CHAPTER 16

NETWORK THEORY AND PRACTICE IN PUBLIC ADMINISTRATION

Designing Resilience for Metropolitan Regions

LOUISE K. COMFORT, CLAYTON WUKICH,
STEVE SCHEINERT, AND LEONARD J. HUGGINS

Metropolitan regions are undergoing significant changes that create greater interdependencies among governmental entities, nonprofit organizations, and private businesses in their shared service areas (Miller 2002; Rusk 2003). As populations in these regions have sought to increase regional economic development by spreading to suburbs, these policies have resulted in a concentration of low-income households in depressed neighborhoods in central cities (Downs 1994). The resulting shift in economic development has led to increased unemployment, impoverishment, crime and violence in the central cities, as well as a diminishing tax base, declining quality in public education, aging infrastructure, and an increased demand for governmental services to counter deteriorating social and economic conditions for the urban population (Downs 1994; Leavitt and Kiefer 2006). Yet, *perceived inefficiency* and *growing distrust* of governmental services (Barzelay 2001) have resulted in the reluctance of citizens to raise taxes needed to fund public services.

In older industrial regions, such as Allegheny County, Pennsylvania, population is decreasing, but *demand for services is still increasing,* due to high rates of unemployment, aging populations, and a declining tax base that funds urban services. Given these conditions, urban regions are becoming increasingly vulnerable to a range of threats (Cutter, Boruff, and Shirley 2003) that require innovative strategies in the design, delivery, and management of public services.

The consequence of these social, economic, infrastructural, and demographic changes is an evolution in administrative structures of urban regions. Where traditional administrative hierarchy had focused primarily on maintaining control over personnel and resources to ensure reasonable equity and accountability in managing public funds (Behn 1998), increasing demands for public services are requiring public agencies to find new ways of getting the work done (Behn 2001; Kettl 1993). Traditional administrative practice led to orderly performance in stable societies, but largely failed to adapt to changing conditions. In practice, ineffective hierarchical structures are giving way to informal methods of addressing shared problems among multiple entities in metropolitan regions (Bryson 2004; Frederickson and Smith 2003). These methods are leading to significant change in the administrative framework of urban regions. This chapter explores an approach to network theory and practice that may be used to develop resiliency in metropolitan governance.

DESIGNING RESILIENCE FOR METROPOLITAN REGIONS

Much of the professional debate regarding networks has centered on their capacity to absorb shocks and adapt to changing conditions more readily than hierarchical administrative structures. This capacity, termed *resilience,* has generated an outpouring of research and exploration to determine exactly what factors contribute to it and whether it can be developed systematically in complex environments exposed to risk. A working definition of resilience (Boin, Comfort, and Demchak (2010, chapter 2) is stated as follows: "Resilience is the capacity of a social system (e.g., an organization, city, or society) to proactively adapt to, and recover from, disturbances that are perceived within the system to fall outside the range of normal and expected disturbances."

Metropolitan regions are intrinsically complex. The scope and frequency of daily interactions among physical, engineered, social, and economic systems generate risk. In such environments, vulnerability in operational structures and processes may be reversed through self-organization, networked communication and collaboration, and continuous monitoring and review by experienced managers. In these complex settings, facilitating the search, exchange, and feedback processes characteristic of distributed cognition creates a productive working strategy for managing the interdependence of public, private, and nonprofit organizations (Comfort 2008). Risk reduction on a regional scale is fundamentally a governance process.

INFORMAL NETWORKS

Changes in administrative structure can be observed directly in the informal networks of action that have emerged among public, private, and nonprofit organizations (Feiock and Scholz 2010) to reduce urban risk and manage threats to public health and safety (Comfort, Mosse, and Znati 2009). These networks of action cross jurisdictional and disciplinary boundaries as communities search for effective mechanisms to mitigate shared exposure to risk, but are limited in resources and personnel. As expanding populations move into regions previously deemed unsafe (e.g., coastal zones, flood plains, canyons prone to wildland fires) or critical infrastructure deteriorates under heavy use and lack of maintenance, the demand for emergency services outstrips the capacity of particular communities to protect their populations (Morrow 1999). This situation creates a dilemma of increasing demand but diminishing capacity that compels public organizations to search for new means of engaging their communities in managing risk (Nakagawa and Shaw 2004). Ironically, the crucible of shared risk often compels disparate organizations to search for, and find, a common interest in public safety that allows them to overcome narrow interests and forge more collaborative means of providing essential public services for their communities (Dynes 2006).

The cumulative pattern of change in the economic, social, and political conditions of metropolitan regions over the last fifty years has created urban environments characterized by complex organizational and jurisdictional interactions, uncertainty in the outcomes of prescribed policies, and scarcity of resources to meet mounting public problems. These deteriorating conditions have fostered a lively and vigorous debate regarding the need for change in the design, delivery, and management of public services. If indeed change is needed, it also requires new methods of monitoring, measurement, and calibration of resources and attention to adapt policy and practice to the interdependent demands of urban regions.

NETWORK THEORY AND DEBATE

Multiple threads of theory and analysis weave through the debate on urban problems that are nested in the structure of intergovernmental policy and practice. A key thread is recognition of the declining capacity of government to manage effectively the growing complexity in the design and delivery of public services at any level of operation (Milward and Provan 1998). Milward and Provan term this decline the "hollow state" and provocatively acknowledge the decreasing capacity of government to cope with the growing demands of difficult, interdependent, and expensive issues in public administration. The option of contracting services to private or nonprofit agencies places government personnel at a deep disadvantage, if this decision is not informed by seasoned expertise and careful oversight. This option becomes even more problematic as these same public agencies face declining budgets and diminished ranks in personnel (Kettl 1993).

The disadvantages of contracting out governmental services can be countered, DiIulio (1994) argues, by developing strong principal/agent relationships that provide a coping mechanism for public agencies facing increased demands. Such relationships largely shift the burden of oversight and authority to the federal level. This practice has had the undesirable consequence of weakening subnational governments still further, as these agencies bear the brunt of increased demand for services without the personnel or expertise to manage them effectively (Bryson 2004).

The debate continued with a vigorous set of claims for addressing the seemingly intractable issues of managing the complex design and delivery of public services at multiple levels of jurisdictional operation and geographic location (Barzelay 2001). These claims led to the rise of new public management (NPM), which increased emphasis on monitoring and measurement of performance in the set of agencies involved in service delivery. The focus of management then shifted to tracking the information processes used by a lengthening chain of agencies (Pollitt 2003). In important but unexpected ways, the NPM approach created the basis for developing a focus on networked management of services that crossed sectoral boundaries.

The shift in focus to intersectoral networks, public/private partnerships, and joined-up government represents different approaches for coping with the realities of heterogeneous populations in urban regions. These realities include: increased access to information by citizens regarding governmental performance; conflicting goals among community groups; and the instabilities of economic performance in democratic societies (Schneider and Ingram 2005). Although the values of individual rights, social equity, and civic participation remain strong, the challenges of achieving this vision of a democratic society—in a highly differentiated, resource-constrained, public environment that is subject to random fluctuations caused by extreme events—are significant. Public agencies may choose strategies of action to cope with declining resources, such as postponing repair of basic infrastructure, but the random occurrence of a natural disaster may compel an entirely different allocation of budget and personnel in practice, with serious consequences for the community. The long-developing deterioration of a complex set of levees and pumps in the city of New Orleans foreshadowed the ensuing catastrophe of Hurricane Katrina and illustrates this dilemma. It is this tension between choice and randomness (Kauffman 1993) in managing public affairs that creates a context in which networked forms of organization that provide essential public services offer singular advantages in facilitating adaptation to changing conditions.

The central task of managing change, given the interaction between choice and randomness in the public arena, spurs the generation of complex forms of organization to meet public needs. For example, the spontaneous organization of community groups to rebuild damaged communities after disaster builds partnerships among affected residents that did not exist prior to the event (Phillips 2009). In these evolving settings, the capacity of one organization to serve as the inter-

mediary among many organizations in transmitting information, resources, or expertise required to solve a specific problem will create a base of knowledge and experience for that organization that represents soft power, or centrality, in the network. The organization is, essentially, filling a 'structural hole' or gap in the network of organizations (Burt 1992) that may carry over into other areas of community practice long after the recovery from the initial event has stabilized.

Other threads in the debate include the tension between leadership and frontline personnel in generating change (Kelman 2005; Radin 2006). The focus on social capital as a means of overcoming the inherent uncertainty attendant in efforts to manage change has likely been romanticized rather than rigorously evaluated in most instances of social action. Social capital may indeed bridge gaps in understanding and experience among unlikely actors in unexpected situations and forge bonds of commitment among newfound partners to achieve a shared goal of civil security, but the measurement of its reliability and robustness over time remains questionable in dynamic environments.

The debate regarding strategies for managing change summarizes a set of conditions that acknowledges a shifting balance in authority and expertise among public, private, and nonprofit organizations. No longer do governmental agencies play the commanding role in terms of resources and expertise. Given the legal responsibility for the protection of lives, property, and continuity of operations in civil society as implied in the preamble of the U.S. Constitution (Tribe 1988, xxxi) public agencies are compelled to innovate and explore more effective forms of interaction with other actors in organized society. This dynamic has driven the public search for partnerships with other organizations, exemplified by George H.W. Bush (1988) in his call for a "thousand points of light" to support public service.

CHANGING THE INFORMATION INFRASTRUCTURE TO SUPPORT COORDINATED ACTION

The dynamics driving social, economic, and political change have had different degrees of impact on different population groups within metropolitan regions, creating gaps in equity and access to public services that generate social needs. Yet, significant advances in computational power, telecommunications, and the design of technical infrastructure have created the capacity for individuals and organizations to search for, and exchange, information over wide distances and diverse loci of operations to support coordinated action to meet those needs (Coakes, Willis, and Clarke 2002). These technical advances in communications that enable the timely exchange of information have altered irrevocably the organizational world. Public administration is based fundamentally on processes of decision making (Simon 1997), and assumes accurate, timely information as a basis for decision. Without access to timely, accurate information, public agencies are constrained in the actions they can reasonably take and limited by the cognitive capacity of human managers (Miller 1956), despite their good intentions or commitment to public values.

These technical advances do not diminish the political context of decision making in changing, uncertain environments (Boin et al. 2005), but they do make it easier to update and store information, disseminate information more widely, and trace decision processes over time. The changes in technical infrastructure are nonetheless related to the economic costs and benefits of implementing public policy. Benefits gained from reducing paperwork and time involved in communication and coordination by using information management and communication processes were touted by the Clinton administration in the 1990s as a major force in their *Reinventing Government* campaign (Kettl 1994). This campaign, established as a major priority in the Clinton administration and led by then vice president Al Gore, was designed in part to respond to the public reluctance to

pay taxes for perceived inefficiencies in governmental practice. By incorporating effective uses of information technology into its management functions, the Reinventing Government program sought to increase efficiency, decrease costs, and improve performance in the administration of public programs. While considerable public attention was focused on this effort, the Clinton administration learned from experience that introducing information technology effectively into administrative processes involved more than buying computers and software. Rather, it meant redesigning the organizational processes by which agency personnel determined what data to collect, where and how it should be stored, who had access to it and when, as well as creating a staff of sociotechnical experts who understood the organizational functions of the agency sufficiently to design appropriate technical support for the staff (DiIulio and Kettl 1995).

The bold hopes of the Clinton administration to offset the costs of public administration by increasing the efficiency and timeliness of a diminished public service (U.S. Senate 1993) were largely not met, but this national experiment demonstrated the potential for reconsidering government as a sociotechnical system. While the tools approach advanced by Salamon (2002) and his coauthors focused largely on the financial instruments used to enact public programs and bring together public, private, and nonprofit organizations in the common enterprise of public service, Reinventing Government substantially shifted the administrative change effort to managing information needed for timely, efficient decision making. In so doing, the program strengthened the technical and conceptual basis for designing networks of action to address public sector problems.

Social media are increasingly triggering changes in the technical infrastructure of urban regions to enable faster and more efficient information exchange. Advanced information and communication technologies such as Twitter, Facebook, and other Web 2.0 technologies are revolutionizing how people interact with public administrators and share information with one another as well as other organizations, energizing an innovative form of networked governance. "Twitterers," for example, have emerged as the new first responders for information dissemination from crime scenes, disasters, and even normal daily operations that affect people, places, and policies. Policy makers receive a range of information and significant detail in real time and near real time, which can prompt quicker, more instantaneous decision making. Essentially, the emergence of Web 2.0 technologies has further challenged the shortcomings of rational choice theories (Buchanan and Tullock 1999), but has enhanced the collective action approach proposed by Ostrom (2005) and others. Increased access to multiple means of communication for a wider group of participants raises the rate of citizen engagement in coordinated action. Yet, administrators need to balance organizational communication processes with the changing technology, and design institutions that are capable of evolution, learning, and adaptation (Goodin 1996). The challenge for urban governments is to support, utilize, and manage these Web 2.0 information technologies to improve networked governance, a task that entails minimizing disruption of the governing process while maximizing its productivity.

THE EMERGENCE OF NETWORKS IN PUBLIC ADMINISTRATION

Although the concept of networks in public administration is not new, the preceding review of different forms of informal, reciprocal interaction among organizations from different sectors, disciplines, and jurisdictions creates a distinct knowledge base to support inquiry into more advanced forms of networks capable of managing more challenging sets of policy problems (Ostrom 2005). Informal communication processes to link information to action have been recognized as part of the political process since Brutus betrayed Caesar, but the types of networks that are drawing attention in current public administration have a different profile (Barabási 2002; Watts

2003). These networks are focused on action and are formed to achieve a specific goal (Churchman 1979). Their components are intelligent in that they seek, store, and exchange information to support decision making in reference to a shared goal. The goal is directed toward achieving the public good, as defined by the set of participating actors, not the limited benefit of specific actors for particular ends. The networks, further, are cognizant of their own actions, errors, and accomplishments, and interactions among members of the networks constitute a self-correcting, self-organizing dynamic to maintain their focus on inquiry. While the goals of some networks may be disputed by other actors in the society (Sageman 2004), the organization of the network depends on, first, its clear articulation of a shared goal, and second, the flow of information among its members to achieve that goal. The third characteristic of this type of network, used for either constructive or destructive purposes, is its ability to monitor its own actions and to update, correct, and synthesize information collected by its members to support the group's continued effort to achieve its stated goal.

INTELLIGENT NETWORKS

Known as *intelligent networks,* this form includes any actor that can send, receive, store, and process information. Such networks include individuals, groups, organizations, computers, and institutions as actors (Breiger, Carley, and Pattison 2003), each operating at its own level of capacity and contributing to the shared knowledge base for the whole system. Information search and exchange processes drive the formation and adaptation of these networks, and the impact of the network on its immediate environment relies on the asymmetry of information generated by the density of interactions within the network in contrast to the more dispersed transactions among other actors in the wider environment. Theorists examining such networks, explored also as potential instruments for disrupting enemy actions in military environments (Alberts and Papp 2000), acknowledge the neutrality of networks as an organizational form. The impact of the network is defined by its goal, and the value of the goal is assigned by the designers of the network. Such networks may be used to achieve either positive or negative results, as declared by members of the network in contrast to the wider society (Raab and Milward 2003). Intelligent networks are, foremost, social instruments designed to mobilize collective action, and their sustainability is measured by outcomes achieved against their defined goals.

What all networks demonstrate, positive and negative alike, is that the communications patterns, both among members within the network and between the network and its external environment, change the organizational structure of the network. Tracing the information flow among the members within the network identifies which members influence the actions of other members under what conditions and at what times. Further, tracing the information flow between the network and other actors in its operating environment reveals the degree of influence that the network is able to exert in the service of its goal. Understanding the dynamics of networks as vehicles for mobilizing public action compels managers in metropolitan regions to think more creatively about what options are available to them for managing change.

The task of managing change in metropolitan regions under uncertain conditions presents a particular challenge for public administration. The articulation of governance as a mode of management that integrates resources and personnel from public, private, and nonprofit organizations (Salamon 2002; Kettl 2009) offers a framework, albeit a temporary one, for action in complex, dynamic environments. The basis for mobilizing action is shared knowledge, and while this knowledge is distributed (Hutchins 1995), the process of information search and exchange stimulates a learning process among the participants that guides the action in real time. This is especially important in

dynamic conditions in which the capacity to adapt quickly is vital to sustaining the shared goal of the community. In this process, the relationships among public, private, and nonprofit actors are realigned to create a better fit with the demands of the changing environment, as the participating actors update and adapt their actions to balance efficiency, equity, and effectiveness in daily practice more appropriately.

THE SCIENCE OF NETWORKS

Albert Barabási selected *The New Science of Networks* as the subtitle for his 2002 book, *Linked.* In doing so, he acknowledges the primary weaknesses of networks as they have been adopted, applied, and identified in much of the literature in public administration and management. In practice, networks of communication and exchange are easily recognized, yet they are documented, characterized, and measured with much greater difficulty. In part, this difficulty stems from the continual flux of social interaction in which action networks operate. Yet, a larger part of the difficulty derives from the time and systematic effort required to gather, code, collate, and analyze data on network performance. This cost in time and effort is especially characteristic of the kinds of multilevel, multiorganizational, multisector networks that operate in the public arena.

In an effort to address the theoretical and analytical problems of understanding institutional diversity, Elinor Ostrom (2005) proposed a framework to examine the analysis and development of organizations operating in different action situations in different public arenas. Her institutional analysis and development (IAD) framework links actors involved in specific action situations to the larger issues that animate the public arena. In doing so, Ostrom offers a means of identifying interdependencies among actors operating at different levels of action and authority. This analytical framework is particularly useful for the kinds of intergovernmental networks characteristic of public administration.

The measurement of performance in interdependent networks remains a critical factor in assessing their impact in public affairs. Such networks represent relationships among actors that form, dissolve, reform, and adapt to changing conditions (Axelrod and Cohen 1999). The dynamic characteristics of networks attracted the interest and attention of mathematicians, physicists, and computer scientists. A wide-ranging group of researchers focused on devising means to measure and model the changing impact of networks, both on their members and on the environments in which they operated (Carrington, Scott, and Wasserman 2005). Many shared a background of research on complex, adaptive systems, and recognized networks of public policy and administration as a subset of this larger domain. John Holland (1995), a computer scientist interested in the dynamic exchange of information among diverse actors, offered a conceptual framework for the development of complex systems. His argument, that complex systems emerge out of an inherent search for order among organizations interacting in unstructured environments, captures one dimension of this dynamic. The opposite dimension, the equally powerful tendency for systems to disintegrate without a continual influx of fresh energy, or entropy (Fermi 1956; Tong 2008), represents the counterforce in this dynamic process.

Efforts to characterize and measure the changing dynamics of networks were facilitated by the rapid advance of computational theory during the nineties. Although sociologists had earlier recognized the importance of networks, their focus was largely limited to small groups and single organizations (Doreian and Hummon 1976). With the advent of increased access to computational power, researchers in business organizations (Nohria and Eccles 1992) and public organizations (Axelrod 1984) developed methods to simulate organizational behavior under different sets of conditions. These efforts cumulated in a coherent approach termed *computational organizational theory*

(Prietula, Carley, and Gasser 1998). Using computational methods, these researchers successfully demonstrated the merits of conditional exploration of different strategies of action undertaken by different sets of actors under different initial conditions of resources, knowledge, communication, and time (Carley 2000). Complemented by parallel explorations of network structure, dynamics, and measurement among mathematicians, sociologists, economists, and other modelers (Wasserman and Faust 1994; Watts 1999), the systematic development of a science of networks began to shape the understanding of networks, their design, and their functions in the public arena. Applying these methods to actual policy problems and testing them for validity and reliability in the world of practice have become the focus for a distinguished set of policy and management researchers (Newman, Barabási, and Watts 2006). This expanding group of researchers has developed a new set of tools and computational programs to advance the design and management of networks operating as large-scale systems in the public arena.

NETWORKS AND THE MANAGEMENT OF LARGE-SCALE SOCIOTECHNICAL SYSTEMS

For public administrators concerned with the management of large-scale sociotechnical systems providing public services, the concepts proposed by the network analysts offered fresh ways of thinking about intergovernmental and intersectoral problems. Network analysis bridges the study of organizational systems that manage public services with the management of technical systems, such as telecommunications, transportation, water, power, and wastewater distribution systems, that provide these services. Both sets of systems—organizational and technical—are geographically distributed, and maintaining effective performance between the two types of operating systems at multiple levels of operation is essential to the efficient delivery of public services. For example, the concept of "scale-free networks" that draw resources, knowledge, and participants from multiple levels of operation by choice as well as random events (Barabási 2009) to address a particular policy problem, such as shelter after a storm, clarifies the phenomenon of preferential attachment in networks of action that often stymies public managers seeking to balance equity with efficiency by introducing legal requirements through public policy.

Given the developments in theory and method over the last twenty years, social network analysis has emerged as a leading technique for studying the emergent and rapidly changing environments that characterize the complex adaptive systems that public managers so frequently encounter. Rather than focusing on the characteristics of the actors involved in the situation under study, social network analysis (SNA) examines the ties that exist between these actors. The analysis includes the relative characteristics of each interaction, but it focuses on the observed set of interactions, the distribution and patterns of the interactions, and the content of the interactions, including directionality. Such analytical methods provide a more accurate means of assessing rapidly changing situations by examining both the constituent parts and the whole of the operating systems. SNA examines actor and network performance by assessing the resources of each actor as well as their patterns of distribution and utilization.

For example, SNA will readily show when needed resources are present in a system, but cannot reach the actors who need them or who would otherwise use them, by showing the lack of connection between the actors. It can also explain network performance in rapidly deteriorating situations by providing models of the network and system resilience that are necessary for effective intervention. It is this combination of tools that makes SNA an effective method for the study of complex adaptive systems.

Simon and Feiock (2008) summarize the basic network measures, including density, which

calculates a ratio of the number of observed connections to the number of possible connections in the network. They also explain several methods for identifying the key actors, that is, the most central actors, of a network and describe small world networks. This frequently observed phenomenon can be measured mathematically to determine how information can be transmitted rapidly to a large number of agents by a small set of key actors, each of whom has a wide set of interactions in a given domain or region. By identifying central actors, analysts can also assess which organizations would face the heaviest workloads under urgent stress. Managers can then use these results to determine whether the organization that has formal authority in a given situation actually performs the functions expected by that authority in practice.

Density, in contrast, measures the frequency of interactions among actors in the network regarding a specific task or problem occurring in a given location at a particular time. Measures of density also reveal when interactions among agents are constricted or controlled due to "structural holes," or gaps in the pattern of connections among actors in the network (Simon and Feiock 2008). Wasserman and Faust (1994) compare different types of networks operating at different levels of interaction, focusing on the identification of subgroups or cliques in the performance of different functions within the network. They also discuss the measurement of qualitative concepts, such as the prestige or social capital of an actor. When paired with network maps that visually depict the network's structure (Borgatti, Everett and Freeman 2002), this set of analytic methods provides an informed profile of an action network.

The focus on structure and process allows network researchers to analyze complex adaptive systems more effectively than other methods. By charting interactions, SNA not only shows their frequency among members of a network, but also measures the robustness and reliability of the network's performance. When the content of interactions among members is coded, network analysis can be used to characterize access to information and other resources within the system and provide a measure of resilience for a system under stress. For example, Comfort and her coauthors (Comfort and Haase 2006; Comfort, Oh, and Ertan 2009) analyzed the networks of organizations engaged in response operations following the 2005 and 2008 hurricanes on the Gulf Coast. These analyses identified differences in practice by emergency service agencies mobilized in response to similar urgent events. While standard after-action reports create a useful dialogue regarding the effectiveness of multiorganizational actions taken in reference to specific disasters, social network methods additionally provide measures of strength or weakness in interagency performance that can assist managers in planning to reduce risk in future extreme events.

The contribution of network analysis to public administration and theory lies in its measurement of dynamic interactions among individuals and organizations in relation to the changing conditions of their operational environment. Building on the analytical framework of network analysis, computational simulation of organizational action has emerged as an important method of assessing possible strategies of action in environments that are too large or too dangerous or too extreme to study in actual practice. Simulation is developing as a powerful method for investigating alternative strategies of organized action in extreme situations, such as battlefield environments, earthquake disasters, or breakdowns of large-scale technical systems such as nuclear plants. This method has increased in utility as computers have become more powerful and accessible. Accordingly, researchers have become more innovative in adapting simulation to explore relationships among variables identified in their studies.

As researchers have applied simulation techniques to real-world policy problems, they have communicated their findings to wider audiences of practicing managers as well as other interested researchers in the social sciences (Gilbert and Troitzsch 2005). Through continued development, simulation has advanced research on complex systems, drawing from theories of nonlinear dy-

namics, distributed cognition, artificial intelligence, and dynamic aspects of change (Conte and Castelfranchi 1995). Social scientists doing simulation research often work in conjunction with computer scientists (Lin and Carley 2003) or information scientists (Zagorecki, Ko, and Comfort 2010) to integrate social concepts with technical skills in the development of a new class of sociotechnical models that explore complex administrative systems in practice.

As methods of inquiry into administrative practice, social network analysis and simulation modeling have distinct limits in representing complex environments. Standard network analysis assumes that relationships among actors are dichotomous. Yet, the depiction of a dichotomous relationship indicating a random interaction between just two actors may not represent accurately an action system or event. Many, if not most, interactions include more than two actors. Observed interactions include at least three actors, and often more. This lack of specificity in defining interaction gives these techniques flexibility in application, but also adds complexity to the interpretation of findings from these methods. For example, many interactions exhibit what network analysts refer to as multiplexity, that is, the existence of multiple ties between two actors (Isett and Provan 2005).

GISCIENCE

Capturing the context of social networks and their actors goes beyond the usual identification of structure and process in network analysis. Not new, but increasingly used in the analysis of interdependent functions in metropolitan regions, geographic information science represents a useful means to explore spatial dynamic processes (Gimblett 2002). Developing a geographic information system (GIS) enables an analyst to capture, store, manipulate, analyze, and display geographic information using digital computation. Using GIS software, an analyst can generate a map of spatially located relationships. For example, comparative network studies of nested systems that are typical of regional or metropolitan analysis may represent social interactions at different spatial scales (Chase-Dunn and Hall 1997). Traditional network analysis does not explicitly consider space, yet networks are inherently spatial. GIS enables the modeling of interactions among actors, physical locations, and available resources. Successful incorporation of social science data into a GIS knowledge base and the construction of spatially explicit models from these data remain inconsistent and somewhat pedantic. The inherently static data used in GIS analysis often limit its capacity to model dynamic processes (Goodchild, Parks, and Steyaert 1993). Not only do social scientists use GIS to overlay data and conduct complex spatial analyses, but over the past decade, researchers have explored ways to integrate social networks and GIS (Butts 2009). This method allows analysts to isolate and characterize segments of the networks by attributes, which not only improves visualization, but also reveals the dynamic structure of the network.

GIScience is used to analyze, forecast, and visualize spatial interactions across networks. Visualizing how distance affects relationships increases the merit of network analysis. For example, one can estimate how a disease might spread in a population through the integration of the sociospatial processes of GIS in network analysis, and thus improve estimation and governance of rates of spread of the disease in metropolitan regions. GIS enables network analysts to construct visualizations of how networks have changed their spatial scale over time. In fact, incorporating spatial dimensions into networks may reveal that some networks are not as scale free as suggested by Barabási (2002). Geographic distance and location may limit some networks. GIS can therefore enable network analysts to test further complex causal models over time and space, which would then provide evidence and strategies for improved governance and information flow. Analyzing spatial movement in networks can influence how networks are

managed or interpreted as they cross organizational boundaries or traverse different jurisdictional and spatial scales.

The cumulative set of concepts, methods, and metrics that form the basis of the new science of networks makes a substantive contribution to the field of public administration. This science acknowledges the technical dimension in large-scale organized systems that characterize metropolitan regions, and provides a means of measuring the interaction between the technical systems of transportation, communications, electrical power, gas, water, and wastewater distribution and the organizations that operate them. In addition to instruments of financial management advocated by Salamon (2002) and his coauthors as a means of facilitating governance, the set of network analytic methods and models enables managers from both organizational and technical agencies to create a common knowledge base to support informed decision making for their given metropolitan region. Such a common knowledge base may be accessed by public, private, and nonprofit managers who operate interdependent systems, thereby informing their concurrent decisions in terms of meeting regional needs.

SOCIOTECHNICAL SYSTEMS

The distinguishing characteristic of metropolitan regions is the interdependence of their technical and organizational systems, as indicated previously. This interdependence has given rise to a model of governance that is based not just on shared financial responsibility among public, private, and nonprofit organizations, but also on the shared knowledge and critical expertise required to manage these large-scale systems effectively. For example, if the mayor of a city, often trained in law, does not understand the vulnerabilities posed to the transportation system by the region's aging engineered structures, she or he may not recognize the risk generated for the wider community by delaying needed maintenance of key bridges for budgetary reasons. The collapse of the I-35W bridge in Minneapolis on August 1, 2007, even as the bridge was being repaired, illustrates this risk. The need is not for an omniscient mayor, but rather for shared recognition that the knowledge needed to manage metropolitan regions is distributed (Hutchins 1995). That is, no single official or agency has all the information that is needed to make informed decisions on the wide range of issues that current public managers confront on a daily basis. In contrast, different organizations, and different managers within those organizations, have partial knowledge needed to balance risk of malfunction against resources of funds, attention, and personnel time to maintain continuity of operations. The challenge is to pool the shared knowledge in a timely, valid way and make it accessible to each manager who participates in decisions regarding management of the system under review.

Essential services for a metropolitan region, such as water and power distribution, human resources, and financial management, need collaborative management in order to maintain continuity of operations over time. Collaborative management in complex regional settings requires an information infrastructure sufficient to support the timely search and exchange of valid information regarding the status and performance of sociotechnical systems (Comfort and Haase 2006).

FUTURE RESEARCH

In a continuing effort to understand the rapidly changing environments of metropolitan regions, maintaining research on current issues is critical. While many problems in this interdependent policy environment deserve attention and action, four are basic to creating the learning environment that is essential for professional administrators. First, the need to enhance processes for rapid feedback, updating information, and organizational learning is central to effective management

of public issues in a dynamic environment. Current technologies for information exchange, such as Twitter, Facebook, and instant messaging, speed the flow of information rapidly across large numbers of people in spontaneous and undirected ways. Understanding these dynamic information processes and how they influence civic engagement in, or resistance to, governmental action is critical to maintaining an open, responsible, democratic society.

Second, and related to the first issue, is the task of building and maintaining current knowledge bases regarding complex public issues that are interdisciplinary, but accessible to interested citizens as well as relevant agencies, officials, and managers. The benefit of constructing current databases, especially on contested or controversial problems, is that of providing a neutral source of information to foster individual and organizational learning on both sides of the debate. Determining how to engage multiple actors in this task and creating an open, transparent, public knowledge base sets an example of informed participation by citizens and officials that enhances governance structures and processes.

Third, reviewing, designing, and advancing the methods and metrics for assessing risk in the interdependent functions of metropolitan regions is a key area needed for improving public management in metro regions. It is not only the municipal level of operation that needs exploration, but also county, state, and federal arenas of action and the interdependencies among them that constitute key areas for future research.

Finally, exploring ways to strengthen the scientific expertise required to manage increasingly complex and difficult public issues, such as climate change, energy production and distribution, and public health threats, is basic to improving shared governance among agencies and organizations operating in metropolitan regions.

CONCLUSIONS

In this brief review of network theory and practice in public administration, we draw four primary conclusions. First, network science offers a disciplined approach to monitoring and measuring the interdependent set of policy issues and practice that characterize metropolitan regions. The current concepts of governance, while insightful, lack the rigorous measurement of dynamic interactions among public, private, and nonprofit organizations that lead to policy change. Without such measurement, it is difficult for policy makers to craft viable strategies to manage the uncertainty generated by dynamic interactions among public, private, and nonprofit organizations in the daily operations of a metro region.

Second, network science is based fundamentally on an understanding of networks as systems of action. In these action systems, the participants—individuals, groups, organizations, computers, institutions—search for and exchange information as a basis for their respective actions in reference to actions taken by others. Consequently, identifying the relationships that link one actor to another under what conditions and to what degree becomes a primary step in assessing the degrees of independence, dependence, and interdependence in the complex set of administrative relationships that characterize metropolitan regions. Only when the underlying structure of relationships among actors is understood and mapped for particular administrative or policy issues can effective change be achieved in practice.

Third, effective decision making in interdependent environments, such as metropolitan regions, depends upon timely, valid processes of information search and exchange. This basic requirement for collaborative decision making can be facilitated by a well-designed decision support system (Comfort, Mosse, and Znati 2009). Designing and implementing decision support systems (DSS) to enhance institutional capacity and performance at local, state, and federal levels of operation represent key steps for strengthening governance in practice. A DSS uses improved communications

processes and computation to gather, store, analyze, and exchange data that show the current state of the sociotechnical systems that operate in metropolitan regions. It provides that information quickly and efficiently to those who need it.

Finally, the concepts, analytical techniques and models presented by social network analysis, GIScience, and computational simulation provide public managers with an increased ability to anticipate risk in dynamic environments, calibrate different patterns of response to uncertain events, and assess the interdependencies among operating systems identified by other methods and measures. The emerging science of networks offers the conceptual and analytical tools to enable public managers to function more efficiently and effectively in the complex, dynamic environments characteristic of metropolitan regions. Linked to decision processes within and among organizations, network science offers a powerful method of improving administrative practice in more nuanced, calibrated ways. As decision makers learn and apply these methods in practice, they will enable metropolitan regions to become more resilient in managing risk and random events.

REFERENCES

Alberts, D.S., and D.S. Papp. 2000. *The Information Age Anthology.* Washington, DC: Institute for National Strategic Studies, National Defense University.

Axelrod, R.M. 1984. *The Evolution of Cooperation.* New York: Basic Books.

Axelrod, R.M., and M.D. Cohen. 1999. *Harnessing Complexity: Organizational Implications of a Scientific Frontier.* New York: Free Press.

Barabási, A.-L. 2002. *Linked: The New Science of Networks.* Cambridge, MA: Perseus.

———. 2009. Scale-free networks: A decade and beyond. *Science* 325:412–413.

Barzelay, M. 2001. *The New Public Management: Improving Research and Policy Dialogue.* Berkeley: University of California Press.

Behn, R.D. 1998. The new public management paradigm and the search for democratic accountability. *International Public Management Journal* 1 (2): 131–164.

———. 2001. *Rethinking Democratic Accountability.* Washington, DC: Brookings Institution Press.

Boin, A., L.K. Comfort, and C. Demchak. 2010. The rise of resilience: Concepts, questions and theoretical approaches. In *Designing Resilience:Preparedness for Extreme Events,* ed. L.K. Comfort, A. Boin, and C. Demchak. Pittsburgh: University of Pittsburgh Press.

Boin, A., P. t'Hart, E. Stern, and B. Sundelius. 2005. *The Politics of Crisis Management: Public Leadership Under Pressure.* New York: Cambridge University Press.

Borgatti, S.P., M.G. Everett, and L.C. Freeman. 2002. *UCINET for Windows: Software for Social Network Analysis.* Harvard, MA: Analytic Technologies.

Breiger, R., K.M. Carley, and P. Pattison, eds. 2003. Dynamic social network modeling and analysis: Workshop summary and papers. Committee on Human Factors, Board on Behavioral, Cognitive, and Sensory Sciences. Washington, DC: National Academy Press.

Bryson, J.M. 2004. *Strategic Planning for Public and Nonprofit Organizations: A Guide to Strengthening and Sustaining Organizational Achievement.* San Francisco: Jossey-Bass.

Buchanan, J., and Tullock, G. 1999. *The Calculus of Consent: Logical Foundations of Constitutional Democracy.* Indianapolis: Liberty Fund.

Burt, R.S. 1992. *Structural Holes: The Social Structure of Competition.* Cambridge, MA: Harvard University Press.

Bush, G.H.W. 1988. 1988 Republican national convention acceptance address. American Rhetoric. www.americanrhetoric.com/speeches/georgehbush1988rnc.htm (accessed January 16, 2010).

Butts, C.T. 2009. Revisiting the foundations of network analysis. *Science* 325:414–416.

Carley, Kathleen. 2000. Computational analysis of social and organizational systems. *Organizational Science* 34 (2): 4–10.

Carrington, P.J., J. Scott, and S. Wasserman, eds. 2005. *Models and Methods in Social Network Analysis.* Cambridge: Cambridge University Press.

Chase-Dunn, C., and T.D. Hall. 1997. *Rise and Demise: Comparing World Systems.* Boulder, CO: Westview Press.

Churchman, C.W. 1979. *The Systems Approach and Its Enemies.* New York: Basic Books.
Coakes, E., D. Willis, and S. Clarke. 2002. *Knowledge Management in the Sociotechnical World.* London: Springer Verlag.
Comfort, L.K. 2008. Distributed cognition: The basis for coordinated action in dynamic environments. Paper presented at the workshop Exploring Innovative and Sustainable Approaches to Improve Community Resilience in Disaster Prevention and Response, Davos, Switzerland, August 29–30.
Comfort, L.K., and T.W. Haase. 2006. Communication, coherence, and collective action: The impact of hurricane Katrina on communications infrastructure. *Public Works Management and Policy* 11 (1): 1–16.
Comfort, L.K., D. Mosse, and T. Znati. 2009. Managing risk in real time: Integrating information technology into disaster risk reduction and response. *Commonwealth: A Journal of Political Science* 15:27–46.
Comfort, L.K., N. Oh, and G. Ertan. 2009. The dynamics of disaster recovery: Resilience and entropy in hurricane response systems 2005–2008. *Public Organization Review* 9: 309–323.
Conte, R., and C. Castelfranchi. 1995. Understanding the functions of norms in social groups. In *Artificial Societies: The Computer Simulation of Social Life,* ed. N. Gilbert and R. Conte, 252–267. London: UCL Press.
Cutter, S.L., B.J. Boruff, and W.L. Shirley. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly* 84:242–261.
DiIulio, J.J. 1994. *Deregulating the Public Service: Can Government Be Improved.* Washington, DC: Brookings Institution.
DiIulio, J.J., and D.F. Kettl. 1995. *Fine Print: The Contract with America, Devolution, and the Administrative Realities of American Federalism.* Washington, DC: Center for Public Management, Brookings Institution.
Doreian, P., and N. Hummon. 1976. *Modeling Social Processes.* New York: Elsevier North-Holland.
Downs, A. 1994. *New Visions for Metropolitan America.* Washington, DC: Brookings Institution.
Dynes, R.R. 2006. Social capital: Dealing with community emergencies. *Homeland Security Affairs* 2 (2): 1–26.
Feiock, R.C., and J. Scholz, eds. 2010. *Self-Organizing Federalism.* Cambridge: Cambridge University Press.
Fermi, E. 1956. *Thermodynamics*. New York: Dover Publications.
Frederickson, H.G., and K.B. Smith. 2003. *The Public Administration Theory Primer.* Boulder, CO: Westview Press.
Gilbert, N., and K.G. Troitzsch. 2005. *Simulation for the Social Scientist.* 2d ed. Philadelphia: Open University Press.
Gimblett, R. 2002. *Integrating Geographic Information Systems and Agent-Based Modeling: Techniques for Simulating Social and Ecological Processes.* New York: Oxford University Press.
Goodchild, M., B.O. Parks, and L.T. Steyaert, eds. 1993. *Environmental Modeling with GIS.* Oxford: Oxford University Press.
Goodin, R. 1996. Institutions and their design. In *The Theory of Institutional Design,* ed. R. Goodin. Cambridge: Cambridge University Press.
Holland, J.H. 1995. *Hidden Order: How Adaptation Builds Complexity.* Reading, MA: Addison-Wesley.
Hutchins, E. 1995. *Cognition in the Wild.* Cambridge, MA: MIT Press.
Isett, K.R., and K.G. Provan. 2005. The evolution of dyadic interorganizational relationships in a network of publicly funded nonprofit agencies. *Journal of Public Administration Research and Theory* 15:149–165.
Kauffman, S.A. 1993. *The Origins of Order: Self-Organization and Selection in Evolution.* New York: Oxford University Press.
Kelman, S. 2005. *Unleashing Change: A Study of Organizational Renewal in Government.* Washington, DC: Brookings Institution Press.
Kettl, D.F. 1993. *Sharing Power: Public Governance and Private Markets.* Washington, DC: Brookings Institution.
———. 1994. *Reinventing Government? Appraising the National Performance Review.* Washington, DC: Center for Public Management, Brookings Institution.
———. 2009. *The Next Government of the United States: Why Our Institutions Fail and How to Fix Them.* New York: W.W. Norton.
Leavitt, W.M., and J.J. Kiefer. 2006. Infrastructure interdependency and the creation of a normal disaster: The case of hurricane Katrina and the city of New Orleans. *Public Works Management Policy* 10:306–314.

Lin, Z., and K.M. Carley. 2003. *Designing Stress Resistant Organizations: Computational Theorizing and Crisis Applications.* Boston: Kluwer Academic Publishers.
Miller, D.Y. 2002. *The Regional Governing of Metropolitan America.* Boulder, CO: Westview.
Miller, George A. 1956. The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review* 63:81–97.
Milward, H.B., and K.G. Provan. 1998. Principles for controlling agents: The political economy of network structure. *Journal of Public Administration Research and Theory* 8:203–219.
Morrow, B.H. 1999. Identifying and mapping community vulnerability. *Disasters* 23:1–18.
Nakagawa, Y., and R. Shaw. 2004. Social capital: A missing link to disaster recovery. *International Journal of Mass Emergencies and Disasters* 22:5–34.
Newman, M.E.J., A.-L. Barabási, and D.J. Watts. 2006. *The Structure and Dynamics of Networks.* Princeton, NJ: Princeton University Press.
Nohria, N., and R.G. Eccles. 1992. *Networks and Organizations: Structure, Form and Action.* Boston, MA: Harvard Business School Press.
Ostrom, E. 2005. *Understanding Institutional Diversity.* Princeton, NJ: Princeton University Press.
Phillips, B. 2009. *Disaster Recovery.* New York: Auerbach Publications.
Pollitt, C. 2003. *The Essential Public Manager.* Philadelphia: Open University Press/McGraw Hill.
Prietula, M.J., K.M. Carley, and L.G. Gasser. 1998. *Simulating Organizations: Computational Models of Institutions and Groups.* Menlo Park, CA: AAAI Press/MIT Press.
Raab, J., and H.B. Milward. 2003. Dark networks as problems. *Journal of Public Administration Research and Theory* 13:413–439.
Radin, B. 2006. *Challenging the Performance Movement: Accountability, Complexity and Democratic Values.* Washington, DC: Georgetown University Press.
Rusk, D. 2003. *Cities Without Suburbs: A Census 2000 Update.* 3d ed. Washington, DC: Woodrow Wilson Center Press.
Sageman, M. 2004. *Understanding Terror Networks.* Philadelphia: University of Pennsylvania Press.
Salamon, L.M. ed. 2002. *The Tools of Government: A Guide to the New Governance.* New York: Oxford University Press.
Schneider, A.L., and H.M. Ingram. 2005. *Deserving and Entitled: Social Constructions and Public Policy.* Albany: State University of New York.
Simon, A.A., and R.C. Feiock. 2008. Methods of network analysis. In *Handbook of Research Methods in Public Administration.* 2d ed., ed. Y. Kaifeng and G.J. Miller. Boca Raton, FL: Auerbach Publications.
Simon, H.A. 1997. *The Sciences of the Artificial.* 3d ed. Cambridge, MA: MIT Press.
Tong, Ming. 2008. Entropy: A New Perspective of Risk and Crisis Management Studies. Paper presented at the International Conference on Risk, Crisis, and Public Management, Nanjing University, Nanjing, China, September 26–27. (2008). Trans. by Wen Jiun Wang. Pittsburgh, PA: University of Pittsburgh.
Tribe, L., ed. 1988. *American Constitutional Law.* 2d ed. Mineola, NY: Foundation Press.
U.S. Senate. 1993. Government Performance and Results Act of 1993. Calendar No. 96, Report 103–58. Washington, DC: Senate Committee on Governmental Affairs.
Wasserman, S., and K. Faust. 1994. *Social Network Analysis: Methods and Applications.* New York: Cambridge University Press.
Watts, D.J. 1999. *Small Worlds: The Dynamics of Networks Between Order and Randomness.* Princeton, NJ: Princeton University Press.
———. 2003. *Six Degrees: The Science of a Connected Age.* New York: W.W. Norton.
Zagorecki, Adam, Kilkon Ko, and Louise K. Comfort. 2010. Interorganizational Information Exchange and Efficiency: Organizational Performance in Emergency Environments. *Journal of Artificial Societies and Social Simulation* 13 (3) 3. Available at http://jasss.soc.surrey.ac.uk/13/3/3.html (accessed August 20, 2010).