make water management decisions. In 2007, the IWR, Sandia National Laboratories, and the US Institute for Environmental Conflict Resolution collaborated to form CADRe (Computer Aided Dispute Resolution). One of the areas emphasized in this new endeavor is to integrate model-based collaboration into NEPA processes.

These efforts are still evolving and, of course, will have their critics. They offer promise, however, and seem to reflect that federal agencies do recognize the need to develop systems-based tools and processes and that there are champions within the agencies to promote this new mode of operating. Just as it takes time to appreciate the counterintuitive relationships that system dynamics models bring to light, it will take time for the new methods to meld with (and in some instances replace) the old.

Criticisms about procedure over substance, the lack of integrated, interdisciplinary thinking, and issues with public input have been leveled at NEPA nearly since its inception. Therefore, pursuing new, maybe radical, change is warranted. In 1971, Forrester cautioned "against continuing to depend on the same past approaches that have led to present feelings of frustration" (p. 1). It might be argued that this premise—a need to do things differently—is what drove Caldwell (and others) to pursue developing a national environmental policy. Forrester, the founder of system dynamics, and Caldwell, the framer of NEPA, had contemporaneous careers and, while I do not know whether their paths ever crossed, their arguments in their respective pursuits carry many similarities. Both saw the importance of systems and linkages among sometimes seemingly disparate variables, and both saw a clear need for new ways of thinking and hence new ways of acting. Integrating their legacies by employing system dynamics to realize the full intent of NEPA would seem a logical step.

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