Public Safety Networks as a Type of Complex Adaptive System

Arthur P. Tomasino
Bentley University
Department of Information and Process Management
tomasin_arth@bentley.edu

Public Safety Networks are receiving more attention and priority in the United States as the country deals with ever increasing threats from terrorism and natural disasters. As a network of public safety agencies, supported by an information and communications technology infrastructure, Public Safety Networks emerge from the individual and collaborative behaviors of their member agencies. Behaviors at the agency level aggregate to complex network behaviors in reaction to public safety events.

Reductionist theoretical conceptualization of public safety agency behavior is limited by proximity in time and environment whereas conceptualizations based on complex adaptive systems capture the distal environmental context and describes agency behaviors contributing to both incremental and differential safety events. Public Safety Networks operate as complex adaptive systems because they consist of multiple agencies, acting on condition and in parallel with member agencies resulting in continuous adaptation and evolution.

Public safety activities, such as anti-terrorism, law enforcement, fire control and emergency medical, are ill-defined and unsolvable "wicked problems" and Public Safety Networks organize themselves as a type of complex adaptive system in their attempts to solve these problems. This study utilizes complex adaptive systems theory to understand and explain the evolution of Public Safety Networks as they address the "wicked problems" they face on a daily basis. Theoretical concept and descriptions are supplemented with examples from case studies of two established United States Public Safety Networks.

This research is the first study of its kind; analyzing Public Safety Networks as Complex Adaptive Systems. It can be generalized to a broad range of cross-agency intergovernmental collaborative initiatives employing interorganizational systems. This research should lead to improvements and efficiencies in cost, performance, and social fabrics in Public Safety Networks in line with federal calls for improved transparency and cross-agency data sharing and operations. The study concludes with practical considerations for Public Safety Network managers. [1]

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1. Introduction

Natural disasters, life-threatening accidents and acts of terrorism drive the call for coordinated and efficient public safety services in the United States (U.S.). Public safety events, such as 9/11, Hurricane Katrina, and the recent (2011) Tucson mass shooting and assassination attempt of US Representative Gabrielle Giffords highlight the need for inter-agency public safety cooperation and coordination.

The United States has no overarching federal agency tasked with the coordination, development and management of state, county, or local public safety agencies and organizations. Public safety organizations band together sharing services and technology forming an interorganizational system referred to as a Public Safety Network (PSN). We define PSNs as inter-agency, agent-based, collaborations focused on the development and use of information and communication technologies (ICT) to support the information sharing and functional interoperability needs of public safety organizations engaged in law enforcement, criminal justice, and emergency response. They are agent-based systems consisting of a number of independent public safety agencies, such as police, sheriff, fire, medical, and emergency management, sharing technical and non-technical services under both formal and informal agreements between themselves [Williams, et al. 2009].

The formation, governance, and operation of PSNs are impacted by multiple aspects of the environmental and agency contexts in which they exist. Interdependencies among these contexts highlight the challenges of PSN evolution [Fedorowicz, et al. 2007]. PSNs use ICTs for cross-boundary information sharing and communications as a unifying force among member agencies but face conflicting demands from regulations, political agendas, safety agencies and citizens dictating the use of the ICT pushing the member agencies apart [Dawes, et al. 2004]. Without alignment of PSN member agencies operational efficiencies are jeopardized and ultimately citizen safety can be compromised.

Understanding agent-based organizations and increasing public safety has created a need for new models of PSNs integrating various threads of theory and practice to improve our understanding of the public safety domain. Complex Adaptive System (CAS) theory has been proposed as framework for organization in public service [Comfort, et al. 2004]. Therefore we ask, can we add to and extend public service CAS theories by characterizing PSNs as a type of CAS with a goal of generalizing to a broader range of cross-agency intergovernmental collaborative initiatives employing interorganizational systems? In practice, how can CAS theory be applied to PSNs increasing the safety and security of the public?

In the next section we briefly summarize extant PSN research utilizing rational choice, institutional and network theories. We use this to as a backdrop and contrast to our alternate view of the PSNs as a complex adaptive systems. Two case studies, the Capital Information Wireless Net (CapWIN) and Clermont County Division of Public Safety Services (DPSS), are use to apply the CAS perspective to PSNs and differentiate this view from previous perspectives [Fedorowicz, Gogan and Williams 2007, Tomasino, et al. 2011]). Propositions are presented from our analysis. We conclude with a practice viewpoint for PSN managers.

2. PSNs and Rational Choice, Institution and Network Theory

Resource dependency, institutional and network theories have been used to explain collaborative nature of nonprofit organizations. For example, Galaskiewicz and Bielefeld [Haveman 2001] first introduce the concept of the complementary nature of resource dependence, institutional, and network theories for the explanation of growth and decline of nonprofit organizations. They argue that this view is required because previous research was too centered on the profitable operation (and technologies) of production processes in the examination of organizations making it an unfit analysis for nonprofits.

Guo and Acar [2005] add to the analysis of nonprofit collaboration by examining the formal and informal collaborative activities, in nonprofits, that result in a restructuring of the organization. They find that older, large budget organizations with significant, single-stream, government funding form formal collaborations. They relate their findings directly to resource dependency, institutional and network theories based on the characteristics of each agent in the network.

Recent research extends these concepts to include PSNs. Fedorowicz, Gogan, and Williams [2007] detail specific factors for the growth and development of PSNs in their analysis of the CapWIN PSN. They show the large number of factors influencing the PSN including the interorganizational systems (IOS) as a support system for the PSN. Their analysis is one of the first to examine the *multitude and complexity of factors* for PSNs. Additionally they address the critical notion that PSNs not only operate in a day-to-day routine fashion but must also accommodate and respond to episodic, non-routine and unpredictable public safety events and suggest the need for future research to address these conditions.

Their later work focuses on the size and maturity of PSNs [Williams, et al. 2010]. Again, they model size and maturity as a function of rational choice (dependency) and institutional factors. Although their hypotheses are intriguing, relating PSN size and maturity to needs, resources and costs (rational choice), they produce surprising results showing histories of institutional reform and professional management do not correlate to PSN size and maturity as theory would predict. What they show is that the PSN *emerges* from the collaboration in an *unpredictable* fashion. As such, they acknowledge that PSN research needs to extend from the current rational choice and institutional factors to additional factors involving governance, system design and nature of the implementation, collaborations, and performance.

Complexity theory, and in particular CAS theory, is increasingly used to understand public administration and public service domains [Rhodes and MacKechnie 2003, Janssen and Joha 2006]. CAS theory is acknowledged as a new and "fresh" perspective to public administration studies [Rhodes, et al. 2011]. Therefore our contribution is to extend and add to the existing research on the public service CAS by including PSNs as a type of CAS. By typing PSNs as CASs we open a new window into the exploration and discovery of the complex behaviors of public service organizations and heed the call for expanding the theoretical understanding of

PSN evolution. Our goal is to generalize our findings to a broader range of cross-agency intergovernmental collaborative initiatives employing interorganizational systems In the next section we view the PSN as a CAS by examining the nature of public safety problems and the interacting elements and their emergent properties PSNs.

3. PSNs as Complex Adaptive Systems

Three aspects of Complex Systems [Waldrop 1992, Morel and Ramanujam 1999] are applicable to PSNs and contribute to our characterization of PSNs as a type of CAS. First, PSNs face a class of "wicked problems", second they exhibit large numbers of interacting elements and third, patterns emerge in the behavior of their interacting elements. Each aspect is explained in more detail in the following sections.

Our analysis is a descriptive case study of two PSNs, the Capital Wireless Integrated Network (CapWIN) and Clermont County Division of Public Safety Services (DPSS).

CapWIN is a first responder initiative created as a partnership among the States of Maryland and Virginia, the District of Columbia (DC), and the federal government to develop and integrated transportation and criminal justice information wireless network. Law enforcement, fire, emergency medical and transportation agencies, in the metropolitan DC area, are supported utilizing a browser-based system. CapWIN has enrolled and trained 41 agencies and 947 users and fielded over 25,000 event queries.

DPSS was created to support the Clermont County Sherriff's Department's communication needs and grown to support almost all the law enforcement, fire, and emergency medical agencies throughout the county. They provide mobile radio communications, internet access, and computer-aided dispatch for field and office operations. They also support communications capabilities for the State of Ohio within the county.

3.1. Wicked Problems

Rittel and Webber [1973, Churchman 1967] defined a class of problems that are ill formatted, emply confusing information, many clients and decision makers, conflicting values and resolutions that have "thoroughly confusing" ramifications, which they call "wicked problems". IOS organize as CAS to solve "wicked problems" [Waldrop 1992].

Similarly, PSNs face problems with no formal guidance structures, a multiplicity of information to process (criminal, fire, geographic, health, medical, etc.), multiple agents (law enforcement, fire, emergency medical, etc.), and individual agent-based values. PSNs tend to re-solve their problems by restructuring based on reactions to critical safety events or the exertions of member agencies with the greatest power.

Head and Alford [2008] show that "wicked problems" result in *substantive*, *strategic*, and *institutional* uncertainty in organizations. Such uncertainties are best

illustrated through examples from our research cases, CapWIN and DPSS. In 2008, DPSS faced *substantive* uncertainty in definition of public safety due to conflicting needs to support day-to-day operations (police and fire) and prepare for large emergency events. Within the PSN they could not agree to the definition (or substance) of their safety problems.

CapWIN dealt with *strategic* uncertainties caused by conflicting agency needs by the eventual emergence of "champions" that consolidated and focused the multitude of opinions on the organization of the PSN. Likewise, DPSS, as a county PSN, balances the needs of the county Sheriff and local Police Departments for law enforcement support. PSNs must resolve individual and sometimes conflicting agency needs and demands.

As such, PSNs consist of multiple agents without over-arching management. As a result they organize and adapt, as a CAS, to relieve *institutional* uncertainty. Therefore PSNs organize and adapt to substantive, strategic, and institutional uncertainties, produced by the "wicked problems", into CASs.

3.2. Interacting Elements

PSNs, as an interorganizational system, are in response to many internal and external forces. Within the public sector such forces include regulatory requirements, political agendas, crime rates, emergency preparedness/response and citizen public safety demands. Additionally they work with community groups, public initiatives and the general public. PSNs are cross-sector collaborations or "partnerships involving government, business, nonprofits and philanthropies, communities, and/or the public as a whole" [Bryson, et al. 2006]. PSNs deal with multiple internal organizational interacting elements.

From the technology perspective the cross-sector collaboration requires ICTs for the sharing of information across the organizations belonging to the PSN. This creates a need for cross-boundary data and information sharing [Fedorowicz, Gogan and Williams 2007, Dawes, Pardo and Cresswell 2004]. Technological issues involve the procurement of systems, functional capabilities, interoperability between different systems, and support services. Storage, ownership, and access to data can be problematic. As such, the PSN faces multiple internal interacting technical elements.

Many times ICT becomes a focal point for implementation of the PSN, but as Scholl [2005] explains organizational, legal, political and social challenges are just as important adding to the complexity of the interactions within a PSN. DPSS is mandated to support the county sheriff but also support police and fire agencies through informal arrangements monitored by a county communications council. Therefore in addition to the aforementioned internal organizational and technical elements, PSNs face multiple interacting internal social elements. Social elements may include actors, agencies, or a combination of both [Kapucu 2005].

PSNs must also interact with external organizational, technical and social elements. For example PSNs funding can come from state or local government budgets or federal grants. The PSN competes for the same funds that are allocated to its member agencies. With ever decreasing local budgets and grant opportunities,

PSNs still need to serve and adapt to the demands [Ulbrich 2005] of their member agencies while competing with them for resources. PSNs face social, technical and financial challenges caused by the interactions between the PSN and their member agencies and external agencies.

PSNs consist of a large number of different types of agencies interacting across sectors, utilizing ICTs to enable collaborations by sharing data and information.

3.3. Emergent Properties

PSNs are agent-based organizations where member agencies must cooperate with each other for efficient operations. Cooperating agencies examine the resources to share the problem, mobilize, and, finally, cooperate to solve the problem. The process is not smooth, but rather a combination of systematic and random effects [Weiss 1987]. Random effects appear as critical events to the agencies (such as a sudden decrease in funding or a new law). These events can be either large or small in magnitude but, nonetheless, cause new emergent PSN properties as the PSN adapts to the events.

For PSNs these types of events are typically public safety crises or technology changes. In an extreme event, such as a terrorist attack or catastrophic weather conditions, public safety organizations must act swiftly and efficiently to ensure public safety. Studies of these events show that the organization may fail in their attempts to maintain efficient operations but then change either the organization or processes in reaction to the events [Comfort, Dunn, Johnson, Skertich and Zagorecki 2004]. New organizational structure or processes emerge as a result of the critical event.

Also, PSNs adapt dynamically, as technologies change [Tyworth and Sawyer 2006]. They are in a state of constant redevelopment. Because the agencies in the PSN rely on ICT, for both formal and informal communications, an emergent structure, or pattern of development arises mimicking the structure of the ICT. Not only does the structure of the PSN resemble the structure best supported by the ICT but the frequency of interactions (or behaviors) also follows the ICT structure (architecture) and the PSN will change as the technology changes. For example, when DPSS switched to new dispatch system implementation problems resulted in a need for enhanced transparency to the PSN members, regarding their operations. As a result they reorganized making dispatch a separate directorship.

Therefore the PSN adapts in response to its environment, exemplified by critical safety events or technology changes. As such emergent properties modify the structure of their communications and agencies. Since PSNs experience “wicked problems and exhibit the characteristics of complex systems we contend that PSNs are a specific type of complex system, a complex adaptive system.

4. CAS characteristics and PSNs

CAS theory can be used to analyze the changes in the PSN modes of operation (rules), interaction of agents (police, fire, etc.), and the fitness (or performance) of the PSN. Williams, et. al [2010] indicate fitness is a key characteristic for PSN research and connects PSN practice.

We adopt Anderson's [1999] definition of CASs; *agents with schemata, self-organizing networks sustained by importing energy, coevolution to the edge of chaos and recombination and system evolution*. We apply each concept to PSNs giving examples from our case studies resulting in propositions extending CAS theory to PSNs.

4.1. Agents with Schemata

CAS theory examines how changes in agents' decision rules, interconnections among agents, and fitness functions the agents employ produce different aggregate outcomes. Agents follow a set of rules, or 'schemata' that they use to control the complexity of their environment.

PSNs implement standards and procedures (schemata) for day-to-day operations and emergencies. For example, at DPSS they are pursuing the APCO (The Association of Public Safety Communications Officials) certification for the fire and police dispatch services. APCO certification results in the documentation of a set of rules or "schemata" for DPSS helping them control the complexities of dispatch operations.

Additionally they perform 'tabletop' simulations of critical public safety events where they predict activities and actions during critical events and create detailed, documented, procedures for these operations. Failures of the system in emergencies may necessitate changes to these plans. The simulations and resulting procedures helps DPSS understand and document the complex interaction of their member agencies during critical safety events resulting in "schemata" that drives their operations and decisions.

Proposition 1: PSN member agencies must employ a set of rules, or "schemata", to control the complexity of their environment. These rules specify actions and activities for the PSN in day-to-day and critical safety operations.

4.2. Self Organizing Networks Sustained by Importing Energy

When the interaction of large numbers of components involves feedback loops, some behaviors die out and some self-amplify, crowding out other behaviors. This causes the CAS to never reach equilibrium, thus it always requires increasing energy inputs to maintain operations. Agents within the system supply this energy by the work they perform or by inputting new sources of energy (e.g. members, suppliers, partners, customers). Influential and powerful agents determine the application of energy and the evolutionary direction of the CAS. Loose coupling of the agents promotes feedback and the system self-organizes around the influential members.

At CapWIN a key event in the evolution of the PSN was the movement from centering strategies on mobile technologies to shared data services. This move allowed CapWIN to service entirely new areas in public safety and expanded their influence into new areas bringing additional "energy" into the PSN. Additionally this represented a shift in power in the organization as agencies controlling the data now had stronger voice in the decision making for the PSN.

DPSS was actively trying to expand their services to different geographic areas. In particular they were trying to absorb neighboring PSNs to create a regional PSN. Their goal is to be the most powerful PSN in the area and crowd out other PSNs. As they grow they become more powerful enabling them to absorb additional PSNs and associated technologies, clients, and funding. Both CapWIN and DPSS are self-organizing networks importing energy.

Proposition 2: PSN networks are constantly changing due to interactions of their members. They import energy into the system by adding new members or restructuring around powerful agents.

4.3. Coevolution at the Edge of Chaos

Because agents maintain autonomy in the CAS they cannot forecast system-level consequences of their actions. Instead they base their choices to optimize their own fitness, not necessarily the fitness of the CAS. As a result the environment is in constant change due to the choices made by each agent.

Coevolution of each agent occurs due to their choice to optimize their own fitness. As such, the CAS operates far from equilibrium where small or large changes in behavior trigger varying impacts to the system. The CAS 'stabilizes' into a condition where it is sensitized to both large and small events because this makes the CAS the most efficient. By operating at the 'edge of chaos' the CAS can respond to changes and reach higher fitness levels than by incremental evolutionary change. They exist in a balance between flexibility and stability.

PSNs are very sensitive to critical (or large) public safety events. These events, although infrequent tend to cause major changes in the PSN. The terrorist attacks of September 11th and Hurricane Katrina would both be considered very critical public safety events. These events can expose both failures and successes of PSNs and tend to have far reaching implications to the PSN.

For example, at CapWIN two critical events were key determinants for the formation and expansion of the PSN. In 1998 an attempted suicide by jumping from a heavily used bridge caused massive disruptions to suburban transportation. Failures in communications between the responding agencies precipitated the formation of CapWIN to address this type of problem. The September 11 terrorist attacks on the World Trade Center and the Pentagon caused interest in the CapWIN project to broaden and intensify (as it services the Washington, D.C. area) yielding additional funding and growth.

Similarly, small changes in one agent's operation (for example due to a new technology) will 'ripple-through' all the other agents as their success or failure is communicated. At DPSS a small member police force opted to upgrade their radio

systems to the latest Project 25 system which was not interoperable with the existing Project 16 system (supported by DPSS). Not only did this create a communications problem for DPSS (with the small police force) but it sensitized other agencies to the deficiencies in the Project 16 system. These agencies then pressured DPSS to adopt the newer system. This resulted in a new DPSS technology plan requiring a $14 million upgrade to their systems by 2014. A small, yet critical, event by one member caused a large de-stabilization in DPSS operations and planning but will result in a more efficient PSN when the new Project 25 system is operational.

Proposition 3: PSNs exhibit sensitivity to large and small disruptions in daily operations. Large disruptions result from public safety critical events and small disruption result from changes introduced by member agencies. Either disruption may significantly change the PSN and result in increased effectiveness of public safety services.

4.4. Recombination and System Evolution

CASs are nested hierarchies that contain other CASs. Every aspect of the CAS is subject to change over time. This includes the positive feedback loops in the CAS. As the loops break and reform it causes a recombination of the CAS agents into new hierarchic systems. New agents or new schemata may be introduced to the CAS. In particular, technology changes may cause recombination and evolution of the CAS.

Participation in the PSN is almost always on a voluntary basis. Agents opt for inclusion in the PSN because it increases their ability to provide safety services or reduces the costs of maintaining current levels of services. Membership in the PSN is voluntary, thus agents are loosely coupled within and across the PSN allowing them to change their operations or secede from the PSN if so desired. Additionally new agents can join the PSN relatively easily and with little cost (in many cases the PSN absorbs most of the infrastructure cost). Therefore agents enter, exist, or modify their operation in the PSN based on their individual needs. With each change the PSN recombines into a new form, in most cases evolving into higher safety fitness.

In 2004 DPSS decided to support an Ohio mobile radio initiative, Ohio MARCS (Multi-Agency Radio Communications Trunking System). As a result of the decision, MARCS, a statewide radio capability, is dependent on DPSS for providing services in Clermont County. In Clermont County DPSS provides the ICT infrastructure for MARCS. This voluntary action, by DPSS, to support MARCS, extends the capabilities of DPSS by ensuring their future compliance with the state systems and brings them additional funds from the state (for MARCS infrastructure support). DPSS is evolving and combining with Ohio state-wide safety initiatives.

CapWIN evolved by adopting a new governance structure, utilizing an Executive Leadership Council that allows for inputs from many diverse sources. This has lead to the evolution of the PSN into areas of cross-boundary data sharing and mechanisms for greater member representation. The willingness of the Executive Leadership Council to work through evolving priorities and political agendas introduced new schemata, and was key to the PSN's continuation and growth. Both

DPSS and CapWIN exhibit organizational evolution by introducing new agents or schemata and absorbing and recombining these changes into a modified structure.

Proposition 4: PSN member agencies are loosely coupled and can enter or exit the PSN at will. The PSN reacts to changes in membership by restructuring to maintain a high public safety fitness landscape. They are constantly evolving by restructuring through the recombination of agencies, resources and services.

5. Discussion

The application of complexity theory and complex adaptive systems theory to organizational studies has a history of doubts and anxiety regarding its applicability. There are many definitions of complexity and types of complexity theories [Manson 2001]. Some doubt whether there is a single complexity theory, theories or a framework and that the meanings given to the terminology associated with complexity are all problematic [Morel and Ramanujam 1999]. A major criticism of CAS theory has been that it is merely an extension of Weick's "sensemaking" [Weick 1993] and that complexity is just a new way of talking and believing about organizations and enacting a new metaphor for organizations [Lissack 1999].

We acknowledge these views but suggest a different interpretation that considers that CAS theory does not replace current thinking, research or theories on organizations but rather incorporates these theories when examining the process and attributes of organizational evolution. CAS theory provides the framework for organizational evolution and at each step different agency-based theories may apply. We believe this view is particularly suited to viewing PSNs as complex adaptive systems.

To illustrate, in 2008 DPSS embarked on a large project to upgrade their entire computer aided dispatch (CAD) system to a new system. Although they performed a detailed analysis of the system they were constrained by the fact that previous installations of the new system were at sites that were not as technically demanding as needed by DPSS. As a result when the system was installed it failed. After numerous attempts to fix the problems DPSS was forced, by member agencies, to re-install their old system and then acquire a different system (which was a success). In addition to the technical difficulties with the CAD system, the failure identified communications and resource deficiencies in DPSS that intensified the problem and eventually led to major changes in the DPSS organization.

From a CAS theory perspective this would be classified as a critical event for DPSS. The CAD failure created a drastic change in the fitness landscape for each individual DPSS agency (police, sheriff, fire) causing actions on their part to increase their efficiencies. One agency, at the periphery of the DPSS service geography switched to a different PSN and others become more engaged and vocal in county meetings demanding changes in the transparency of DPSS operations and structural changes in the PSN. With the successful installation of the new system DPSS also restructured making CAD a separate department (previously it had been part of emergency services) and hiring a new director. DPSS had experienced a critical event that caused changes to the PSN resulting (or recombining) into a system with

different members, a new structure, and different interactions (enhanced presence of agents at county meetings).

Although CAS theory provides a very valid means for analyzing the DPSS CAD system event one could also apply other organizational theories. For example rational choice theories would explain the decision of DPSS to upgrade their CAD system based on increasing efficiencies and effectiveness of CAD operations. Contingency theory would help explain the how the flawed system could be chosen because the environment imposed certain constraints on DPSS CAD analysis techniques. Stakeholder theory would apply to the reaction of the member agencies and their actions to become vocal and active members of county planning meetings. One could also view the resulting restructuring of DPSS from a network theory perspective as a valid solution because it increased the linkages (by creating a separate CAD department and director) between DPSS and its member agencies. As such we see a confluence of organizational theories explaining this PSN event.

Our contention is to view CAS theory and other organizational theories as complementary when applied to PSNs. Other organizational theories apply when we consider the PSN context as fixed or constrained, at the agency level, which we do by examining single events or small time spans for PSN evolution. CAS theory is required for system level analysis.

We see similarities in our analysis to the work of Meyer, Gaba, and Colwell [Meyer, et al. 2005] in their analysis of Nanotech Alliance Network. Their study of the network of nanotech start-ups and investment firms parallels our description of the PSN as a network of public safety agencies. During the process of organizing the network, organizational theories such as resource dependency, contingency, institutionalism, rational choice, and stakeholder theories would aptly apply but from the "world" view CAS theory is more appropriate. Once organized the evolution of the network, similar to a PSN, exhibits the characteristics of a CAS; agents with schemata, self-organizing networks sustained by importing energy, coevolution to the edge of chaos and recombination and system evolution.

Characterization of PSNs as a type of CAS is also very similar, and supported by economic research on poly-centric systems. Through a series of studies culminating in her Nobel Lecture, Elinor Ostrom notes the necessity to view public industries as "poly-centric", with many centers of decision making and under a chaotic hierarchy. She concludes that problem solving and decision making is much more complex than predicted by rational choice theory. As she states, "to explain the world of interactions and outcomes occurring at multiple levels, we also have to be willing to deal with complexity instead of rejecting it" [Ostrom 2010].

6. Conclusion and Areas for Future Research

Through the application of the concepts of complexity theory we have shown that PSNs (and specifically by empirical analysis of two U.S. PSNs) can be considered a type of CAS. Two important contributions result, first, extending and opening new avenues for theoretical exploration of public administration and services as complex

systems and, second, increasing efficiencies and effectiveness of PSNs by applying CAS knowledge to the public safety domain.

More specifically we see opportunities to tie PSN research to poly-centric systems in the larger domain of public safety [Parks and Ostrom 1999]. We also see potential applications of agent-based modeling and simulation since PSNs consist of autonomous, interconnected agents exhibited by agent-based systems [Bonabeau, et al. 2003, Cardellini, et al. 2007, Bulleit and Drewek 2005].

There are also opportunities to extend current research on CASs in public administration to include PSNs. Public administration researchers acknowledge the need for additional research cases [Rhodes and MacKechnie 2003, Rhodes, Murphy, Muir and Murray 2011]. Additionally we see application of PSN research to extend research in complex ICT enabled public sector shared services organizations [Ulbrich 2005, Borman 2010, Frank 2010, Janssen and Wagenaar 2003]. We see PSNs research as not only a means to extend and further develop public service CAS and public safety theory but also, in practice, to improve public safety. As such, we conclude with practical considerations for PSN managers based on CAS theory.

7. Practical Application of CAS Theory to PSNs

We have shown that PSNs face problems that are both difficult to define and resistant to solution such that we refer to them as "wicked problems" [Rittel and Webber 1973, Churchman 1967]. We conclude by illustrating how PSN problems face "wicked problems" and suggest practical considerations for PSN managers based on the view of PSNs as complex adaptive systems.

In Table 1 we list each characteristic of "wicked problems" [Rittel and Webber 1973] and suggest actions for the PSN manager to mitigate these problems. As we have stated, these problems may appear unsolvable but we believe that public safety managers, by addressing and understanding the complexities of the problems encountered by PSNs can adapt and change their organizations and ultimately increase public safety.

"Wicked Problem" Characteristic	Practical Application
There is no definitive formulation of a wicked problem	There are no criteria for sufficient understanding of the problem and no end to the causal chains. Continuous learning by the PSN manager and organization is required. New problems and challenges will always exist.
Wicked problems have no stopping rule	PSN metrics are valuable to track changes and improvements. The rate of change and direction of change in established metrics is the most important criteria for measuring PSN success.
Solutions to wicked problems are not true-or-false, but good-or-bad	Communications within the PSN is key to the PSN manager. Always seek information on how the PSN is perceived. Never be dismissive to negative (or positive) opinion on the PSN.
There is no immediate	The consequences of a proposed solution cannot be appraised

and no ultimate test of a solution to a wicked problem	until all the repercussions from the solution subside. Every action and plan must be looked at from the long-term perspective and its impact on the PSN as a whole and on the member agencies.
There is no opportunity to learn by trial-and-error, every attempt counts significantly	The PSN has a memory component such that successes and failure will remain for a long time. Successes will create inertia to change and failures will impact the perceived competency of the PSN managers. Operational transparency to the member agencies is needed so that they understand why change is needed and why sometime things do not go as planned.
Wicked problems do not have any set of potential solutions,	Plans of action rely on realistic judgment and on the amount of trust and credibility between the PSN manager and agency managers. One way to build trust is to incorporate agency managers into PSN solutions. Change and action must be seen as a team effort, since any change will impact all agents.
Every wicked problem is essentially unique	Despite long lists of similarities between a current problem and a previous one, there always might be additional distinguishing properties of overriding importance. Therefore the PSN is most susceptible to a major problem when managers are of the opinion the PSN is stable and running well.
Every wicked problem can be considered to be a symptom of another problem	Every PSN change will have positive and negative impacts to the PSN and member agencies. A realistic and honest assessment of the impacts must be made. Once the change is made search for unplanned or unintended consequences.
A discrepancy can be explained in numerous ways. The explanation determines the nature of the problem's resolution	Agencies take action to improve their individual fitness without regard to the PSN as a whole. If the PSN becomes the central point for all change and focus of all complaints then the PSN is no longer operating as a CAS. PSN managers need to resist the urge to "run the show" by getting all agency managers working tougher through regular meeting and communications.
The planner has no right to be wrong	PSN managers are liable for the consequences of the actions they generate. Learn from mistakes and celebrate successes.

Table 1: Practical Considerations for PSN Managers

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