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A network modeling approach to policy implementation in natural resource management agencies

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ABSTRACT

Natural resource agencies are responsible for managing specific aspects of the environment through the development and implementation of policies. Computational advances have emerged in recent years that provide opportunities for simulating the influence that agency structure has on policy outcomes, particularly those stemming from the area of network theory and analysis. However, there remains a need for methods that can measure and visualize the confounding effects that multiple agency characteristics may impose on policy implementation. The complex interactions among these factors require an approach that can evaluate these factors in relation to one another and provide a way to abstract meaningful findings that can be useful for both scientists and agencies to consider for future policy development. In this study, we present a network simulation modeling approach that (1) builds upon existing conceptualizations of bureaucrat decision-making within agency networks, (2) uses network theory to construct idealized natural resource agency networks that can be used to evaluate how agency structure influences policy implementation, and (3) visualizes simulation results to better understand how bureaucrat behaviors and relationships in concert with agency structure influence policy outcomes. Using this approach, we demonstrate how different aspects of decision-making by bureaucrats interact with the spatial constraints of institutional networks to influence policy outcomes. The network modeling and visualization methods presented here offer an alternative approach in the policy science toolbox that can help generate new assumptions and questions about the ways in which natural resources are governed.

1. Introduction

Federal natural resource management agencies are responsible for developing and implementing policies to manage the landscapes and resources. Such agencies are comprised of individual bureaucrats who interact with each other in a complex institutional framework constrained by agency norms and culture (Manring, 1994) and by the need to enforce a variety of existing laws and rules that may at times conflict (Meyers & Dillon, 1999; Simon, 1983). At the same time, individual bureaucrats retain a degree of discretion permitting them control over how to implement policies depending on their position in the agency (Lipsky, 1983), which can lead to significant divergence between policies as how they are conceived versus how they are implemented. This is all the more true because congressional legislation rarely contains sufficient detail for a policy to be implemented, thereby ensuring agency discretion within the process. Among the many factors that can lead to this divergence between policy as conceived and policy as implemented are the beliefs of street-level bureaucrats (Riccucci, 2005) their willingness to collaborate with one another (Matland, 1995), the physical distance between them (Gastner & Newman, 2006; Lubell, Robins, & Wang, 2014), and pressure from bureaucrats at higher positions in an agency who are likely concerned with multiple issues beyond any given policy (Stern, Andrew Predmore, Mortimer, & Seesholtz, 2010).

The beliefs of bureaucrats have been shown to influence how they make decisions about policy implementation in a variety of contexts. Street-level bureaucrats may view their job priorities differently than overall policy goals, and that these differences impacted how bureaucrats believe their services should be performed (Riccucci, 2005). Similarly, natural resource bureaucrats have based their support of overall project priorities upon their personal beliefs when providing input (Trusty & Cerveny, 2012). Bureaucrats' beliefs about the effectiveness of specific policy instruments and tolerance towards populations who would be affected by specific policies can also affect their behaviors when enforcing policy (Winter, 2003). Additionally, bureaucrats' beliefs about technology and about the adequacy of training for the implementation of new technological systems into state agencies can influence how likely there were to use them (Berry, Berry, & Foster, 1998).

With regards to pressure from senior level bureaucrats, budget pressure and pressure to meet existing targets often influence implementation within a natural resource agency (Moseley & Charnley, 2014; Stern

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et al., 2010; Winter, 2003). At the same time, direct supervision by supervisors has been observed to increase usage of a policy instrument, but not necessarily in the way envisioned by policy makers (Evans, 2011; Scott, 1997). Collaboration within organizations and between organizations also has the potential to exert influence on the implementation of policies. Matland (1995) argues that successful implementation will depend upon the strength of the political collaborations when ambiguity and conflict are high, while others argue that collaborative approaches in the public sector are essential to dealing with complex problems (Agranoff, 2012).

Distance between bureaucrats can represent both physical separation as well as the strength of relationships between them. Distance is an important measure in agencies because, as Friedkin (1982) revealed, stronger ties are more important for facilitating more effective information flows. Physical distance between individuals has been shown to be an important factor for understanding innovation diffusion among firms (Gluckler, 2007; Hägerstrand, 1967), while stronger relationships between individuals with closer occupations has demonstrated a higher degree of knowledge transfer (Crona & Bodin, 2006).

Multiple theoretical approaches under the broad umbrella of policy science provide a means to understand how natural resource agencies operate and how the various aforementioned agency and bureaucrat characteristics influence policy outcomes. These include rational policy analysis (Oyono, Kouna, & Mala, 2005), institutional policy analysis (Sekher, 2001), and critical policy analysis (Elands & Wiersum, 2001), all of which can be used to contextualize natural resource governance into frameworks that provide a means for interrogation (Arts, 2012). Of the current approaches to policy analysis, policy network analysis has gained substantial attention in the literature for understanding policies related to natural resource agencies (Bodin, Crona, & Ernstson, 2006). Network theory operates by representing individuals, their behaviors, and their relationships with one another in the context of a network where individuals (i.e. nodes) are connected to one another (by edges). As such, network theory facilitates an understanding of how individual's decisions, influence, and power operate within the larger agency context (Castells, 2011; Enroth, 2010).

In addition to providing a theoretical context in which to situate institutional systems, network theory provides a set of analytical and modeling tools that can quantitatively measure how elements of institutional networks influence policy implementation. Network analysis and modeling (commonly referred to as social network analysis, or SNA) involve computational abstractions of real world networks through encoding individuals as nodes that are connected by edges representing the relationships between them. The most prominent component of SNA has been geared towards the measurement of networks by employing metrics to calculate network size, average degree (i.e. the average number of edges connected to each node), average path length (i.e. the average shortest path between all pairs of nodes), and the overall connectedness of nodes in the network (Gonzalès & Parrott, 2012).

Network simulation modeling also offers an exploratory, scenario-based approach to emulate how networks can potentially behave in specific situations or contexts (Guizani, Rayes, Khan, & Al-Fuqaha, 2010). Network simulation modeling involves digitizing a network and embedding behaviors into nodes and edges that collectively determine how social objects such as information, communication, and policies change as they make their way through a network. These can be represented as agent-based models (ABM) in which agents are the rudimentary decision makers representing bureaucrats' actions. Such models make available the opportunity to create “what-if” scenarios where the modeler can alter the number of individuals in the network, their relationships, how individuals are connected, and how they influence one another. Having the ability to manipulate the network as such is useful for understanding how specific network parameters as well as the structure of the network influence the emergence of policy outcomes.

Despite its potential, research in utilizing network theory and simulation modeling for informing policy implementation in natural resource agencies remains in its infancy (Kim, Johnston, & Kang, 2011). Notable examples of existing work includes Beilin, Reichelt, King, Long, and Cam’s (2013) study using social network analysis as a visualization tool for revealing the network structure of a diverse set of actors in a community based natural resource management setting. This study found such visualizations successful for communicating important management information with stakeholders. In a more analytical context, Sandström and Carlsson's (2008) study employed network analysis for determining how the structure, organizing capacity, and performance of policy networks influence the ways in which policies emerge in an education policy sector. Similarly, Parrott, Chion, Gonzalès, and Latombe (2012) employed social network analysis for evaluating the outcomes of agent-based simulation models in order to understand how the structure and configuration of a diverse network of actors influence ecological performance measures such as biodiversity. Agent-based modeling was also employed by Agrawal et al. (2013) to simulate how the network structure of villagers involved in common-pool resource use influences the sustainability of forest consumption. The latter three studies each reveal that the outcomes of governance-related networks are dependent in some form or another on the types of actors involved, their characteristics, and the ways they interact with one another.

Given the visualization and analytical potential of network theory and modeling demonstrated in the literature, this study uses this approach for providing insights into how the interaction of beliefs, pressure, collaboration, and distance at the local bureaucrat level affect the outcomes of policy implementation. We build upon existing conceptualizations of bureaucrat decision-making within agency networks to construct an agent-based network model of bureaucrat behaviors and relationships. Specifically, we adopt a generic representation of the policy implementation process of the United States Forest Service (USFS) as described by Moseley and Charnley (2014). Our intent is not to inform policy making within the USFS, but instead to use this organization, which we believe is emblematic of environmental, land use, and natural resource agencies in the United States and beyond, as a backdrop for demonstrating our approach. Utilizing results from our model, we develop a novel visualization for understanding how bureaucrat behaviors and relationships, in concert with agency structure, influence policy outcomes.

2. Methods

The agent-based network model developed for this study simulates the structural and bureaucratic characteristics of the USFS using network theory and provides a demonstration of the utility of our visualization strategy. The description of the model, which was developed in NetLogo 5.1, is organized using the Overview, Design concepts, and Details (ODD) protocol (Grimm et al., 2010).

2.1. Purpose

The purpose of this model is to simulate the policy implementation process within the USFS in order to illustrate how bureaucratic characteristics, distance, and network structure influence how support for new policies changes as they move through the agency network. We use a simplified version of the general structure and bureaucrat characteristics defined in Moseley and Charnley (2014) as the basis to our model development. While Moseley and