Examining Hazard Governance from a

Complex Systems Perspective

by

Joshua Michael Uebelherr

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved May 2017 by the
Graduate Supervisory Committee

Erik Johnston, Chair
Karen Mossberger
Brian Gerber
David Hondula

ARIZONA STATE UNIVERSITY

August 2017

ABSTRACT

The Maricopa County Heat Relief Network (HRN) is an ad-hoc partially self-organized network with some attributes of hierarchical coordination that forms each year to provide heat relief and hydration to residents in need by operating as cooling centers. These HRN organizations are a collection of non-profit, governmental and religious organizations. This dissertation looks at the HRN from a complexity governance perspective and engaged different parts of the network in interviews to learn more about their perspective in delivering heat relief. Further, participatory modeling with a prototype agent based model was done with the HRN coordinating agencies to look for emergent outcomes in the HRN system and learn from their perspective. Chapter one evaluates organizational theory and complexity with climate adaptation, hazard preparedness and resilience in the HRN. Chapter two presents results from interviews with HRN facility managers and evaluates their perspective on how they function to offer heat relief. Chapter three finds that the HRN is a good example of complexity governance when engaged through a participatory agent based modeling approach. Chapter four engages the HRN coordinators in participatory agent based modeling interviews to increase their systems level awareness, learn about their perspective on heat relief delivery, and how the system can be improved. Chapter five looks across the different levels of the HRN investigated, the facility managers and coordinators, for differences and similarities in perspectives. The research conducted in this dissertation shows different levels of systems awareness of the different parts of the HRN and how participatory modeling can be used to increase systems awareness. Results indicate that

there was very little horizontal network connection between HRN facility managers and most of the interaction was vertically coordinated indicating opportunities for increased network communication in the future both horizontally and vertically if communication interventions were put in place.

DEDICATION

This dissertation is dedicated to God, my wife and children, and my parents.

ACKNOWLEDGMENTS

I would like to thank my committee chair Dr. Erik Johnston for his leadership and hard work in mentoring me through my Ph.D. A great thank you goes to Dr. David Hondula whose long hours of work reviewing draft chapters carried me through to the end under tight deadlines. I would also like to express my gratitude to other committee members, Dr. Karen Mossberger and Dr. Brian Gerber, for their hard work and guidance in support of the dissertation.

A great thank you goes to my parents for their years of support that has taken me this far. A special thank you goes to my wife Beth and three children, Morgan, Kallin and Payton, for their constant support in this journey. Thank you all for your sacrifice and love. Finally, I have a great deal of appreciation for all of the research participants who gave of their time in support of this research through interviews and participatory modeling.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

ORGANIZATIONS AS COMPLEX

SYSTEMS IN A CLIMATE CHANGE CONTEXT

Introduction

People in Arizona die of heat every year, and it is almost always avoidable given sufficient access to water and cool space. The motivation of this dissertation is to learn how institutions in non-centralized organizations can help save people's lives under different governance arrangements other than vertically integrated hierarchy, and how reducing heat health risk can be improved. Two basic questions being investigated in this dissertation are: **(1)** How are people that are part of the HRN aware of where they are within the overall system? And, **(2)** once they are aware of their position within the system, how do they respond? The common thread that binds all of the chapters together are efforts to understand the HRN governance in the larger context issue of climate change adaptation that affects heat health risk.

This public administration PhD dissertation investigates how self-organization of different types of resources are used to address multi-jurisdictional challenges within a governance network. The dissertation investigates the organizational arrangements surrounding an ad-hoc network of organizations that volunteer each year to serve as cooling centers by providing cool space and hydration to those with heat health risk in Maricopa County, Arizona — known as the Heat Relief Network (HRN). The case

studied here is interesting because it is a network of voluntary organizations that choose to participate each year through a self-selecting process, hence it is an emergent feature of governance that cannot be predicted precisely before-hand. It is this emergent feature that cannot be predicted in advance that characterizes complex systems, and complexity governance when applied to appropriate governance cases. This is a study of heat relief efforts from a public administration and policy standpoint that intersects with the chronic environmental heat hazard in Maricopa County. These heat risks are substantial and include regular exceedances of over 100° F from May through September (Harlan et al., 2014a) and several National Weather Service extreme heat warnings issued each year.

The underlying approach for this dissertation is to examine how to allow for the self-organization of different types of resources to address multi-jurisdictional challenges. The effort to reduce heat related death and illness in the greater Phoenix, AZ area is the restricted case applied here through which we seek better understanding of different levels of network governance and the role of two different levels of the system. The overarching lens that this system is viewed through a complex systems framework, where system attributes of self-organizing governance activities in the HRN recur on an annual time-scale to reduce heat related mortality and morbidity. The HRN is a network of cooling centers that offer people hydration and cool space to seek refuge from extreme heat outdoors. This first chapter reviews organizational theory relevant to learning in a changing environment, how organization perceive and process information, and the importance of organizational culture. Then the importance of climate change and urbanization is explained in context of climate adaptation to increased extreme heat health risk in the future, along with a discussion of hazard preparedness and resilience in

Maricopa County. This chapter then concludes by giving a detailed introduction to the HRN in Maricopa County.

Organizational theory has a great deal to offer with regard to how organizations perceive changes in their environment, exhibit distributed cognition, and react to changes in the environment as a consequence of learning (Hedberg, 1981; Yih-Tong Sun & Scott, 2005). Such learning is an important aspect of how organizations change and adapt over time, sometimes rapidly but more often changes are incremental. The organizational theory described below uses concepts from general systems theory (Boulding, 1956) to frame organizations, and subsequently reviews different conceptions of how organizations perceive, learn and change over time, as well as the importance of organizational culture (Fiol & Lyles, 1985) and climate (Schneider, Brief, & Guzzo, 1996). Much of the discussion centers on concepts of organizational learning and extended examples of learning on a larger scale across multiple organizations. This is important because the cooling centers that are the focus case of this dissertation are embedded within layers of organizations that persist, learn, and change over time. Hence concepts of how organizations learn, perceive and change are central to understanding how these cooling centers adapt over time to the health challenges they work to mitigate. Institutional adaptation to climate change and urbanization occurs through organizations, so it is critical to understand how organizations function and learn as they adapt in a changing environment. Importantly, this investigation is interested in the perspectives of the different organizations within this system to better understand their constraints and decision making.

There are many factors of climate adaptation and hazard preparedness that come together to affect heat health risk that is covered in a subsequent section, and is introduced briefly here. These factors include increased temperature from climate change, and regional temperature increases due to urbanization that are expected to increase. This is in addition to the increasing total population in urban areas and an aging population as well. Hence many studies show future increases with anticipated climate and urbanization change, although past observation shows reduction in heat health mortality with time, leading to some potentially conflicting results (Hondula, Balling, Vanos, & Georgescu, 2015). It seems that large scale adaptation such as air conditioning use, or local institutional or individual behavior can all have effects on reducing vulnerability to extreme heat health risk (O'Neill et al., 2010). Hence the ability to adapt is a critical aspect to learn about to understand how the HRN cooling centers function. Importantly, small scale factors such as cooling centers among other interventions, were shown to have finer scale impact on heat health reduction (Lissner, Holsten, Walther, & Kropp, 2012; O'Neill et al., 2010; Schifano et al., 2012) and should be investigated to learn about successful characteristics and challenges. The hazard preparedness literature suggests cyclical planning cycles for institutions that experience a natural hazard such as extreme heat, which includes organizations learning in such cycles. This is an iterative process of resilience that is defined in terms of a process of continual learning as related to natural hazards (Cutter et al., 2008). The Maricopa HRN cooling centers are then placed within a resilience context to better help understand the unique environment and socioeconomic factors that contribute to heat health risk. Maricopa County has many positive attributes such as the HRN for mitigating heat health risk, but overall capacity

for resilience is hindered by a relative lack of social cohesion, driven in part by historical neighborhood segregation (Harlan, Declet-Barreto, Stefanov, & Petitti, 2013; Virginia G. Piper Charitable Trust, 2016). Hence there are many layers to fine scale heat health risk as well as many potential opportunities to reduce this risk with interventions that are tailored to this scale.

The Maricopa HRN is a collection of organizations that volunteer annually to open their space as either cooling centers or hydration stations where respective cool space and water were given to reduce heat health risk. The majority of facilities had cool space to offer and so the term cooling centers will be used from this point forward to refer to the entire network of cooling centers and hydration stations for simplicity. The HRN originally formed after several deaths among the homeless in a short period of time in 2005, and has been operating annually since. These volunteer HRN organizations include senior centers, parks and recreation facilities, poor and homeless services, and religious ministries among others. This is a highly diverse set of organizations that offer heat relief for a variety of reasons, but often because their primary clients are at risk to extreme heat, and so being part of the HRN makes sense to serve their clients and others (Berisha et al., 2017). The central network of the HRN is represented by the public health agencies that come together to work on heat health risk reduction by doing work in several areas. For example, the Maricopa Association of Governments (MAG) and the City of Phoenix lead the coordination of the HRN formation each year and produce the maps and schedules that each cooling center is open. The Maricopa County Department of Public Health, Arizona Department of Health Services, and University researchers coordinate sharing of data and collaboration with the HRN coordinators to track

outcomes for heat associated deaths and propose collaborative solutions to reduce risk. The relevant aspect of the HRN is that although there is some central authority that helps coordinate and aggregate the cooling center maps, they are loosely coordinated in that individual centers self-selects each year to participate and sets their own open-hours of operation. This means that the spatial and temporal pattern of cooling center availability differs from year to year according to who participates, although most cooling centers do return each year as they continue to serve the community. It is this emergent feature of the HRN that makes it a good candidate for a complexity governance approach, viewing the system through a complex systems lens.

The dissertation is organized into five chapters. This first chapter introduces concepts of organizational learning theory, concepts of climate adaptation, and introduces the Maricopa County HRN in more detail. The second chapter explores perspectives of cooling center managers in the HRN through case study semi-structured interviews with 16 different facility managers. The idea is to learn about the manager's perspective on serving those in need of heat relief through qualitative analysis of recorded interviews. This includes how they articulate their role, frame their responsibilities and articulate awareness of the rest of the system, among other research questions of interest. Chapter three investigates how the HRN fits in with the concept of complexity governance and details development of a prototype agent based model of the HRN for use in later participatory modeling. The approach is designed to use a complex systems lens to build the system from the bottom-up to capture the emergent features of individual decision making within the HRN system. The fourth chapter engages the coordinating public health agencies of the HRN in participatory modeling exercises using the prototype

model, totaling three open-ended interviews and one focus group with recorded interactions analyzed qualitatively. The goal of these interviews is to learn what problems they think are important for improving the HRN, and how those problems could be addressed in the modeling framework. Similar to the questions asked in chapter two, the fourth chapter research questions include, among others, how those public health related organizations articulate their role in mitigating heat health risk, frame their responsibilities, and articulate their awareness to the rest of the system. Chapter five is an integrative concluding chapter that looks at the how the results from the first four chapters sum together to yield a larger picture of understanding.

Organizational Theory and Complexity

Organizational theory tells us about how organizations learn in a potentially changing environment. There is a critical difference between how individuals and organizations learn, so it is useful to review organizational theory surrounding how organizations perceive and learn. Organizational culture and the climate it produces has critical implications for how organizations function and learn over time. This is an appropriate framework for the rest of the dissertation because the research looks at different points of view of members of different organizations. Also consider that climate change and urbanization are slowly changing in the backdrop of HRN cooling center activities. Hence organizational learning takes place in a complex environment with other actors, such as is the case with the HRN. Hence looking at the HRN from an

organizational theory complexity perspective is appropriate since the HRN exists as an embedded complex system within a larger system of governance.

Resilience trade-offs and complexity. There has been a great deal of change in the concept of how organizations learn over the last several decades. Public service delivery is increasingly a partnership of public and private organizations (Brinkerhoff & Brinkerhoff, 2011) to meet the needs of increasing urban populations (Koppenjan & Enserink, 2009). Challenges like adaptation to increasing frequency and intensity of severe weather events are met largely through organizational infrastructure. This includes both hard infrastructure (i.e. water lines) and soft infrastructure such as policies and rules-in-use (Anderies & Janssen, 2013). Policy implementation is achieved by setting system rules and deploying resources across organizations, historically hierarchically imposed but less so in the modern network governance era (Koliba, Zia, & Lee, 2011). Such organizational coupled infrastructure systems (CIS, hard and soft infrastructure) are the means to more resilient social systems (Anderies, 2015). Resilience is, "… a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." (Holling, 1973, p. 14) Robustness is, "the maintenance of some desired system characteristics despite fluctuations in the behavior of its component parts or its environment" (Carlson & Doyle, 2002). There are almost always trade-offs between system performance and resilience, and there is often no single best choice of multiple possible combinations of such trade-offs (Anderies, Janssen, & Ostrom, 2004). A simple example is adding armor to a military vehicle, it increases resilience against enemy fire but decreases vehicle range due to extra weight – there are always trade-offs. Despite the

technical challenges and normative choices at hand, it is critical that organizations find ways to adapt and public policy to evolve to deliver public services in a rapidly changing environment.

It is useful to identify the current state of knowledge and overall theories that pertain to organizational change barriers, as well as establish definitions for relevant concepts. Understanding how to reduce barriers to organizational learning in an increasingly variable environment increases social resilience by allowing choice of the appropriate economic trade-off between the efficiency of organizational output and adaptive measures that increase resilience of infrastructure systems – once again a trade-off between system performance and resilience. Implications are relevant to both public and private organizations. The level of organizational learning related to infrastructure and pace of implementation of adaptation measures can be supported or hindered depending on whether barriers to organizational learning are present. This underscores the importance of evaluating barriers in the learning cycles of organizations in the context of climate change, one of the greatest collective action challenges of the 21st century.

Boulding (1956) described nine levels of organization in general systems theory: (1) static structures (i.e. electrons orbiting a nucleus), (2) simple dynamic systems like a clock, (3) cybernetic control system such as a thermostat, (4) open self-sustaining systems like cells, (5) genetic societal level such as plants, (6) animal genetic social level, (7) individual human level, (8) human social organizations, and (9) transcendental systems. These delineations to some extent represent the perspectives of the mid-20th century, particularly the separate levels of plants, animals and humans. It is useful to think more holistically about assemblages of different organisms within the environment

as ecosystems when considering socio-ecological systems (SES) (*sensu* Anderies et al., 2004). This larger context of human social systems is that it represents the final concrete level of Boulding's (1956) system organization that is built upon multiple nested levels of subsystems; atoms, cells, and organisms are the component scale for human elements of organizations. After all, natural capital is one of the primary inputs for macro-economic systems. From this perspective, it makes sense to approach barriers to organizational learning and adaptation using a complex systems perspective based on general systems theory. At the same time, there is a substantial extant literature to be considered that can provide the content within such a framework.

Non-profit and governance organizations operate under resource constraints where resource input must be exceeded by the value of organization output to retain a positive social benefit to cost ratio. Hence in a world of limited resources bounded rational (adaptive rational behavior) decision making (Simon, 1956), tempered by elements of behavioral game theory applied to economics (Camerer, Loewenstein, & Rabin, 2004; Camerer & Malmendier, 2004), one would anticipate decisions that support organizational output which creates the most social value. Of course, this conception is idealized as there are no perfectly functioning markets where perfect information is available to participants (full disclosure) and there are no market externalities (i.g. carbon dioxide pollution cost of fossil fuels). Hence the ability of an organization to learn and adapt is of critical importance for its continued existence by ensuring social value of output exceeds resource input costs, as social values and environmental constraints change over time.

The present research advances the understanding of the soft infrastructure that the HRN employs, i.e. the rules in use, policies and practices implemented on the ground. There are always trade-offs to be made when choosing system performance and resilience, there are not cost free solutions that create resilience in every dimension. Likewise, the HRN cooling centers must make trade-off decisions for example providing heat relief or extending services to their traditional clientele. These organizations generally exist in a world of very limited resources and so this dissertation research can tell us how the HRN operates under resource constraints.

Organization distributed cognition and environment mapping. Cognition and learning within organizations has been described as, "The cognitive system is a combination of beliefs, attitudes, values, opinions, presumptions, and memories that governs the way meaning is provided" (Yih-Tong Sun & Scott, 2005). The definition from organizational theory used here is: organizational learning is knowledge and insight development as well as the relationship between past actions, their effectiveness and the course of future action; organizational adaptation is through incremental changes based on environmental variation and shifting goals (Fiol & Lyles, 1985). Knowledge is "meaning made by the mind", where unorganized information is processed and assigned normative value by cognitive structures (Marakas, 1999). In an organizational context with multiple individuals one could say that knowledge creates new knowledge only when it is shared (*cf* Yih-Tong Sun & Scott, 2005). These definitions are helpful because they separate the cognitive aspect from behavior change itself. This is an important distinction, as not all organizational change is the result of learning. There must be an

understanding of the connection between organization change in action, and resulting organizational output change to be organizational learning.

The development of organizational theory over time is discussed below keeping in mind the above distinctions and the perspective that organizations are extensions of biologic systems and operate under the similar constraints from the environment. There is similarity between cognition in individual and in organizations, where cognition and memories occurs across individuals within an organization (Lazlo, 1972). Such information processing in organizations is subject to distortion, filtering, and insufficient band-width. This can lead to outcomes where the larger organization theories of action as a whole may not have as much knowledge as the most informed sub-group (Argyris & Schön, 1978). Such theories of action, also known as myths or sagas, are to organizations as cognitive structures are to individuals (Hedberg, 1981). The current exponential increase in digital information poses risks of organizations missing critical information because it is obscured among disparate data sources, or overwhelmed by sheer volume of data. Three central means to deal with large volumes of data include communication strategy, organization structure, and technology (Daft & Huber, 1987). Decentralization along with distributed management can also reduce cognitive information overload, and "… can improve the quality of upward communications, and can stimulate innovation and learning" (Hedberg, 1981).

One aspect of cognition in organizations is that cognitive processes occur at the individual level unevenly across organizations, as information diffuses differentially through or across organizations. Information needed to solve relevant organizational challenges may not reach the organizational level with the greatest capacity for a

particular task (Daft & Huber, 1987). In addition, the exponential increase in information generated by organizations and the environment which can overwhelm individual cognitive capacity. As a result, organizations have developed strategies for message routing and summarizing to help increase communication efficacy. Information uncertainty generally increases with information quantity but can be aided by development of a systems-structural perspective (logistical, structural, and message routing) and interpretive perspective (interpretive, symbolic, message summarizing). "To fully understand organizational learning, one must view the organization as a structure both for acquiring and distributing data and for interpreting and sharing meaning." (Daft & Huber, 1987)

Organizations can choose to invest more or less resource into mapping and trying to understand an ambiguous environment, or learning. In a stable environment from which the organization has learned and successfully adapted, spending resources on learning more about the surrounding environment may not be as productive as directing resources to operations. Stabilizing current organizational strategies is rewarded in a more slowly changing environment once the optimal operational strategies have been learned for organization output in a given environment. In this sense defensive routines of organizations should not be necessarily seen as negative, but rather as reinforcing the status quo through single loop learning (Diamond, 2008). However, as organizations transition through time to environments that they are not historically adapted to work in, investing resource in learning about environmental factors that constrain the organization's output can be more productive than investing in current strategies. New knowledge is created through organizational learning in a practical sense when a, "…

cognitive system becomes re-defined so that belief, values, attitudes, and assumptions are altered, potentially altering individuals' behavior" (Schimmel & Muntslag, 2009). Such a shift across a group of individuals is related to organizational culture, an attribute that does not exist at the individual level.

The relationship between integrative organizational cognitive map complexity and environmental complexity is one with a high degree of correspondence between the two for low levels of complexity, decreasing as environmental complexity increases (Hedberg, 1981). At high levels of environmental complexity, the capacity of the mind to map the phenomenon is exceeded, beyond which heuristic approximations of "reality" are increasingly relied upon. The case of climate change is an extreme example where the complexity of the systems exceeds the ability of even the most sophisticated computer models cannot fully replicate and therefore predict. How can organizations and governance systems best address these policy challenges that exceed easy ability to understand by even the most dedicated experts? Solutions are likely to reside in overcoming barriers to organizational learning, and the aggregate social learning across institutions that informs public policy and governance. "To learn, unlearn, and relearn is the organizational walk: development comes to an end when one of these legs is missing" (Hedberg, 1981). The early learning cycle envisioned by Cyert & March (1963) was organizations existing in number of different potential alternative states, with some states more preferable to others at any given time given uncontrollable external environmental shocks. The learning cycle conceived by March & Olsen (1976) is a four stage loop where the stages are individual beliefs, individual action, organizational action, and

environmental response. This learning cycle is less complex than more recent cycles of learning, but does have the basic elements of aggregating individual to collective action.

There are cognitive limitations that can distort an organization's interpretation of information due to ambiguity that can impede learning cycles. Four types of incomplete learning cycles were conceived by March & Olsen (1976): 1) role-constrained learning (individual action and belief decoupling), 2) audience learning (individual and organizational action decoupled), 3) superstitious learning (individual and environmental response coupling ambiguous), and 4) incomplete learning cycles (individual beliefs and environmental response coupling problematic). A review of the organizational learning literature by Shirvastava (1983) was divided into four categories adaptive learning, assumption sharing, development of knowledge, and institutional experience. Fiol & Lyles (1985) provides four main contextual factors that affect probability of organizational learning: organizational culture, strategic posture, structure for learning (not mechanistic but adaptive), and internal and external organizational environment. Despite extensive organizational research, ". . . [m]ost knowledge of barriers to and incentives for change is not derived from well-designed prospective studies, but rather from observational studies and theoretical reflections … we still lack the information on how to effectively tailor interventions to produce [organizational] change" (Grol & Wensing, 2004). Barriers to learning show up in case studies with many forms which is why there is so much variance in the organizational literature case studies.

The research in this dissertation advances the concept of these theories by looking at distributed cognition of the HRN across the facility managers and coordinators to see their different perspectives on heat relief which is at the inter-organizational scale (Yih-

15

Tong Sun & Scott, 2005). This research also looks at different aspects of communication

in the HRN which relates to organizational theory on information transfer and potential

overload. This begs the question, are there any examples of structures or processes that

aid in organizational message routing and summarizing? The current research also

advances the idea of whether the HRN appears to exist in a changing or static

environment, and so determines whether there would be a large benefit in investing in

additional mapping of the environment an organization exists within.

      Organizational culture and climate. There are similarities between individuals

and organizations in terms of distributed cognition, collective mental maps – yet there is

something to organizations that makes them more than the sum of individual members.

Social climates have been shown to change individual behavior (Lewin, Lippitt, & White,

1939) and organizational climate can affect worker motivation (McGregor, 1957).

Bouldings (1956) penultimate organizational level as mentioned previously, before

transcendental, is human-social where organizations operate. Human-social systems,

including organizations, have the element of culture that is an emergent feature of that

level of organization that cannot necessarily be predicted from the sum of its parts. What

is it that sets social culture apart from the individual? Maslow's hierarchy of needs

(Maslow, 1943) explains in part why gains in salary beyond upper middle income satisfy

status within social culture, rather than meeting additional basic individual human needs.

This is an example of human-social organizational level competition within a cultural

context. Schneider, Brief, & Guzzo (1996) describe four key organizational climate

dimensions: 1) nature of interpersonal relationships, 2) nature of the hierarchy, 3) nature

of work, and 4) focus of support and rewards. "… [W]hat people in an organization

experience as the climate and believe is the culture ultimately determines whether sustained change is accomplished." (Schneider et al., 1996).

The cultural perspective for organizational learning encompasses factors that affect how individuals interact as a collective, normative values, and leadership among others. A theoretical consideration is that most research on organizational learning has focused on how individuals learn in an organizational context, or how theories of individual learning could be applied to organizations (S. D. N. Cook & Yanow, 2011). Yet from the discussion above it is clear that organizations have features that are not found at the individual level, which underscores the importance of considering organizational culture when considering organizational learning. There is a fine distinction between individuals learning *in* organizations, and learning *by* organizations, where the former does not directly change organizational culture whereas the latter does.

The culture of an organization should be considered though a wider view of how organizations function internally and interact with the external environment suggests there is more to consider. Yih-Tong Sun & Scott (2005) point to four different levels that learning relevant to organizations takes place: individual level, team, organization, and inter-organization. Organizational culture, and the climate it creates, is important at all four of these levels. The effects of culture are different for an individual versus an inter-organizational scale. Teams represent the smallest organizational collective level where individuals learn through dialogue, inquiry, and advocacy. Organizational sub-units, such as teams, must transfer new knowledge to the wider organization to spur learning at the entire organization level. This new knowledge is transferred and alters the organization's

assumptions and beliefs that result in a shift in perspective, procedures, and system design (Yih-Tong Sun & Scott, 2005).

There are different tiers of organizational climate beyond the individual level, such as team, organizational and inter-organizational climate that overlap differentially and interact to contribute to overall culture. In a team setting, individual normative adherence can occur due to not feeling that the climate is safe to express their true opinions; this can contribute to situations of insular thinking and group-think (Janis & Mann, 1977). Time and information are limited and managerial work fragmented (Mintzberg, 1973). The more critical decisions are, the more important creative solutions and dissenting opinions become. Team climate and leadership has been known to influence how individuals interact, such as democratic, authoritarian or laissez-faire (Lewin et al., 1939). Other important barriers from the individual to team level include personality differences, communication skill, confidence in other team members, divergent or hidden agendas, hostile learning environment, as well as fear of loss of ownership, knowledge control, and competitive edge (Yih-Tong Sun & Scott, 2005). Inter-organizational information exchange occurs through strategic alliances that allows learning and improves organizational output, while unintended information sharing can lead to reduction in core competencies (Yih-Tong Sun & Scott, 2005).

The current research advances our understanding of these theories by looking at the culture and climate in different organizations through their responses to interviews. The culture and climate it creates in an organization determines whether sustained change or learning takes place, and the research presented here gives an idea of HRN culture and climate based on interviewee response. The cultural aspect of an HRN member has a lot

to do with the motivation of an organization to be a cooling center in the first place. Such self-selection to be a cooling center in the first place says a lot about the motivation of an organization and the climate it produces related to serving those in need. Interviews with HRN facility managers also gives an understanding of the type of leadership being exhibited in the different cooling centers. The current research also seeks to understand how communication and coordination in the HRN could lead to strategic alliances to optimize service delivery of heat relief.

       Single and double loop learning. General systems theory provides basic tools to assess learning cycles in organizations using a single control loop comprised of a norm, measuring unit, comparator, and correction unit (Boulding, 1956). A thermostat is an example of such a cybernetic control loop, which can be translated to organizational single-loop learning by using the four variables above plus a fifth element of evaluation mechanism (Argyris & Schön, 1996; Schimmel & Muntslag, 2009). The type of organizational learning that includes meta-level learning where "norms, values and world views" (Hedberg, 1981) that define the single loop learning cycle (*cf* Cyert & March, 1963) are termed double loop learning (Argyris, 1976), or deutero learning (Bateson, 1972). Such a simple stimulus-response models of organizational learning consider this as a result of the experimental relation between learning and the environment, which suggests, "… that ideal learning conditions fall somewhere between the extremes of environmental stability and turbulence" (Hedberg, 1981). A stimulus-response model would be tantamount to single loop learning (positive assessment), while a second learning loop evaluates the comparator (normative assessment) in a cybernetic control loop (Boulding, 1956; Schimmel & Muntslag, 2009). Here we could say that the

thermostat represents an analogue to single loop learning, whereas the outer control loop to decide to change the set temperature of the thermostat by the user would be double loop learning.

Another way to consider organizations is from literature cases of barriers to organizational change, or learning barriers. A challenge with such an approach is that organizational learning barriers have a wide variety of forms and with different labels. A review of the literature on organizations by Schimmel & Muntslag (2009) categorized seven collective learning barriers: environmental structures, strategy, organizational culture, organizational structure, management, processes, and information systems. Organizational learning barriers often have the same cause, and conversely many learning barriers can have several causes; this is limited to the role of change agents which cannot directly affect learning barriers from the environment, organizational culture and structure (Schimmel & Muntslag, 2009). These authors also found that problems with single-loop learning always have the same problems with double-loop learning — that functioning single-loop learning cycle completion is requisite for any double-loop learning. There are several important types of barriers to organizational learning. One important learning barrier is the absence of feedback loops that can be caused by isolation of organizational structures, as well as information and communication restriction (Schimmel & Muntslag, 2009). "Apart from a lack of reliable input due to problems with single-loop learning, there are only two classes of learning barriers with regard to double loop learning: They are caused by either the absence of dialogue or the absence of [organizational] experiments." (Schimmel & Muntslag, 2009) Further, dialogue is often

the culprit in double-loop learning barriers since it is a requisite of experiments to foster organizational learning.

Examples of double-loop learning are rare because it requires that effective organizational single-loop learning mechanisms are properly functioning. Consider that defensive routines of organizations occur where errors are covered up and not brought to light to prevent embarrassment and protect one's position in the organization, hence management may not receive feedback for improvement (Argyris, 1992). Inability to complete strategic management cycles (i.e. lack of evaluation or implementation) not only prevents new learning, but also may inhibit unlearning behaviors that no longer serve organizational objectives (Hedberg, 1981). The distribution of information about a problem within an organization may not reach levels with the greatest ability to solve the problem (Daft & Huber, 1987). Inappropriate strategic scope can overlook parts of the environment that are relevant to organizational output, which can be related to limitations in individual cognition from information overload (Schimmel & Muntslag, 2009).

Importantly, more deep and lasting organizational learning goes beyond fine tuning the processes of single-loop learning; changes in cognition and attitude requires double-loop learning (Schimmel & Muntslag, 2009). The framework used by Schimmel & Muntslag (2009) follows the systems theory cybernetic control loop (Boulding, 1956) for single and double loop organizational learning (Argyris & Schön, 1996). This approach allows consideration of different organizational learning barrier locations within these learning cycles. Collective learning is achieved through understanding of how different actions impact organizational output under different environmental conditions. Unless a cause and effect understanding of how organizational output affects

is achieved, then organizational change itself does not constitute organizational learning. Often organizational learning manifests over time as improvements in internal mission, policies, and goals over time to match changes in the external environment. Policy change over time, at both the organizational and larger public policy scale, represent normative values asserted as prioritization of resource deployment, rules and regulations. Policy models that account for public policy change usually consider inter-organizational level and larger governance scales. While noting that organizational learning cycles are different than policy process learning, it is clear that organizational learning below the public policy scale is an important contribution to public policy change at larger scales and over long time-periods.

The interest in investigating the organizational theory on learning is related to wanting to understand how cooling centers in the Phoenix HRN learn and adapt as climate change, urbanization, population increase, and aging populations are expected to increase the relative heat health risk over time. Do these HRN cooling centers perceive the changes around them and respond through learning, or are they generally pushed to the limit of their resources generally making them able to only focus on daily operations? Do these organizations give any indication of single loop versus double loop learning? These and other research questions are to be addressed in subsequent data content chapters to learn more about the perspectives of the HRN from both cooling center managers and HRN coordinating public health agencies. The discussion now turns to climate adaptation, hazard preparedness, and resilience in Maricopa County.

The current research advances the understanding of the idea of first or second loop learning by specifically asking whether first or second loop learning type thinking is

occurring for the research questions asked of the interview data in chapters two and four. This helps give insight as to whether first loop learning or second loop learning is dominant, as we would expect based on the literature.

Climate Adaptation and Urbanization, Hazard Preparedness, and Resilience in Maricopa County

   Climate adaptation and urbanization. Individual heat health risk fits within a larger context in Maricopa County where regional climate forecasts indicate more frequent and intense heat waves in the southwest U.S. (Garfin et al., 2014) as well as increased urbanization that contributes to the urban heat island effect (Hondula, Georgescu, & Balling, 2014). These effects impact individual experience of extreme heat ranging from global to local decisions. This is because respective aggregate CO_2 emissions globally, and local urban development policy affect the attributes of climate change driven southwest U.S. mean temperature increase and changes to temperature due to urbanization. Hence it can be seen that there are multiple scales of interaction of heat health risk in Maricopa County.

   There has been a great deal of discussion of climate adaptation, with a substantial focus in the climate change (Huang et al., 2013; Knight-Lenihan, 2015; Murphy, 2014) and disaster literature (Alexander, 2013; Cutter et al., 2008; Djalante, Holley, Thomalla, & Carnegie, 2013). Different conceptions of adaptation to increase resilience exist, here we shall consider adaptation as a moving toward increased resilience and decreased vulnerability. "Vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of

capacity to adapt" (Adger, 2006, p. 268). Here resilience and vulnerability can be considered as an approximate inverse of one another.

There has been less heat illness due heat exposure, driven in part by climate change and urbanization, than there would be otherwise due to adaptation at the individual and social level — though not all scholars agree with this interpretation. There is little debate that anthropogenic emissions of greenhouse gasses are predicted to increase global average temperatures in the future (IPCC, 2013). Observations of warming due to climate change and urbanization indicate that there would have been more substantial increases in heat-related mortality and morbidity without concomitant increases in human adaptation to these changes in climate, "… via physiological, behavioral, infrastructural, and/or technological adaptation …" (Hondula et al., 2015) Here, a practical definition of adaptation will be used to refer to action that reduces health impact of extreme weather exposure or change in climate (Deschenes, 2014). The urban heat island is the effect where concrete in the cities retains heat into the evening hours and remains warmer than the surrounding country-side (Declet-Barreto, Brazel, Martin, Chow, & Harlan, 2012). Human ability to adapt to a changing climate and urban heat island effects has led to less heat related illness than would have been observed without this adaptive capacity, and is due in part to changes in attributes of some intervening aspects of an increased technologically advanced society, for example improved access to air conditioning and cool space during times of extreme heat.

The level of resilience in society is also a function of the nature and structure of the institutions and built environment that potentially provide refuge from extreme heat. Institutional interventions to reduce heat health risk can be important to reducing related

mortality and morbidity. An important consideration is that extreme heat related

mortality is a leading cause of weather related deaths in the U.S. (Berko, Ingram, Saha, &

Parker, 2014; Borden & Cutter, 2008). Hence understanding the ability of behavior,

technology and other aspects of human society to intervene between extreme weather and

human health risk is essential to know to understand the benefits of such intervention.

Risk is not evenly spread across all residents in the built environment, where social-

economic status contributes to increased risks. This heterogeneity of risk falls

disproportionately on, "… urban residents who are physiologically susceptible,

socioeconomically disadvantaged, and live in the most degraded environments." (Harlan

& Ruddell, 2011) These degraded environments could be devoid of green spaces to curb

the urban heat island effect, or in areas of poverty where some residents either do not

have access to air conditioning, or cannot afford to run it sufficiently to cool the living

space. Consider for example that more affluent higher income neighborhoods were more

likely than low income neighborhoods to have vegetation and greenspace to cool the

climate in a study of Phoenix, Arizona (Harlan et al., 2008). It has also been shown that

air conditioning penetration into the housing stock has been responsible for a large

majority of the reduction in hot day related fatalities in the U.S. since the 1960s (Barreca,

Clay, Deschenes, Greenstone, & Shapiro, 2016), while other studies disagree with this

conclusion (Bobb, Peng, Bell, & Dominici, 2014). Hence access to cool space has likely

had a large positive effect in reducing heat health risk, and such adaptation to anticipated

climate change temperature increases and urbanization are likely to reduce levels of heat

related mortality and morbidity (Deschenes, 2014).

The built environment and urban heat island effects interacts with heat waves to increase risk, but small scale social factors are also important. The human social aspects of the built urban environment are important because of the interaction and amplification between extreme temperature events like heat waves that interact with the built environment through the urban heat island effect for example. It has been reported that the total heat effect of urban heat islands and heat waves is expected to be greater than the sum of their individual impacts, bringing increased synergistic impact of heat waves to urban areas which is of concern due to anticipated increase in urban populations in the future (Li & Bou-Zeid, 2013). Indeed, acceleration of development of the built environment through increased urbanization suggests a future increase in heat related mortality risk (Burkart et al., 2014). Although large scale urbanization and global climate change induced temperature increases predict large scale increases in heat related mortality, it has been shown that small scale distribution of societal factors determines heat related health impacts on finer scales (Lissner et al., 2012). This means that detailed social, institutional, household and individual factors are important for determining fine scale heat health risk.

Individual and social level factors such as heat response plan intervention can help overcome large scale factors like climate change and urbanization. Despite urbanization and climate change effects to increase temperatures and heat wave frequency and intensity, there are examples of decreases in mortality over time due to different drivers. For example, a study of 16 cities from Italy showed a decrease in heat health risk among the elderly after a heat response plan intervention was implemented between the 1998-2002 and the 2006-2010 periods (Schifano et al., 2012). "Reasons

offered for the drivers of these declines include increasing availability of air conditioning, the introduction of heat warning systems, coordination of networks of cooling centers, increased healthcare expenditures, and broad-scale epidemiologic transition including life expectancy increases related to sensitivity to infectious disease." (Hondula et al., 2015, p. 146) In another instance it was found that community mobilization and public health campaigns contributed to a 49% decrease in emergency medical services used before and after the intervention for a 1995 compared to a 1999 heat wave in Milwaukee, Wisconsin (O'Neill et al., 2010). This indicates that social, institutional, and individual factors are important in determining the interaction between heat health risk and human populations.

Climate adaptation manifests in a variety of ways. This is because there are a variety of ways people experience vulnerability to extreme heat. "Determinants of vulnerability to heat-related health effects include: biomedical (underlying disease status); sociodemographic (income, age, race); and community (air- conditioning access, vegetation)." (O'Neill et al., 2010) Some examples of adaptation to extreme heat includes heat warning systems, improved weather forecasting, and emergency preparedness during extreme events (Harlan & Ruddell, 2011), individual level physiologic and behavioral adaptation, infrastructure and technology access such as air conditioning. Individual behavior could change activity structure of time allocated to certain activities to avoid extreme temperatures, or geographic mobility to areas with less extreme temperatures; larger scale infrastructure adaptation includes broader systems of communication, healthcare and the built environment (Hondula et al., 2015). In these examples, there are institutional level adaptations that help inform the public about risk, and individual level adaptation choices that could be the result of hearing a warning or

simply knowing it was excessively hot outside. Other drivers of adaptation could be socioeconomic and technologic, where ability to afford air conditioning could reduce heat health risk.

The discrepancy between observed past reductions in heat related mortality, and predicted future increases can be resolved in part by better studying adaptation measures. There are relatively few projection studies that incorporate adaptation into forecasts of future heat related mortality with increase in temperature anticipated from climate change (Deschenes, 2014). This lack of ability for most predictions models to incorporate adaptation explains in part why there has been an observed decrease in heat related mortality over the last several decades in the U.S., while the prediction models themselves generally forecast an increase in heat related mortality with increased mean temperature and urbanization (Hondula et al., 2015). Resolving this discrepancy will likely include further detailed studies of climate adaptation measures to better understand the mitigating effect they can have on heat related mortality, improve understanding of best practices for adaptation, and improve model forecast of future increases in heat related mortality and morbidity. The discussion now turns to a brief overview of natural hazards and vulnerability.

Natural hazard preparedness. Natural hazards in the U.S. cause hundreds of deaths each year, with a study of U.S. mortality from natural hazards showing that everyday severe weather and heat as the greatest source of mortality (Borden & Cutter, 2008). "It is not obvious what leads to resilience within coupled human–environment systems or what variables should be utilized to measure it. Because of the multidimensional nature of resilience and its different component parts, a broad model of

28

resilience has yet to be empirically tested at the community level." (Borden & Cutter, 2008, p. 601) For this reason, among others, any discussion about climate adaptation would be incomplete without including the critical aspect of resilience to natural disasters. The natural hazards literature offers an important perspective. Resilience is the ability of social systems to respond and recover from natural disasters, impact absorption and coping mechanisms – including post-disaster adaptive processes for "social system to re-organize, change, and learn in response to a threat" (Cutter et al., 2008, p. 599). Holling (1973, p. 14), as mentioned earlier, described resilience as a "measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." Vulnerability on the other hand describes pre-event conditions of social systems for potential harm as a function of risk exposure (Adger, 2006). Adaptive capacity is defined here as "the ability of a system to adjust to change, moderate the effects, and cope with a disturbance" (Borden & Cutter, 2008). This description is the same type of cyclical learning process in organizations.

There are various perspectives that could be taken from many different types of vulnerability assessment. Four main common elements were 1) approaching vulnerability from a SES perspective, 2) importance of place based studies, 3) vulnerability conceived as a human rights issue, 4) pre-impact hazard mitigation planning based on vulnerability assessment for determination of hazard zones (Borden & Cutter, 2008). Use of SES framework for vulnerability assessment is consistent with approaches discussed in previous sections. The Disaster Resilience of Place (DROP) model has similar system learning feedbacks of short and long-term SES processes that are analogous to single-

loop and double-loop learning in organizations (Cutter et al., 2008). This approach

considers the built environment along with ecosystems and governance, and can be

applied to acute or chronic natural disasters. Importantly, "[p]rocess-related resilience is

defined more in terms of *continual learning* [emphasis added] and taking responsibility

for making better decisions to improve the capacity to handle hazards" (Cutter et al.,

2008). Moser & Ekstrom (2010) considered a framework to diagnose barriers to climate

change adaptation, adopting the SES perspective. Managing, understanding and planning

are offered as the three main stages of climate adaptation and focus their analysis on

enumerating the types of barriers that could be present at each stage.

At present, there is a lack of evidence on the effectiveness of climate resilience

interventions; hence additional studies need to be more focus on the design, evaluation

and reporting of such interventions (Hess, Eidson, Tlumak, Raab, & Luber, 2014). Once

better organizational case data is available in the literature on such climate adaptation

interventions, they could be evaluated using evidence based public health approach

(EBPH). The EBPH processes is similar to other learning cycles beginning with 1)

problem assessment, 2) evidence acquisition 3) evaluation, 4) recommendation, 5)

prioritization, 6) intervention, and 7) knowledge gap identification for next steps (Hess et

al., 2014).

Similar evaluation and learning cycles for climate adaptation have been adopted

by the U.S. Center for Disease Control (CDC). The Building Resilience Against Climate

Effects (BRACE) project emphasizes iterative, learning based, adaptive management of

climate change health effects using 1) vulnerability assessment , 2) health risk, 3)

intervention assessment, 4) develop/implement adaptation plan, and 5) evaluate and

iteratively improve management (Marinucci, Luber, Uejio, Saha, & Hess, 2014). That

study points to four types of data needed: baseline disease rate, exposure outcomes,

demographic projections and general circulation models of climate. An important

challenge to climate adaptation is that impacts are often interdisciplinary in nature, and

there are large uncertainties related to climate impacts that act as barriers to public health

adaptation (Huang et al., 2011). As a result, future work should employ climate

adaptation interventions with adaptive learning cycles that engages with stakeholders to

improve understanding of what approaches work in different places and situations. The

next few paragraphs focuses in on the complex system that Maricopa County, Arizona is

placed within to give some local context to the case examined in this dissertation.

   Resilience in Maricopa County. Nested complex systems are considered in the

Building Community Resilience in Maricopa County report (Virginia G. Piper Charitable

Trust, 2016) where a nested resilience frame is used across community/environment,

social/economic, and household/individual scales. This Virginia G. Piper Charitable

Trust report is referenced here because it is the most current resilience report for

Maricopa County. Although Maricopa County has the HRN and other sources of

resilience, there are challenges such as lack of social cohesion. "The single largest

challenge we noted [for Maricopa County] – and one that is critical to the success of

building resilience in all three domains [environment, socio-economic, and individual] –

is the lack of social cohesion within Maricopa County." (Virginia G. Piper Charitable

Trust, 2016, p. 7) This challenge is hindered further by the fact that only 38% of

Arizonans were born in the state, leading to an increased potential for disconnectedness

to others in the community (Aisch & Gebeloff, 2014a). This disconnectedness to other

community members in Maricopa County is not helpful in terms of community resilience because it likely reduces the amount of empathy residents have for those in situations they do not identify with, such as being poor or homeless and in need of heat relief.

The report also noted that social resilience in Maricopa County is also challenged by a large amount of physical segregation by race and class. Further, "redlining" is a part of the historical physical design of the greater Phoenix area where major highways are barriers to movement between neighborhoods "all based on the segregation of the 1950s" (Virginia G. Piper Charitable Trust, 2016, p. 25). Hence the long-term effects of bigotry and discrimination still negatively affect residents of Maricopa County through literal separation of what should be a single community, into several communities with disparate access to education, resources, and opportunity. This means that there are concentrated areas of poverty that have higher heat health risk that are segregated from wealthier areas (Harlan et al., 2013). In addition, reduced resource allocation to public education for predominantly minority communities through historical "redlining" and resource diversion to other areas leads to a community that is more likely to have jobs that require outdoor work or do not pay as well as jobs that require a higher degree of education. This pattern of low investment in these communities leads to a state of poverty and human capital that makes such residents at greater risk to extreme heat due in part to fewer resources that leads to poverty and outdoor work that gives them at greater heat risk. Poverty, however, is not the only cause of heat health risk — consider people with health conditions that increase their risk. Similarly, even those individuals who might be from wealthier communities can experience mental health problems that can

lead to homelessness given the lack of access to adequate mental health care in the county.

Individuals who are at high risk for extreme heat mortality and morbidity include the very young (< age 6), the very old (> 65), the homeless (very poor, mentally ill, addiction), low income households (i.e. cannot afford AC), and outdoor workers (less educated). These groups are shown to be at higher risk due to observed heat related mortality and morbidity (MCDPH, 2014). Here it can be seen how different levels of the community in Maricopa County, Arizona contribute to extreme heat vulnerability since each higher scale of organization is comprised of lower scale elements – from the individual to global scale. This individual and household level is critical because resources are needed to protect our most at risk citizens from extreme heat health risks. At the social and economic level, an individual's and household extreme heat health risk factors come together in aggregate.

Socioeconomic status is important to have enough money to pay utility costs driven largely by air conditioning use. Failure to have enough capital at the individual and household level can lead to problems in coping with extreme heat health risk, with some finding inadequate cool space, often due to high costs of running air conditioning during the summer in Maricopa County. Consider that 13% of Maricopa County residents do not have air conditioning or an evaporative cooler (Harlan et al., 2013). In addition, many residents who do have air conditioning are poor enough to qualify for federal energy assistance, yet there is not enough funding allocation to meet the needs of all who qualify. "Statewide, 26% of Arizona's households (617,000) meet federal energy assistance requirements of earning at or below 150% of the poverty rate. During 2014,

federal funding allocated to the State of Arizona assisted 30,520 households with financial resources with utility bill assistance – less than 5% of the total eligible households." (Virginia G. Piper Charitable Trust, 2016, p. 13)

The impact in terms of CO_2 and other greenhouse gas emissions is expected to lead to more frequent and severe heat-waves in the Southwest U.S including Arizona, Colorado, New Mexico, and Utah (Garfin et al., 2014). Consider Figure 1 (Virginia G. Piper Charitable Trust, 2016) that shows the aggregate temperature anomalies in the Southwest U.S. since temperature records have been kept, which shows the Southwest region has had almost entirely higher temperature anomalies relative to the historical
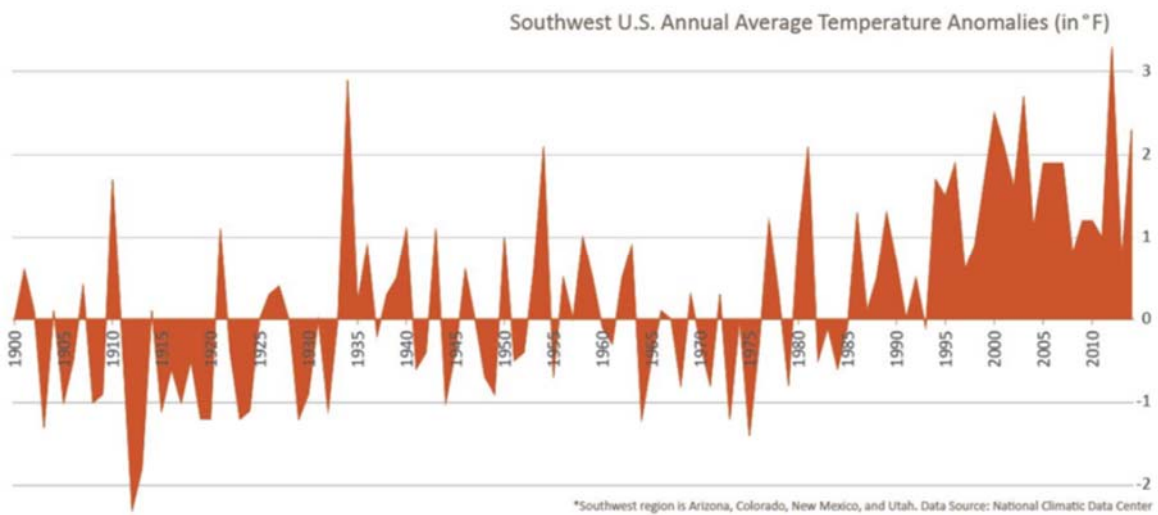

Figure 1: Southwest U.S. temperature anomalies from Virginia G. Piper Charitable Trust (2016, p. 30)

record since the year 1995. This trend is expected to continue (Pachauri, Meyer, Plattner, & Stocker, 2015), and will contribute to the extreme heat health risk in Maricopa County, Arizona.

Despite these global factors challenging resilience in Maricopa County, individual small scale factors and efforts to mitigate heat health risk through social interventions, warning systems, and individual behaviors can have an important impact on reducing heat health risk. As the environment of risk changes, it is useful to use different natural hazard preparedness approaches to continually prepare for likely health risks. The specific environment of Maricopa County is one of extreme chronic heat and a social distribution with large socioeconomic disparities that contribute to increased heat health risk. Hence it makes sense that there is an ongoing intervention of the HRN cooling centers here in Maricopa County to help relieve the mortality and morbidity burden on its residents.

The Maricopa County Arizona Heat Relief Network Case

The need to reduce heat-related deaths led to a cooperative cooling center evaluation project in the summer of 2014 to learn more about what services are offered at individual cooling centers, how cooling center use and demand compare with availability, and how the network functions. Part of the interest in learning about how the network operates is to identify best practices that can be shared with other jurisdictions. The Maricopa County Department of Public Health (MCDPH), Arizona Department of Health Services (ADHS), and Arizona State University (ASU) conducted this research. This prior investigation yielded 658 visitor surveys, and 52 cooling center site assessments and

facility manager interviews (Berisha et al., 2017). These cooling center managers are the topic of further analysis in chapter two. The results of the 2014 cooling center evaluation project with Arizona public health agencies (Berisha et al., 2017) led to the work presented in this dissertation.

A chronically hot climate during summers in the greater Phoenix area is the context in which this institutional adaptation to climate change and urbanization is occurring, but is not the focus of the dissertation. Rather, the institutional arrangements of non-centrally controlled governance with some central coordination is the focus, which could be applied to any type of problem that has multi-level network form of governance that is ad-hoc and emergent. This research looks within and across two layers of the HRN to see how members of the different levels see their place and the nature of extreme heat problems differently. These layers are in part the public health management from government agencies that help coordinate the HRN as higher level network nodes and the HRN facility managers themselves as the lower level nodes. The idea is to look at where alignment and misalignment of perspectives occurs across these two scales in the network to find opportunities to improve this form of non-centralized public health risk intervention. The following is an introduction to the HRN.

The Maricopa HRN is one of the primary public health intervention measures in place in the greater Phoenix area to combat the adverse health effects associated with extreme heat. The HRN was first organized in 2006 in response to a high number of heat-related deaths among the homeless population during the previous summer (Berisha et al., 2017). The coordination of the HRN is currently performed by staff from the MAG and the City of Phoenix, with support and promotion from many other agencies.

Current public investment in heat relief extends to organizational staff time from the City of Phoenix, MAG, and other municipalities and agencies, along with donations drives and funding for bottled water from the public. There appears to be no dedicated public expenditure reserved for increasing the capacity or service provision of the HRN, but rather it relies on organizations to volunteer their cool space to be cooling and hydration centers each year. Hence this network leverages existing services of nonprofit and public facilities in the community to reduce heat health risk.

The HRN works to reduce health risks associated with exposure to extreme heat where, "[t]he goal of the network is to provide resources for vulnerable people and help prevent heat-related deaths." (Kevin Hartke, Continuum of Care Board chair, Maricopa Association of Governments, 2015). The HRN provides an opportunity to examine inter-organizational structure and function that is characteristic of complexity governance — or the view of governance through a complex systems lens. Indeed, the HRN is comprised of a wide range of actors working together to advance the common good and address a shared challenge. The extent to which information and communication technologies support the HRN is not well-defined because the system is not well studied, although the engagement with the HRN we describe here reflects an effort to better understand the system. This investigation seeks knowledge about ways to enhance the collective strength of the HRN as a means of leveraging existing resources to mitigate a critical

public health risk that leads to dozens of mostly avoidable deaths year after year. The goal is to learn about what attributes of the HRN are strengths, and therefore are to be

enhanced, while also learning about weaker attributes of the HRN to understand the limitations it has in reducing heat health risk.

The mission of the HRN is "to coordinate effort by participating community faith-based organizations, government agencies, and businesses to help provide heat relief to homeless, elderly, people with disabilities, and anyone in need during extreme summer weather conditions." (Cole, 2012) Many of the organizations that volunteer as cooling centers have been providing heat refuge and hydration services to vulnerable populations for time spans that often exceed current institutional memory based on anecdotal evidence from interviews. The post-2005 period represents the formal HRN formation and subsequent provision of services. The HRN offers more heat health risk protection than would be available in its absence, and has certainly offered many individuals heat relief based on thousands of water bottles given out at cooling centers each year according to interview data (Berisha et al., 2017). Despite the existence of the HRN, there remain a substantial number of heat-related mortalities in Maricopa County every
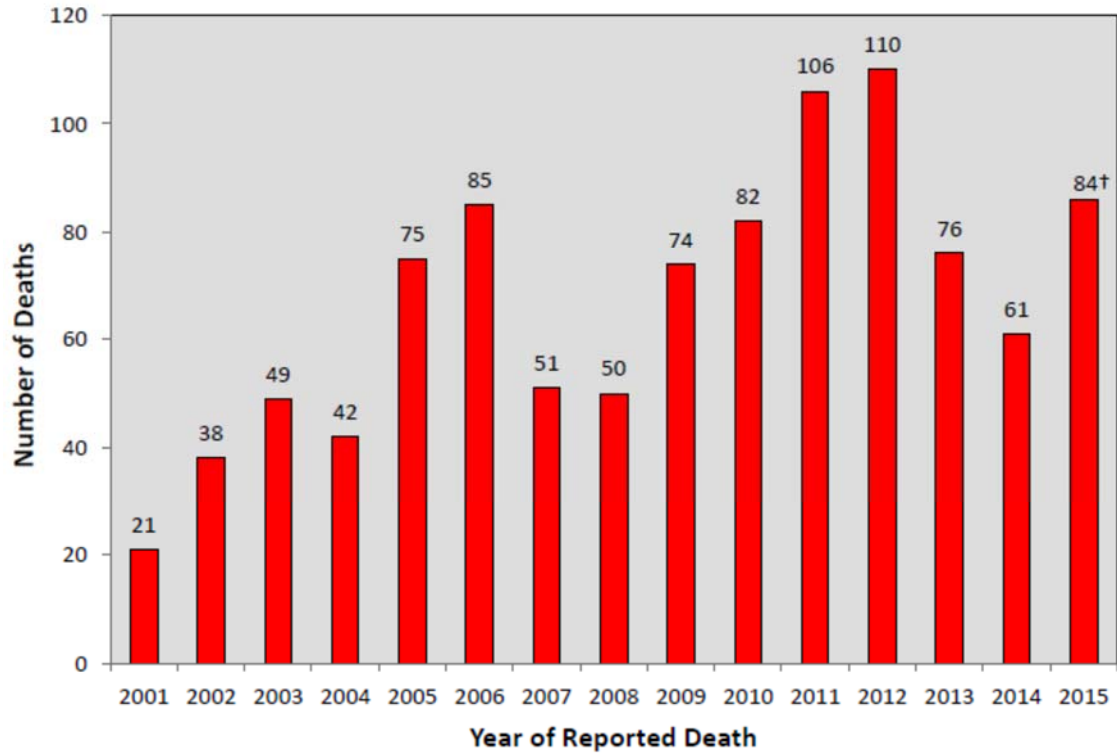
Figure 2: Annual heat related mortality from 2001 – 2015 (MCDPH, 2015, p. 4).

year since the formal HRN began in 2006. Figure 2 shows the Maricopa County

Department of Public Health figure on annual heat related mortality from 2001 through

2015. It is important to note that this is raw mortality data and has not been adjusted for

significant population changes or age effects, so should be considered a rough guide

rather than a controlled epidemiologic accounting of heat related mortality. The HRN

itself is comprised of a mixture of public sector, charitable, religious, and service

organizations. This type of ad-hoc network has been found to improve regional climate

change adaptation capacity in the Southeastern United States in the absence of formal or

mainstream efforts (Dow, Haywood, Kettle, & Lackstrom, 2013).

Dissertation Overview

The previous description of how organizations have different cognition and learning processes than individuals means that unlike individuals, different organizations are likely to have different cultures and climate that support learning. In the context of the HRN cooling centers, each organization has some autonomy to set its own open hours of operation, among other decisions to respond to their perceived scheduling and service constraints. Hence how each organization learns and adapts is generally independent of other cooling centers and important to understand so that we can determine how individual decisions contribute to emergent features of the system that varies annually. It is possible that organizations perceive little change in the environment and continue their mission without much ongoing learning once a stable routine has been developed. However, it may also be the case that at certain points new information led to significant change in an individual organizations behavior, for example deciding to participate as a cooling center for the first time after learning of a number of deaths from heat in the media as well as the overall collective efficacy of the network.

It is this interest in understanding how organizational learning matches against the need for climate adaptation over time that leads to the overarching research questions for this dissertation. These are related to perception: **(1)** How are people that are part of the HRN aware of where they are within the overall system? and action: **(2)** how do they respond under this awareness of their position in the system? These questions are asked because we are interested in learning about the perspective and related action people in cooling centers take with respect to heat relief. This is appropriate because it is difficult to directly quantify organizational learning related to climate adaptation, so asking

subsequent related research questions in later chapters is one means of evaluating these two overarching research questions listed above. How organizations learn as the organizational environment changes is an important question to answer when considering how such institutions become more resilient and adaptive to anticipated future climate and urbanization changes over the next century.

This dissertation, though embedded in the context of adaptation to climate change and urbanization for the specific case of extreme heat mortality and morbidity in Maricopa County, is more generally about multilevel governance under noncentralized organization and the ambiguity experienced by members of the network at different levels. The issue of climate change adaptation is well represented in the litrature (Adger et al., 2009; Sussman et al., 2014), although it has not been evaluated extensively in the context of informal ad-hoc network governance arrangements. Consequently, this research helps fill a gap in the literature.

Chapter one of this dissertation has been introductory and theoretical. Chapter two looks at qualitative analysis of 16 recorded interviews with cooling and hydration center managers to better understand the diversity of their perspectives based on the different organization for which they work and clients they serve. The third chapter examines the concept of complexity governance along with the development of a prototype agent based model that represents some of the system complexity to aid with decision making. Chapter four is a qualitative analysis of four recorded interviews, three individuals and one focus group of seven people, using the prototype agent based model in participatory modeling exercises to improve the prototype model and encourage systems thinking by HRN coordinators and public health agencies. Finally, chapter five

41

seeks to integrate the main lessons learned from each of chapters one through four. This approach is unique in that it looks at two levels of network governance for climate adaptation, for which there are few examples in the academic literature of analysis of several institutional layers that represent the true complexity of many governance arrangements.

The second chapter that follows uses interviews from a 2014 cooling center program evaluation (Berisha et al., 2017). A total of 52 interviews were given to cooling center managers, with a subset of 16 interviews recorded for later analysis presented here. There were set questions for the interviews that makes them semi-structured in format. These questions were originally designed for the cooling center program evaluation study, but were adapted for use in this analysis. Twelve research questions were designed to be answered from the semi-structured interviews, with audio interview data coded for qualitative thematic analysis. Research questions for chapter two included how the managers articulated their role in mitigating heat health risk and how similar are these articulations across the network, among others. The coded audio data was also interrogated for each of the research questions from each interview in analytic memos, shedding light on important aspects of the cooling center manager's experience. These research questions help reveal how the over-arching dissertation research questions are answered — how facility managers see their position within the system, and how they act from that position.

Chapter three describes how the HRN case fits in with the idea of complexity governance, or using a complex systems approach to view multi-level, multijurisdictional governance arrangements. It also reviews creation of a prototype agent based model to

represent the complexity of the HRN in time and space for use in participatory modeling exercises analyzed in chapter four. One critical element of any complex systems is that they exhibit emergent features that cannot be predicted precisely beforehand due to individual agent decision making within the system. The HRN cooling centers have this attribute since they self-select for participation each year and set their own open hours, which gives a certain amount of spatial and temporal variation in cooling center availability from year to year. A simple prototype agent based model was made of the cooling centers using a Geographic Information System (GIS) map layer and a time-sequenced display of hour by hour availability of cooling centers on the map over the course of a week. This simulation also had the peak observed hourly temperature displayed as a background heat intensity color of the map to show the risk from temperature, in addition to the risk reduction available from open cooling centers. The prototype model was later used to interview HRN public health agency representatives in participatory modeling exercises that were recorded for later qualitative analysis in chapter four.

The fourth chapter of this dissertation uses the prototype agent based model developed from chapter three in participatory modeling interviews that were recorded for analysis. This case study uses participatory modeling at the public health regional coordination scale and engaged members of public health organizations that are responsible for helping plan the annual HRN and monitor heat related mortality and morbidity. In this effort, the prototype model was brought to the HRN public health representatives to allow them to become more involved with the system and choose how to respond to it. Recorded interviews were taken as data for the iterative participatory

modeling process to improve a prototype agent based model using experience of these local experts on the ground. These were unstructured interviews that asked the following open ended questions: (1) What are the important questions to ask to improve the HRN? and (2) How can these questions be answered in the modeling framework? There were four participatory modeling interviews recorded, totaling seven individuals since the final interview was conducted with four additional participants (technically this fourth recorded interview with multiple participants is considered a focus group). The results will be divided into two portions 1) recorded interviews evaluated with qualitative analysis and content coding and 2) qualitative descriptions of how the prototype model changed and was improved by the participatory modeling process. The link between these two results sections are the specific suggestions made by those interviewed on how to best improve the model.

The fifth chapter of this dissertation has several contributions. The first is a review and highlight of important results from each of the main chapters one through four. This includes answers to highlighted motivating questions, summarizing how they have been answered. Observations are made across chapters that cover different scales, namely chapters two and four, to show the value of studying across multiple scales. Finally, new questions that are generated based on the research in prior chapters are given along with their importance for understanding.

The research in this dissertation aims to fill the gap in understanding between how organizational arrangements are conceived as intervention to reduce heat health risk, and how they operate in practice when implemented on the ground. The approach is to look at how individuals as members of organizations see themselves as part of the larger

system, and how they respond when aware of that positioning. A critical aspect of understanding the system is to investigate the perspectives of the voluntary organizations that serve as cooling centers through interviews with their facility managers. There may be important facets to providing heat relief that are best understood by those who operate cooling centers daily. The perspective of those who work to coordinate and support the HRN is also important since they have a unique point of view of how the system operates on a larger scale, but does not guarantee they see all relevant aspects of the system. The present investigation includes looking at the HRN through a complex adaptive systems lens by building a prototype agent based model of the cooling centers to see how the system operates as a whole and leads to emergent features of the system that is not apparent from the sum of its parts. This prototype agent based model represents complexity governance, or governance from a complex systems approach to see the emergent features of the system that cannot be predicted based on the individual system components. The prototype model is used in participatory modeling with HRN coordinating agencies and researchers to get a better understanding of their view of the cooling centers from a complex systems perspective and how to best improve the model. Ultimately the lessons from this research will help develop a better understanding of how the two layers of the HRN, namely cooling centers and HRN coordinating agencies and researchers, deliver heat health risk reduction intervention to Maricopa County through access to cool space and water.

CHAPTER 2

UNDERSTANDING THE DIVERSITY OF

PERSPECTIVES OF FACILITY MANAGERS

Introduction

Access to cool space has been shown to be protective against heat health risk (O'Neill et al., 2010). For this reason, use of cooling centers — where people can access cool space and water — among other strategies has been shown to reduce the impact of extreme heat when implemented (Schifano et al., 2012). The Heat Relief Network (HRN) cooling centers are an example of such an institutional intervention to provide cool space to reduce heat health risk (Berisha et al., 2017). This provides an opportunity to learn from the point of view of the cooling center managers based interviews with them. From these interviews, it is important to learn about the two main dissertation questions being asked but articulated for the context of this chapter **(1)** how do people understand the network they are a part of? and **(2)** how do those perceptions vary in the network? In addition, organizational theory about how organizations learn in a changing environment that requires climate adaptation is important to understand.

The question of how one perceives their organizational position in a network and how it affects the outcome of that organization is not new. Research has shown that the network position of organizations, and the perception of that position, has implications for the functioning of those institutions and the individuals that work within them. The position within organizational structure have been suggested to be related to cognition

because it determines what information people in organizations are exposed to, where similar positions in the network lead to similar perceptions (Casciaro, 1998). The position of an actor in a network has consequences in defining its context for action, as well as behavior opportunities and constraints (Borgatti & Foster, 2003). It has also been shown that the position of a firm within a network affects how alliances and learning occur across that organization (Podolny & Page, 1998a). Further, governance of social systems is structured by network position that affects resources and interpreted meaning through network communication of organizations and individuals at different levels of interaction (Folke, Hahn, Olsson, & Norberg, 2005). The current research extends these previous works by looking at the perception of individuals within an ad-hoc governance network.

Each year several dozen people die from extreme heat exposure in Maricopa County Arizona, representing the greater Phoenix metropolitan area (MCDPH, 2015b). Almost every one of these deaths is avoidable given access to water and cool space such as air conditioning (AC). These deaths occur disproportionately across a variety of at risk demographics including the very old, the very young, the poor, homeless, and those who work outdoors. Each year approximately one third of the observed heat related deaths occur indoor (Goodin, Castle, Martinez, Speck, & Trembath, 2015), hence access to adequately cooled indoor space is a critical aspect of saving these lives from avoidable heat related death. This chapter looks at the public health intervention of cooling centers. This is done through qualitative thematic analysis of interviews with Maricopa County Heat Relief Network (HRN) cooling center managers. Within the HRN there are heat refuge stations and hydration only stations that respectively give access to cool space plus

water, or just water. Collectively these heat refuge stations and hydration stations are referred to as cooling centers. The method used is exploratory case study analysis using semi-structured interview data of cooling center managers where the HRN cooling centers represent the different cases.

   Organizational learning. Organizational learning under a changing environment, as is the case with climate change and urbanization (Hondula et al., 2015), is related to the above two dissertation questions in that managers learn to be both aware of their role in the system and how to respond from that position when they are aware. That is, factors affecting organizational learning also affect how different agents in the system respond under different levels of awareness to the rest of the system. "Learning begins with intuition and is largely a subconscious process involving perceptions of patterns and possibilities." (Yih-Tong Sun & Scott, 2005, p. 76) These patterns and possibilities of learning have been largely organized into categories of single versus double loop learning described below.

   Organization behavior that is concerned with fine-tuning current behavior deviations from goals or objectives is known as single loop learning; more radical transformation of an organization's culture, structure or operating procedures is known as double loop learning (Cummings & Worley, 2008). This low level single loop learning concept was first proposed by Argyris (1976), and was the only type of learning discussed in early theories of organizational learning (Cyert & March, 1963). Argyris (1976) also proposed the concept of double loop learning, which is the same as the deutero-learning coined by Bateson (1972) where values, norms and world views are changed. Interaction with sub-systems in the environment contributes new information to

learning. However, as local environmental sub-systems are treated as closed off from the organization, organizational learning has a likelihood of moving toward self-stabilization (J. D. Thompson, 1967). In single loop learning in stable environments, self-stabilizing forces have a high likelihood of gaining enough momentum to immobilize learning response repertoires (Hedberg, 1981). One could say that the value of organizational learning at equilibrium has a zero or negative value (Camerer et al., 2004), though once the environment begins to change the organization may face challenges re-activating its learning cycles. Hence it can be seen how different learning strategies might be adaptive under different environmental conditions external to the organization. For example, if cooling centers perceive that their external environment is relatively unchanging, then they may not exhibit a great deal of learning and focus on stabilizing current operation strategies.

An important example of incomplete learning cycles is where the environmental response and individual belief coupling is problematic (Hedberg, 1981). This is known as learning under ambiguity (March & Olsen, 1976), where, "[d]ifferent individuals may interpret situations and processes differently because of excessive problem complexity, selective perception, different cognitive styles, and mental maps." (Hedberg, 1981, p. 11) Distortion of organizations' interpretations of experiments due to cognitive limitations and ambiguity may block off learning cycles to render them incomplete (March & Olsen, 1976). Further, leaders such as management often work under great time pressure (Mintzberg, 1973), which puts further constraints on them to process enough information from the environment to complete learning cycles. To help with this information overload under time pressure, information systems have two processes that can increase

efficiency of knowledge transfer: message routing and summarizing (Fiol & Lyles, 1985). The effects of message routing and summarizing means that communication attributes are important in organizational learning cycles. Filters of perception in information systems however are not a guarantee of increased learning, as they could be more or less helpful in the search and discovery of relevant information for learning (Glimell, 1975). Hence effective communication systems are critical to proper coupling individual belief about the organization to the state of the environment, and help reduce learning under ambiguity.

An organization's culture creates the conditions that set the climate for the institution. This means that if the climate is not conducive to learning and honest brokering of information, then learning is stifled and such cycles can be broken. The culture of an organization can be seen as ideologies and established behavior patterns (Schein, 1993). For example, having a psychologically safe environment for communicating failure that facilitates learning is primarily related to the climate of an organization, which is the result of its culture (Yih-Tong Sun & Scott, 2005). Without the ability to complete learning cycles, it is difficult to see how organizations will become more adapted to climate change and urbanization as those challenges increase. The goal is increased resilience of the system through learning and change at the institutional level. "Process-related resilience is defined more in terms of continual learning and taking responsibility for making better decisions to improve the capacity to handle hazards" (Cutter et al., 2008, p. 600), where resilience is seen as a process that leads to less vulnerability while noting that resilience can also be viewed as an outcome of processes. As a result of these lessons on organizational learning, it is clear that

properly functioning organizational learning cycles are a trademark of institutions that are able to adapt to a changing environment and exhibit resilience.

Cooling centers, climate adaptation, and environmental justice. Different neighborhoods in Maricopa County, or greater Phoenix, have differing levels of vegetation that contribute to local neighborhood cooling through evaporation (Jenerette, Harlan, Stefanov, & Martin, 2014); these cool green spaces are positively correlated with more affluent neighborhoods which puts socioeconomically challenged areas at greater risk to extreme heat (Harlan et al., 2008). Nearly all of the cooling centers are located in the poorest areas of Maricopa County as shown in Figure 3 map of the 2014 cooling centers compared to 2010 U.S. census bureau median income data. This indicates that the HRN cooling centers are located in areas of Maricopa County that have the lowest income and higher likelihood for heat health risk based on microclimates (Harlan, Brazel, Prashad, Stefanov, & Larsen, 2006). These cooling centers leverage an important intervention to these poorer communities for heat health risk reduction by giving access to water and cool space. In this way, the cooling centers also represent a climate adaptation and environmental justice intervention that helps alleviate social disparities related to income that extend to heat health risk (Chow, Chuang, & Gober, 2012).

Research motivation and description. At the outset of this studies' development stage in the fall of 2013, researchers and public health officials at Maricopa Department of Public Health (MCDPH), Arizona Department of Health Services (ADHS), and Arizona State University (ASU) noted that although the HRN was offered as a solution to mitigate the several dozen heat related deaths each year, there was very little information and understanding on how the HRN functioned. Thus far, these public health and

research agencies were mostly involved in monitoring the number of heat deaths and verifying that they were heat related through use of special epidemiological protocols to ground truth as best as possible whether they were actually heat related or not. During the fall of 2013 MCDPH, ADHS, and ASU decided to conduct a program evaluation of the HRN cooling centers for the upcoming summer of 2014 heat season, where greater Phoenix area temperatures routinely reach above 100° F from May through September (Harlan et al., 2014b). The purpose was to better understand how and in what capacity the cooling centers made cool space and water available to those in need of heat relief. This program evaluation included interviews of every willing cooling center facility manager, site evaluations (capacity, signage, etc.), and visitor surveys. The facility manager interviews from this program evaluation are the focus of the current investigation in this chapter. The interview questions were not specifically designed for the current study, but they are relevant as they lend themselves to responses that help answer the research questions in this chapter.

There were eighteen open ended qualitative interview questions that were asked for which respondents were encouraged to expand upon their experience. This allowed for a semi-structured interview context that allowed the participant to deviate from questions asked if they thought the topic was important. Four main research questions are asked of the interview data. These include questions about how managers see the rest of the system and how that varies across individuals. Organizational theory on how organizations learn in a changing environment as well as adaptation to a changing environment is also relevant. These research questions are: **1)** how do managers articulate awareness, or lack of it, to the rest of the system? **2)** among managers, how

2014 Maricopa County, AZ
HRN Cooling Centers
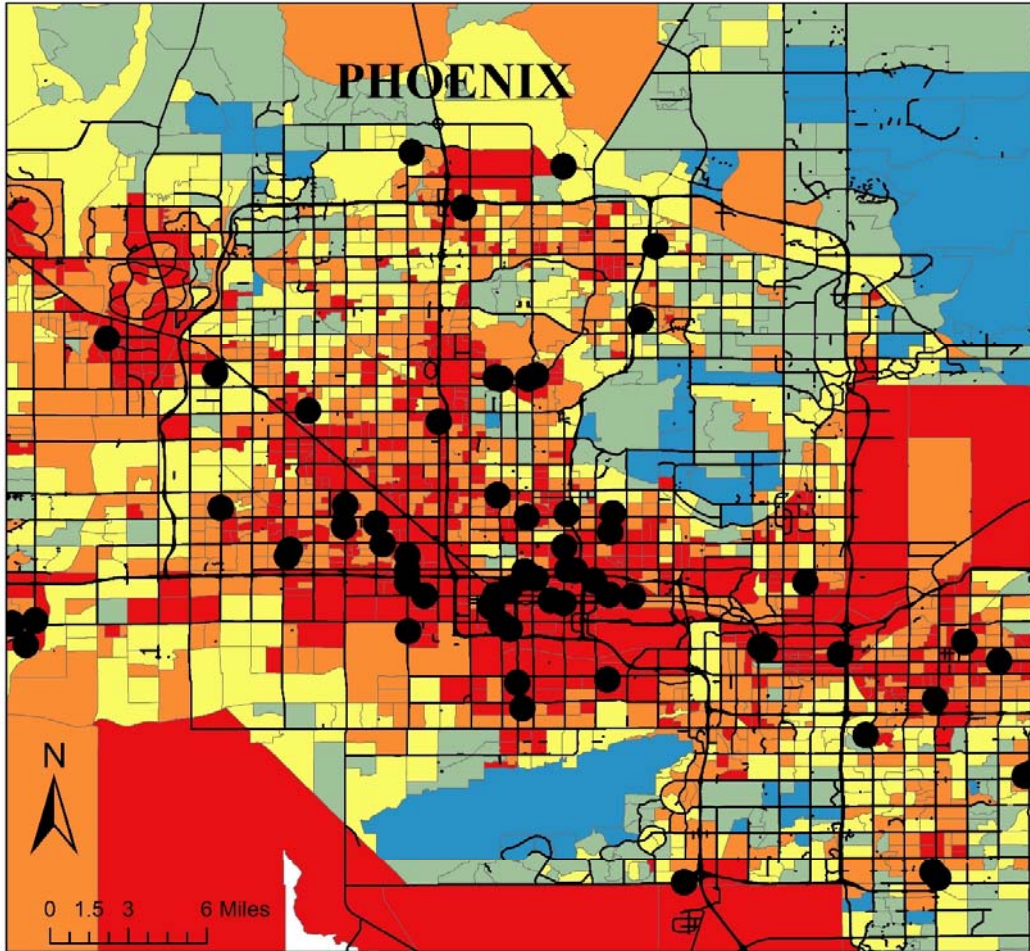
Legend

● Cooling Centers

Median Income ($)

🟥	0 - 38,750
🟧	38,750 - 60,889
🟨	60,889 - 88,866
🟩	88,866 - 132,434
🟦	132,434 - 250,001

Figure 3. 2014 HRN cooling centers mapped against 2010 U.S. Census Bureau median income ($) using Jenks natural breaks to classify the five income categories.

similar are the articulations across those interviewed? **3)** do managers indicate first or second loop learning thinking in their responses? and **4)** what insights does this case bring to climate adaptation and institutional resilience? Additional network attributes, described in the methods section, were asked to interrogate the interview data to answer the above four research questions.

A goal of this research is to learn if and how these individual organizations see themselves as part of a larger network rather than as an isolated node as a result of being part of the larger HRN. Being part of a larger network has the benefit of possibilities for exchanging information with the public health coordinating agencies and other HRN centers for available hours for people to seek heat relief. In addition, there are possibilities to leverage resources such as unevenly distributed bottled water, and best practices across the network. However, just because there are possibilities for exchange of such information, supplies, and best practices, this does not mean that these are in fact occurring. The interest is in learning the extent and limitations of how cooling center facility managers made use of being part of the larger HRN, as opposed to offering similar services as an isolated node unconnected to the rest of the network.

Research Methodology

Epistemology and methodology. The research epistemology that I have is a worldview that comes from pragmatism, that arises from actions, situations, and

consequences instead of focusing on antecedent conditions (Creswell, 2009). In this approach, the focus is on applications that work and problem solutions (Patton, 2002). Rather than considering particular methods from the outset, researchers using a pragmatic worldview emphasize the research problem and use any available approaches to help understand the problem (*cf* Rossman & Wilson, 1985). "Pragmatism is not committed to any one system of philosophy and reality" and "[p]ragmatists have believed in the external world independent of the mind as well as that lodged in the mind" (Creswell, 2009, p. 11). My epistemological view as a researcher is grounded in pragmatic approaches that are based on a realist view of knowledge where external social phenomena exist outside of my view or understanding of the issue at hand. The approach used in this chapter focuses on what approaches work in an applied sense to analyze the data and look for answers to the research questions.

The qualitative strategy of inquiry taken in this chapter is the use of case studies that explore in depth some type of activity, event, or individual. The case study approach is bounded by activity and time where researchers collect information and details with a number of data collection approaches for a certain period of time (Stake, 1995). Such case study research generally involves a detailed description of individuals or setting and is followed by thematic or issue based analysis (Wolcott, 1994). This is an appropriate strategy of inquiry for this research because each cooling center manager represents a different organizational case. The time periods for these case studies are bounded within the summer of 2014. There were sixteen recorded interviews taken as data during this period and each one represents a different case study.

This research uses a exploratory case study methodology where, "… case studies are the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context." (Yin, 1994, p. 1) The exploratory nature of these case studies stems from the fact that the literature is dearth with examples of other cooling center case studies or voluntary ad-hoc governance networks. As a result, there is not a body of specific theory to draw upon to make *a priori* codes for deductive coding approach. Instead, inductive coding was used to allow the data itself to inform me as the researcher what codes and code subcategories to use to organize the analysis (Saldaña, 2015). Code subcategories help organize codes under a common theme and therefore help with thematic analysis (Friese, 2014).

Researcher perspective. In qualitative analysis, the researcher is the interpreter of qualitative data and hence is the primary means by which raw data is processed for more refined understanding. For this reason, the perspective of the researcher is important to understand to know what their perspective, experience, and things that may introduce bias into their interpretations of data. Therefore it is critical for me as a researcher to describe these aspects of myself as the instrument of qualitative interpretation. My education is a Bachelor's in Biology and Environmental Science, and an M.Sc. in Ecology. The doctoral training and research I have undertaken has given me a good understanding of institutional adaptation and learning, especially in the context of extreme heat health risk reduction. I am interested extreme heat and the environment, as well as sociologic impacts — especially those that involve institutional arrangements. I also have experience doing policy work for the environment, mostly focusing on

greenhouse gas emissions reduction policy. As someone trained heavily in the natural sciences, I bring a keen eye to aspects related to extreme heat health risk. At the same time, my experience and education in public policy and organizational theory helps bring an institutional lens to my perspective. Some limitations in my experience, and hence interpretation of the qualitative data, is in having done no prior sociologic or institutional research using qualitative methods before. Hence my interpretations of the data have the benefits of a natural science background, but this benefit is at the expense of prior qualitative research analysis experience for organizations.

  Network attributes from HRN facility manager's perspectives. There were eight network attributes that were investigated when analyzing the interview data to help organize the qualitative analysis results into different thematic categories of interest. These eight network attributes were inquired about the responses given to the eighteen open-ended interview questions. These network attributes are listed in Table 1. These attribute questions are designed to illuminate the four research questions of this work. Other attributes are more specific and focus, for example, on what they would do if given access to unlimited resources, and the nature of their communication with the larger HRN. Coding from the qualitative analysis and contents of analytic research memos was organized according to the four research questions and eight attribute questions to provide a means of effectively sorting the variety of content from the sixteen different facility manager interviews. These are outlined briefly below.

  1) Manager's articulated role in mitigating heat health risk. Cooling center managers come from a wide array of different types of organizations that offer primary

services to the community other than heat relief, with being a cooling center as generally

an ancillary function. This means that one facility could be a senior center, while another

could be a poor and homeless services center, or a parks and recreation facility. The

differences in the primary role of the organization is likely to affect how facility

managers articulate their role in mitigating heat health risk. The intent is to learn about

Table 1

Chapter 2 Network Attributes

Chapter 2 Network Attributes
1) Manager's articulated role in mitigating heat health risk.
2) Responsibilities of individual facilities
3) Flexibility to adjust role or behavior
4) Interactions within the network
5) External forces in the network
6) Unlimited resource access
7) Communication with larger HRN
8) Cooling center public awareness source.

how cooling center managers are aware of where they are within the overall system as a

function of their articulated role in mitigating heat health risk.

2) Responsibilities of individual facilities. There is a wide diversity of cooling center primary service mission besides heat relief. Hence these managers could frame their responsibilities in providing heat relief in exclusive terms, or couch them in a more general way as related to primary service delivery to their main clients. For example, a senior center may not have a lot of walk-ins off the street for heat relief whereas a poor and homeless services organization may have this as their main source of clients. This could potentially affect how managers frame their responsibilities and priorities to their primary service clients versus those seeking heat relief exclusively.

3) Flexibility to adjust role or behavior. A benefit to the cooling centers is that they provide a potential resource for unexpected situations by adjusting their role or behavior. This could be large scale emergencies where there was a large number of people who are in need of heat relief due to power or air conditioning failure. However, such flexibility in accommodations is limited by the excess physical capacity or staff time, among other limitations. The ability to be flexible given available resources can also help inform how much institutional resilience is added to the system through such flexibility to absorb perturbations in the system.

4) Interactions within the network. A positive aspect of having the network of cooling centers assembled as the HRN rather than operating as individual nodes is the ability to leverage all the cooling centers against heat health risk rather than piecemeal. This means that people can go to one resource and see all of the cooling center locations and open hours displayed on a map. This provides an opportunity for cooling centers to refer their clients to other nearby cooling centers if there are increased interactions with adjacent HRN managers. It may also be the case that cooling center managers do not

59

have sufficient extra time to reach out to other adjacent managers, working with limited funding and staff resources.

      5) External forces in the network. There could be broader forces affecting the cooling centers and the populations they serve that are drivers for the services provided. For example, consider that mental health illness including addiction, as well as poverty contribute to heat health risk and therefore represent broader forces that are drivers for social need among the sick, poor, and homeless that is beyond the immediate interactions of the cooling centers. It could also be said that broader physiologic forces are at work when considering an elderly population, many of which are on medications that increase vulnerability to heat.

      6) Unlimited resource access. This attribute allows the cooling center manager to think creatively about what solutions they would offer to people in need of heat relief absent any resource constraints. Again, there are a range of different organizational types that serve different primary populations for heat relief such as the elderly, or the poor and homeless. These solutions could be truly creative bound only by imagination, or they could be an extension of the cooling centers ongoing operations to address current limitations in resources and staff availability. This indicates how a cooling center manager would act from their position within the system without resource constraints.

      7) Communication with larger HRN. One of the benefits of having an ad-hoc network of cooling centers with known participants rather than simply having each organization act on its own is that they can potentially communicate with one another. The benefits of communicating with other cooling centers could be simply to share best practices, and possibly exchange donated resources that are unevenly distributed across

the HRN. For example, donated bottles of water, sunscreen, lip-balm and hats are often received unevenly across different cooling centers. As a result, it could be helpful for these cooling centers to be in contact with one another so that they can exchange different resources to better optimize heat relief.

8) Cooling center public awareness source. There are several ways in which an individual could be made aware that an organization is a cooling center. They could check the HRN maps put online by the Maricopa Association of Governments, or check the online website of the organization if one exists to see if they are a cooling center. Other ways of letting the public know about being a cooling center is by having signs outside, advertisement in newspapers, television adds, in mailings like a newsletter, and by word of mouth. Knowledge of a cooling center is critical because people can't make use of the cooling centers for heat relief unless they are aware of its existence first.

Qualitative interview questions asked of HRN facility managers in interviews. The eighteen specific qualitative interviews questions were asked of facility managers in open ended response format as listed in Appendix A. These eighteen interview questions were originally designed as part of the 2014 HRN cooling center program evaluation study. However, the large number of open ended questions led to a good deal of rich discussion about various aspects of the facilities operations that allowed evaluation of the eight different network attributes for this study. Due to the fact that these eighteen interview questions were from a study for program evaluation to learn about the cooling center programs as a whole, the categories and types of responses observed in the interview are related to the questions asked.

Data collection. The data was collected as a convenience sample of recorded interviews from a 2014 program evaluation study of HRN cooling centers performed by MCDPH, ADHS, and ASU. In that study, a total of 52 facility manager interviews were conducted by all three research teams. A subset of sixteen interviews from the ASU team was selected for analysis in the current study. This is subset of interviews represented from the ASU research team that I helped lead for that program evaluation study. These sixteen recorded interviews represent a set of interviews from a single research team at ASU and therefore represent a consistent sample for analysis. These interviews were conducted between July and August 2014 at each of the cooling centers. The data was recorded as an audio file using a digital voice recorder with permission from the interviewee. The ADHS Institutional Research Board granted exemption approval for this study involving human subjects because it was for program implementation and used anonymized data. This study requires anonymity of participants, so facility managers and their organizations will be referred to in generic terms that prevent identification.

Research setting and interview approach. The setting of the interviews was at each of the cooling center facility manager's office location for their organization. The interviews were begun by introducing the study via standardized description to the interviewee, and getting their recorded permission to record the interview as data. There was a mixture of quantitative and qualitative questions contained in the semi-structured interview format. The semi-structured approach allows for a scripted set of questions to be asked of the interviewee, while still allowing for divergence of discussion to topics other than those asked directly (Bernard, 2011). In this study, quantitative questions were not of interest since the focus is on open ended qualitative responses to such questions.

For example, quantities of water bottles distributed were not of interest, whereas the meaning and reasons behind such distribution were of interest in this investigation. There were eighteen specific open ended questions that each participant was asked directly. The responses to these eighteen open ended interview questions were used to answer questions of the eight network attributes. The results of the answers to the eight attribute questions are used to inform the answers to the four research questions from the introduction.

Data analysis and interpretation. The recorded data was coded using categories and subcategories to help organize different responses by topic to prevent creation of a myriad of different codes that are not organized (Friese, 2014). Coding is tantamount to interpreting a section of data and applying a label to categorize the content. Further, inductive coding based on content of the interviews was used (Creswell, 2009) since there is not an extensive literature on collaborative networks of nonprofit organizations, especially of the ad-hoc type described in this study. Inductive coding is a bottom-up approach that lets the codebook stem from the data rather than starting with *a priori* deductive codes based on theory from the literature for example. Subcategories were applied to responses that had common themes, hence this allowed development of thematic analysis according to subcategory. The method used here is exploratory thematic analysis (Saldaña, 2015), using thematic coding with categories and subcategories to organize codes.

Audio coding. The oral coding technique of Bernauer (2015) was applied in the analysis of this qualitative data, using a modified form of the original application. The original application of this coding technique had the analyst listen to the original audio

source from recorded interviews repeatedly over several days to allow great familiarity with the interview data, extract quotes, and annotate themes or concepts. Then the analyst would record subsequent audio comments containing analytic memos along with reflection on research questions. Those recorded memos and reflections would then be consolidated into abstracts for use in reporting. The approach used here in this chapter uses this same approach of listening to audio interviews, but is different in that the analyst writes reflections and analytic research memos rather than recording them. This puts the synthesis material from the analyst into a readily available written format to be used in research reports and analysis. "This form of oral coding keeps the researcher deeply embedded in the literal voices of participants, allowing nuanced inferenced and interpretations of vocal tones, rates, subtexts, and the like. The interweaving of participant quotes with researcher comments stimulates a dialogic exchange resulting in cumulative and transformative insights." (Saldaña, 2015, p. 74) The approach used in the present study is a modified hybrid coding approach that uses oral coding for listening by the analyst, while retaining more concrete aspects of the analyst writing rather than recording subsequent quotes, as well as research and analytic memos. As a result this captures the benefit of familiarity with the original audio interview data, while using written rather than audio recorded analysis memos for analysis.

Results

   An overall summary of the results from the analytical memos that were taken for each of the eight network attribute inquiries is presented below. The results for the four

research questions is then presented, supported by data from the network attributes. This is a qualitative interpretive analysis, and so meaning within each case is sought, rather than an ability to generalize to a larger population. Some network attributes had a good deal of material that was available from the interviewees as data, while one network attribute did not have much to offer for insight from the data but are reported for completeness.

Summary of thematic code pattern and frequency for codes of interest. There were a total of 139 distinct codes, shown in Appendix B, generated for this thematic code analysis of the sixteen interviews. Where possible, categories and sub-categories were used to help respectively group and distinguish grouping from one another. That is, a category of an answer type may occur for every single interview, with a different sub-category of code response for each of them if responses were sufficiently diverse. The description of coding outcome described below highlights occurrences of interest given the focus on heat health risk reduction for cooling center visitors.

Network Attribute 1) Manager's articulated role in mitigating heat health risk. Generally, there were two main themes that were found in answer to this question. One theme was given usually by poor and homeless service organizations who said that they offered heat relief because it was a core need of their primary service population. The other main theme was the articulation that an organization was there to serve the community in general, including heat relief, and this was associated with senior centers, and parks and recreation facilities. This makes sense in that different organizations are oriented to different primary client bases, namely the homeless and poor, or more the general public at large.

The manager of a poor and homeless services organization said that their role in providing heat health risk reduction was indistinguishable from their core mission to help the basic needs of anyone who comes to them. They are the community action agency for social services in the city in which they reside, so the service of cool space and water to homeless especially is something they would carry out whether they were part of the HRN formally or not. The manager described doing outreach during open hours where coolers of water were brought to people recreating or homeless in the area who need it. They try to relieve the root causes of homelessness and poverty through a variety of social services. He said, "*We're the community action program to provide a, we're one of the few facilities that if you come in you can stay in our lobby all day long provided your behavior stays within the behavior policy whereas other facilities would question why you're there. ... That's essentially what our services are, to provide for our clients in their basic needs. Whether that's food, we don't provide shelter but we can provide resources ... so, a core need is hydration.*"

A different articulation for serving the homeless and poor as their primary service population was offered by a Christian outreach ministry as being related to their faith foundations. The pastor of a poor and homeless outreach ministry indicated that their role in providing heat relief was tied to their purpose for existence, namely caring for those in need as taught in the bible. He indicated they had been giving showers, food and water to the homeless for two decades, long before the official HRN formed. The pastor said, "*Well, we're a religious institution so we see it as part of our calling. If you can see the little wooden thing up there on the [wall], and so it's an abbreviation for Matthew 25, 34:36, which is the 'I was hungry and you fed me, I was in prison you came to visit me, I*

was thirsty you gave me something to drink ...' So, you that's sort of a part of who we are as a people ... we've always been interested in the needs of the poor going back to our founding."

Another articulation of the role for being a cooling center was described in context of caring about the community needs and was expressed in terms of the value of human kindness. The manager of a poor and homeless services organization indicated that their role in mitigating heat health risk was predicated on their mission to care about people and be there for the community. She said, "*I think it's just caring about the people, their situation, you know, we're about being there for the community and this was one way that, it may not seem like it's a lot, but when you're somebody is in need for water or being cooled down, or whatever the situation is at that time when they walk in I think that it makes a big difference to know that we are a caring facility.*" A different facility manager for a senior center indicates that there is an element of moral responsibility in serving people bottles of water and giving them cool space where, saying, "*At a very human level how much of a difference can it make, just a bottle of water - it is under-rated ... so compassionate and so helpful and so kind.*"

The manager of a large parks and recreation facility saw their role in mitigating heat risk as one of primarily distributing water to those in the park to keep them from heat danger while out hiking on trails. He also mentioned that there were lots of cool areas with trees, riparian areas and cool low spots in the river bottoms where homeless people seek relief from the hot sun during the day time. The parks and recreation described its role as being there to serve homeless people water, and remove them from the parks at the end of the day so they aren't stuck in the habitat without access to water,

trying to find them shelter for the night in a homeless shelter. He said, "*Our whole thing is, and I tell this to the staff that, your role in this is to make contact with as many people as we can [to provide water] because we don't want someone to be a stat [to die]*"

Network Attribute 2) Responsibilities of individual facilities. There were a few interesting themes that came out of the second research question from reviewing the interview data. The first most common theme came generally from poor and homeless services organizations who framed their role in terms of being there to provide for the homeless and heat relief as being integral to providing such services to that population. The second most common theme for framing responsibility for heat relief was in terms of being there to help those in need, no matter where they came from. The network attribute of responsibility of individual facilities is related to the first network attribute in that responsibilities operate partially within the framing of responsibilities for heat relief. Hence there is some overlap in the responses in these two sections. A common theme found more among organizations who serve primary populations other than the homeless had a theme of balancing services between their primary service members and the needs of homeless off the street looking for heat relief. This was found to be the case generally for senior centers and a parks and recreation facility. As can be seen in the results, the opening-up of the senior centers originally as cooling centers came after a large number of homeless deaths during a hot summer, so there are not always clear cut differences in framing of responsibilities across organization type. The results below from the interviews exemplify these themes.

The manager of a senior center indicated that their reason for becoming a cooling center originally came from administrators in downtown Phoenix after a particularly hot

summer to give heat relief to those in need. Hence responsibilities were framed in part by values perceived by central administrators in the City of Phoenix to keep those at risk safe in the heat. She said, "*It came from downtown [decision to be cooling center], if I'm recalling correctly, I think we had a particularly brutal summer you know the year before, and I think it came to everyone's attention that there were a lot of, particularly in the central part of the city, a lot of folks who did not have permanent homes suffering out on the streets. ... I think at one point it was decided that we should utilize the [senior] centers for something a little more concrete, someplace they can actually identify and come in and not wait for groups of people [with water] to identify them [homeless] to distribute these things [water]*"

The pastor of a poor and homeless outreach ministry indicated that their responsibilities for heat relief were intertwined with their primary social mission of helping the neediest in society, the homeless. They were giving water, cool space and other services long before the official HRN formation and so they frame their responsibilities for heat relief in terms of serving the homeless. When asked about how homeless are treated, the pastor responded, "*That's pretty much all we see, so. That's actually not true, we get a lot of people come here to eat even though they might have an apartment or be temporarily housed. The actual homeless people are the primary target for our services*."

A different framing offered by some organizations was one in which they were there to help those in need generally, which may include the homeless but was not necessarily articulated in those specific terms. For example, one manager of a poor and homeless services organization indicated that most of their clients that come through the

door are in crisis or in need, and their primary mission is to meet those needs. Hence responsibilities for heat relief are framed in terms of what do the clients need, and hydration for survival is a core need of their client population. He said, "*Most of clients that do are people that are in crisis or in need, that is the default of our clients, most people that come through the door are here because they are in need of services for those basic needs of hydration, food, utility assistance, rent assistance, eviction notices, shut off notices are critical to the clients and the appointments we have here*."

The manager of a Christian ministry thrift store framed their responsibilities in terms of being in operation to help others, especially those in need. As far as the homeless, they would offer cool space, water, food and even clean clothes to a homeless person who came in off the street. For example, he said, *"... if they're homeless and they're hungry we'll give them a sandwich. You know, if they say they're hungry we will try to accommodate something for them. Cause we get homeless people and that's my concern at that point is you know they, they're hot and they maybe thirsty, but they've got to have nutrients.*"

A third and final major theme that was found is one of balance between service provided to their regular main year-round clients, while also meeting the need of those seeking heat relief off the streets. The manager of a recovery center framed their responsibilities in terms of primarily providing recovery services to their clients, and secondarily providing heat relief to those who might need it. However, as part of their daily operations, having water and cool space for the clients is a minimum they provide so that their clients don't suffer in the heat. In another example, one family homeless center managers said, "*Our big picture is that we are homeless shelter for families, we*

provide and put out food and then just services in terms of getting them into housing, and saving, and employment and those are our main focuses in terms of our population".
But, because homeless families are their primary service population, they also frame their responsibilities as to help homeless and others seeking heat relief.

Network Attribute 3) Flexibility to adjust role or behavior. There were different ways in which managers understood and implemented their capacity to adjust their role or behavior based on how things might change from one day to the next. These different ways of showing flexibility ranged from a variety of different ways of being flexible, to some thematic consistency surrounding making additional space and extended hours available should an acute heat emergency arise such as a local blackout. There were also instances where facility managers expressed an inability to change their role or behavior due to being at the limits of being open extensively already, or having very limited space so not being able to open-up more capacity for heat relief.

The first example of ability under the variety theme is the instance of flexibility of a cooling center that activated on days that were a National Weather Service Excessive Heat Warning to provide service at times of greatest need. The pastor of a religious outreach ministry demonstrated the ability to adjust their behavior and activate as a cooling center when the National Weather Service issued Excessive Heat Warning days. This led the organization to flexibly open up its facility on days it would otherwise not be open from 5-8pm. They also indicated that they were available for heat relief and to give out cold water bottles whenever they were in the ministry at other times and someone came in seeking shelter from the heat. This demonstrates a strategic choice to adjust their behavior based on the observed weather risk.

An example of being flexible and changing role or behavior is doing outreach on the streets outside of the cooling center, which in this example also includes giving food to the homeless. The manager of a Christian ministry thrift store mentioned the ability to adjust their role and behavior in terms of heat relief by doing more than being welcome to the homeless when they walk in, but also keeping an eye out for homeless individuals that are outside the store and inviting them inside for heat relief proactively. This is flexible because they extend their work beyond the thrift store retail operations because of their ministry and reach out to the surrounding neighborhood to invite homeless in for heat refuge. He said, "*We really watch for them [homeless] because of the makeup of the neighborhood, you'll see them, they might even sit down in front of the store and lean up against, we just go out and say hey are you thirsty, if you need cold water come in, so. We give clothes out to them too, that's part of my thing. If you need some clean clothes 'need clothes?', get a couple outfits, so we clothe them and feed them and water them and send them on their way.*"

There are different instances of cooling centers offering their heat relief under emergency situations for large amounts of people. The facility manager of a senior center indicated that they have a substantial amount of indoor space in their facility to accommodate many more people than the average amount of regular users on a daily basis. This allowed them to have many non-regular seniors from public housing come to the senior center to stay cool while the air conditioning was being fixed in a large senior public housing project where the cooling system had failed for a short period of time. The facility manager indicated that they would be willing and able to extend the facilities hours and space available to accommodate such a need for cooling a large group of

people if it were to occur. She said, "*Public housing I guess for senior citizens ... in our area ... one particular instance they had some air conditioning go out in one unit, like one tower, so their solution was we're going to bring our residents all over to the senior center to stay cool*."

In a different instance, a cooling center offered flexibility on the available space offered for cooling if there was an emergency situation. The manager of a poor and homeless services center indicated that they could only fit about fifteen people into their usual cooling center lobby. But, offered an ability to be flexible if there was an emergency situation they could open up space for at least a hundred people, indicating an ability to adjust their normal role. He said, "*If we needed to employ some type kind of emergency protocol, if we had to do that we could fit a couple hundred people. ... We could go in essence commandeer the [adjacent] senior center*."

Network Attribute 4) Interactions within the network. There was a great deal of consistency in the results for this question, with fifteen of the sixteen managers not reporting any interaction with other cooling center mangers. The one instance where there was interaction with other cooling centers was the result of work within the organization's regular local network partners rather than the HRN as the source for the interaction. For example, the manager of a Christian ministry thrift store did not have any interactions with any other cooling center managers as he was unaware of the rest of the HRN system in general. As a consequence, he didn't know where other cooling centers were to refer to those seeking heat relief or who to contact if they needed more supplies like water bottles. This example was typical of cooling center managers not being aware or interacting with adjacent cooling center managers, but rather focusing on

their ongoing daily operations. The one exception of a cooling center manger indicating that he interacted with other cooling centers was a passive interaction where he knew he could refer his homeless clients to the other cooling centers for heat relief and social services on days their own facility was closed. In that case, the pastor of a poor and homeless outreach ministry mentioned that he interacted with two other managers of a nearby cooling centers, to refer their homeless to these other community organizations to get case worker assistance and seek relief from the heat. This interaction was facilitated by local interaction networks of their regular local partners rather than by the HRN itself.

Network Attribute 5) External forces in the network. The most widespread description of broader forces affecting cooling centers with things that impact heat relief that were beyond their immediate control was that of poverty and resource limitation. The impact of poverty was described as a key factor in contributing to the poor not being able to pay their electric bills and being on the edge of homelessness, or being pushed over the edge into homelessness. In addition, cooling centers themselves indicated that they were at times also under significant resource constraint that limited the amount or quality of service they would have otherwise liked to have delivered.

An important cumulative financial impact during the Maricopa County summers are the increased electric bills from May through August from air conditioning use, according to interview data. The increased summer electric bills combined with poor families having to feed their children during the summer when during the school year they get school lunches, means there are two sources of additional expense in Maricopa County as the summer progresses. This puts a large strain on family budgets. One of the broader forces that affect the poor and contributes to homelessness are the large increases

in utility bills through the month of August that can really put a strain on the budget of poor households to meet air conditioning costs and others such as rent and food. A poor and homeless services center manager said, "*Stress levels start getting up in August, your electric bills have gone up the last two months, this is more an overall with our food and utility assistance, your money is going toward other things, electricity is the biggest piece. Kids, if you have a family, your kids are home all summer, that expense goes up because you're having to feed them. So, it's a stressful time so when we start getting into August, people's — the resources are really low, that includes our foodbank, it's always [used] the most in August because of the amount of food boxes that we do during the summer because of the electric bills being in Arizona in the heat. Whereas it would be vice versa in colder areas, we have that issue in August.*"

In another instance, the manager of a Christian ministry thrift store mentioned that there were broader forces of poverty that were affecting the poor and homeless in the area they serve that were affecting their service populations beyond their immediate interactions. He said, "*During the school year we see the mom's take their kids to school that go to school and then they'll come in the store at 8 o'clock, they'll be lined up outside. And they'll be in the store a couple of hours pushing their kids around ... a lot of them, are just, it's the poverty level, they can't afford certain things so they decide what they can do without, my big thing is that I don't want them to be thirsty ...* "

Funding limitations and resource constraints can also limit the activities of cooling centers, such as having to reduce the number of days per week they are open. The manager of a poor and homeless services center suggested that there were some broader economic forces at work such as limited funding and limited volunteers that led

them to reduce the number of days they were open from five to three days a week. Hence the broader forces at work in the community that leads to how many volunteers and funding are available is affecting this organizations ability to be open more days during the week. She said, "*It's hard because there's a lot of people that would like us to be open five days a week, but because of restrictions of, you know, money wise and stuff like that, we had to cut it back to just three [days per week]*."

Network Attribute 6) Unlimited resource access. This network attribute captures what cooling center facility managers said they would do if given access to unlimited resources to address heat relief. The main themes that arose for this question were relatively varied as compared to other questions, with only a few interview responses being similar. Three of the participant cooling center managers suggested that with unlimited resources they would work to provide shelter for the homeless first, and then work on other social problems. This is because although there are many services to help with the symptoms of homelessness, there are very few non-profits that offer permanent housing to the homeless. Another theme given by two facility managers was that of bringing on additional case workers to help get people out of the cycle of homelessness since this seems to be one of the most important factors in getting people permanent housing and changing their lives. Another two facility managers said that they wanted increased signage indicating they were a cooling center to get more traffic of people in need of heat relief, with two managers also mentioning wanting to have showers for the homeless. A final creative theme was an individual facility manager indicating that they would want to do mobile water outreach to remote homeless encampments if given access to unlimited resources.

Permanent housing for the homeless is a rare but important service that can make a large difference in getting people to a place where they can find work to support themselves. It is difficult to find and sustain a job while living on the street without access to regular hygiene among other needs. To help with this problem, one religious homeless food and services provider said, "*Probably the biggest issue we see is homelessness, so people either needing rental assistance or needing assistance to get into a home or apartment. I would say there are a lot of organizations that provide food boxes, a lot of places where you can get water, a lot of places where you can get clothes, but the one where there is very few non-profits that provide help is with housing*". This is a situation where there is a lot of symptom relief for the homeless but not a lot of solutions for the root cause of homelessness.

Another important aspect of helping people at risk for heat is helping people out of homelessness by giving them access to case-workers. This is because case-workers are able to give continued support to the homeless to help them find resources to get out of their situation. For example, putting them in contact with half-way houses where sober living contributes to efforts for avoiding becoming homeless again. A pastor of a poor and homeless outreach ministry suggested that they would want to invest in case managers for the homeless if given access to unlimited resources. This is because, as he said, "*Case management is the biggest single factor in removing somebody from homelessness, there's no argument about that. … Case managers need to be paid, they're not very well paid, but they need to be paid, it's extremely valuable and makes all the difference in the world for being able to actually transform somebodies' life*."

Some of the suggestions for reducing heat health risk included increasing public awareness by having more signs outside and providing showers for the homeless where they could clean up and cool off in showers as a way of seeking refuge from the heat in addition to the cooling center. A senior center manager indicated that if they had unlimited resources related to addressing heat relief, they would want some type of signage or identifier at the senior center that would indicate it was a center for heat relief, as well as large "sandwich" boards out by the nearby bus stops indicated with an arrow and symbols for how to get to the cooling center. The manager also said that having hygiene services and a place to shower and clean up would be an ideal service to provide to those in need of heat relief who are homeless. She said, "*Sometimes I equate people who might be needing more than a just a bottle of water, something with possibly not having like regular shelter or something like that ... somewhere to kind of clean up, more than just a restroom like a shower*."

The final theme for this research question was unique but notable because of the creative thinking behind such a response. The formerly homeless manager of a cooling center offered insight about this strategy to have mobile water delivery to isolated encampments of homeless to help with heat risk reduction, along with distribution of heat safety kits. This recovery center manager mentioned that given unlimited resources they would put together emergency heat safety supply kits with sunscreen, lip-balm and hand sanitizer among other supplies. In addition, she mentioned that it would be great to have mobile water delivery to homeless camps where there is no onsite water to deliver hydration and give out heat safety kits.

Network Attribute 7) Communication with larger HRN. There was generally a consistent split among the different cooling center managers' responses between either having no regular HRN communication, or having an intermediate coordinator that handled communication from the HRN. Senior centers and a recovery organization employed intermediary administrative meta-coordinators that handled communication from the HRN and passed information down to the cooling center managers, which was the case for five of sixteen interviewees. On the other hand, eight of the sixteen participants reported having no regular communication with the HRN with the exception of the initial internet sign up to be a cooling center for the summer.

The presence of a central coordinator in an organization to manage communication from the HRN and distribute it to lower level cooling center managers seemed to be an effective means of managing communication. A senior center manager mentioned that they do not interact directly with the HRN but rather with their regular upper administrative coordinator that works with all the senior centers HRN communications. She said, "*We follow procedure so that information is communicated through our channels of authority, we have our coordinator, our coordinator then interfaces with other department administrators and they then communicate down to us in terms of what's available as far as water, cases of water, they then make sure if we request it, it is distributed. So it's more or less like a communications between ourselves and our coordinators, they then are communicating with everyone else so that they are aware of what is being requested, what the needs are, and if there are any questions or problems.*"

In most instances, there was little or no communication reported with the HRN, and many of these examples were for non-city related organizations, as opposed to senior centers. One manager of a cooling center indicated that they would be interested in having better communication with the HRN even meeting with the HRN members to get to know them. A manager of a Christian ministry thrift store indicated there was no communication with the HRN and any information regarding that was sent down to him from the CEO of his organization, who does the initial sign up to the larger HRN for their organization each year. He said, "*I have none [no HRN communication] because I don't know any of them. My big thing, and I work with PO's and everything and I was an administrator, I was a principle, and so we always like ... communication, that's a key element to anything that I do is that I don't always have the time to say 'oh, I need to call them [the HRN]' but if they touch base with me because it's to me that's what they do for a living is they're [the HRN] the provider, call me and say 'do you need anything, is everything okay, what's going on*?'" He also said that there would be benefits from his perspective from having an HRN meeting that increased communications, saying, "*I would even come to a meeting like that [HRN meeting] just to gather information for me and to meet people because it's all about networking.*"

Another example of lack of communication with the HRN shows that despite efforts to coordinate for water bottle donations, communication was a challenge. The pastor of a religious outreach ministry said, "*I haven't communicated with anyone since the inception of the program ... I called a guy [from the HRN] I can't remember, called some guy and he said he was going to help us to get donations for water, but I never*

80

heard back from him, I didn't hear back from him when he said he would, so that was the end of that"

Network Attribute 8) Cooling center public awareness source. The answers from facility manager interviews for this research question broke down into three main themes. Communication had a variety of modes, including word of mouth communication as the dominant form, but also included use of the internet, newspaper, signs, and flyers to alert the public that they were a cooling center. The first main theme was public awareness spread by word of mouth that the facility was a cooling center, accounting for responses from ten out of sixteen cooling center managers. These reported word of mouth strategies were often used in combination with other aforementioned communication strategies. The second theme reported by two facility managers was a situation where they lacked signage outside their facility indicating they were a cooling center, but wished to have such signs to increase the number of people seeking refuge from the heat in their facility. One of these managers indicated a need to know where other cooling centers were in order to refer his clients to the next facility based on which way they were traveling across town. The third theme was from two cooling centers that indicated they used signs on the outside to increase awareness that they were a cooling center.

The most common means of spreading awareness about the cooling centers was word of mouth. Many of those at risk for heat exposure are homeless, and such individuals generally do not have regular access to the internet based on interview data. Hence their awareness about a facility being a cooling center likely comes from being told by someone initially, or knowing that a facility is a cooling center year after year

which reinforces the original word of mouth advertising. For example, a manager of a poor and homeless service organization said, "*A lot of times people come in for different questions [about other services] and we let them know that we always have water on hand*." It was also mentioned that there are adds online and on television for their services as a heat relief station, saying "*We also have information on the websites, TV, it's publicized through normally channel three*." At another cooling center, the pastor of a poor and homeless outreach ministry said, "*Well, through the other agencies in the city, everybody knows that we're here. The [city] has two outreach workers, they frequent our facility so that when they meet somebody on the street they know they can refer them here. That is your main ones, word of mouth on the street*."

A second less frequent theme, found for only two of the interviewed managers, was one of not having signs outside but wanting them to help increase public awareness. One of those managers indicated they were interested in greater awareness of other cooling centers so they could refer their clients to other locations. One manager of a Christian ministry thrift store mentioned that, as far as public awareness, there needs to be increased signage outside their cooling center as they had none, as well as more awareness needed of where other cooling centers are located to help people find the next one as they move across the city in the extreme heat. He said, "*I need signage, I need to know where other places are [other cooling centers], are we all going to, I mean the light rail is going to be here in two or three years, are there cooling stations all along the light rail? And people come in and say where's the next closest one [cooling center]*?"

The third and final theme for this research question was found for two of the interviewed managers and included the use of signs outside the cooling center to increase

public awareness of their heat relief efforts. One pastor of a religious outreach ministry said that they increase public awareness about their cooling center by, "*Well, we have signs out, also we have flyers and you know they pass by our door so they see the signs on the outside of the facility.*" Another manager of a remotely located senior center indicated that, "*We have signs, we put signs saying we are a heat relief station.*" These efforts to publicly advertise using signage is an important outreach means and is only explicitly mentioned in a couple of interviews.

Research questions. The results for the four main research questions are presented below. The answers to these research questions are generated from the original interview data and on supporting data from the eight network attributes that were described above.

Research Question 1: How do managers articulate awareness (or lack of awareness) to the rest of the system? There is a general consistency of fairly low HRN awareness beyond knowing that the HRN manages the network of cooling centers. Based on the evidence from the network attribute seven (communication with larger HRN), most facility managers report having little or no HRN interaction beyond the initial email sign up or beyond having some initial water bottle donations delivered. There is no evidence of direct cooling center manager interaction with other cooling centers, except to refer their clients to other cooling centers in two of sixteen interviews where awareness of other cooling centers was articulated. There were three main themes that came out in answer to this research question. The first theme was one of HRN basic awareness, with no awareness of other cooling centers accounting for nine of the sixteen interviews. Three of these nine interviews expressed use of a meta-coordinator in their organization

that distributes HRN information from that central node to all the senior centers, for example. This meta-coordinator seemed to be an effective means of consolidating communication between multiple cooling centers within the same organization and the HRN. The second theme, accounting for four of the sixteen interviews, was a situation of very low HRN awareness, with only email sign up for initial contact and confirmation of participation as the only level of communication with the HRN. The third theme was one where there was an awareness of the HRN as well as contextual awareness of the other cooling centers, which occurred in two of the interviews. A final theme is from quotes in network attribute one (manager's articulated role in mitigating heat health risk) and two (responsibilities of individual facilities) that shows cooling center managers often do have an awareness of the needs for those needing heat relief — those seeking heat relief are part of the system.

The first theme was a basic awareness to the rest of the system. A senior center manager indicated that they were generally aware of the nature of the HRN by seeing the maps that they put out each year, but did not have contact with them as far as their daily operations. In this instance, this was likely influenced by the fact that a City of Phoenix meta-level manager was the contact point for all of the cities' senior centers and so the senior center did not interact directly with higher level HRN coordinators or other cooling center facilities. This indicates a non-interactive passive type of awareness of other cooling centers in the city. The manager of a different senior center indicated an awareness of the HRN in general, but did not have any extended awareness of what other facilities were cooling centers besides the City of Phoenix senior centers. The connection she had to the rest of the HRN was moderated by the middle managers at the City of

Phoenix administrative level, and did not interact directly with the HRN coordinators at MAG that may have led to more awareness to the rest of the system. This is supported by the quote from network attribute seven (communication with larger HRN) above related to City of Phoenix senior center meta-coordinators that coordinated communication between the HRN and senior centers. That senior center manager said, "*So, it's more or less like a communications between ourselves and our coordinators, they then are communicating with everyone else …*" It is noteworthy that all the City of Phoenix senior centers have a meta-level coordinator that helps them efficiently receive communication from the HRN. This is likely to make cooling center managers more effective in being aware of the HRN without burdening them with the task of directly interacting with the HRN.

In a separate instance, the manager of a senior center articulated an awareness of other senior centers like themselves being cooling centers since they are all in a competition against one another to see which can get the most donations of things like water bottles, hats, sunscreen, and lip-balm. This is in addition to the manager acknowledging the existence of the larger HRN but did not indicate direct interactions with any of the other cooling centers. The manager of a poor and homeless services organization had an awareness of the larger coordinating arm of the HRN since he received regular email updates and alerts from MAG. This seemed to be in large part due to the organization's close work with the homeless and being close with MAG as part of their internal regular communication network. This is because MAG does a great deal of work generally with the homeless and so this manager was used to getting email updates

from them regularly. The organization manager did not however display any awareness

of other cooling centers, only the HRN coordinators.

        For the second theme, the interview results generally show very little HRN

awareness with only initial email sign up contact at the beginning of the heat season

between the cooling center and the HRN. The manager of a religious homeless food and

services center indicates that there is very little awareness about other HRN cooling

centers, with no interactions with the HRN beyond the initial communication about

signing up at the beginning of the summer. This organization did however say that they

have regular and extensive interaction with their local partners such as city programs for

water bottle donations, and other regular non-profit partners related to other services they

provide.

        The third theme followed two examples are positive reports of more extensive

HRN awareness and awareness of other cooling centers to some extent. The manager of

a poor and homeless services organization displayed a good working awareness of the

larger HRN coordinators through MAG, working with them to deliver pallets of water to

supply their cooling center. The larger working awareness of HRN coordination shows

connection with and awareness of the central node of the HRN. The manager also had a

map of other cooling centers posted on the wall of their cooling center to show others

where there were other places to go to seek refuge from the heat. The posted map

displays a good working knowledge of the HRN and other cooling centers, though there

was no mention of contact with other cooling stations directly. In another example, the

pastor of a poor and homeless outreach ministry mentioned that there was awareness of

the larger HRN in terms of both coordinating with MAG for water bottle donation

delivery, and with other local network partners that were also cooling centers. This is the first and only instance mentioned among any facility manager that there was interaction with other cooling centers in any way. In this instance, it was said that they refer their homeless clients to another community organization that has homeless case workers and also serves as a cooling center. Hence the HRN is not facilitating the interaction in this case, but rather the local network partners are facilitating it.

The fourth theme showed cooling centers having awareness to the rest of the HRN system that includes the public who needs cooling center heat relief as part of the system. So, it is helpful when thinking about cooling center manager awareness of the rest of the system to include awareness of the target populations for heat relief. It is useful to think about providing a service from the perspective of those in need to best serve them. In the network attribute one (manager's articulated role in mitigating heat health risk) section above, there was a parks and recreation manager that gave a quote that shows the underlying motivation and awareness about the acute life threatening aspects of heat. He said, *"Our whole thing is, and I tell this to the staff that, your role in this is to make contact with as many people as we can [to provide water] because we don't want someone to be a stat [to die]."* This shows the underlying value in human life and knowing the hydration needs of those in the outdoor park. A second example of this awareness of the needs of those being served for heat relief comes from the network attribute two (responsibilities of individual facilities) section that frames the perspective of a poor and homeless services manager. He said, "*Most of clients that do are people that are in crisis or in need, that is the default of our clients, most people that come through the door are here because they are in need of services for those basic needs of*

hydration ..." This shows an awareness of the cooling center user part of the system and is an important aspect of consideration since serving them is the purpose of the HRN.

      Research Question 2: Within this layer of the network, how similar are the articulations of heat relief role across those interviewed? There were three main themes that came out of this question. These themes of articulation of heat relief role relate serving as cooling centers and are based on the results found in network attributes one (role in mitigating heat health risk) and two (responsibilities of individual facilities). The first theme had articulations of a cooling center operating primarily to provide service to the poor and homeless, and so could not do so without also handing out water and giving access to cool space. The second theme was held by the majority of the senior centers where they saw their role as primarily serving seniors and other regular members of the community center, and serving the homeless for heat relief as a secondary function. The final theme is of articulations of a role that is different from other cooling centers, related to serving more as a hydration station rather than cooling center in a parks and recreation setting.

      The first theme had examples of the poor and homeless being a primary service population account for articulations from six of the sixteen facility managers interviewed. The manager of a poor and homeless services organization had a similar articulation as other community services organizations that have the poor and homeless as their primary service population. She indicated that their reason for existing was to help the poor and needy, and would be doing what they do for heat relief regardless of whether the HRN existed or not since water and cool space is a basic need that is not being met for many of their primary service population. Another manager of a poor and homeless service

organization had the same type of articulation of role as other organizations that primarily serve those who are destitute, being willing to provide services to those in need as long as they are non-threatening. They see their role as a cooling center as integral and indistinguishable from their regular work with the homeless since water and cool space are something that the homeless need. The articulation of role for how this organization functions is a little different than for example senior centers whose primary service population are elderly members of the center rather than the homeless. There seems to be fewer primary services offered by senior centers for the homeless besides just water and cool space which might be expected from a different type of organization.

A description of the second theme was made by three of the sixteen interviewees. This was the articulation of being part of a dual role where the primary service population were senior or community center members, while heat relief was an important ancillary function. In these facilities, the majority of clients are not seeking heat relief or crisis social services hence the focus is not on the homeless like in other non-profit organizations that serve the homeless primarily. The manager of a senior center had similar articulations about their primary function and as a cooling center as compared to other senior center managers interviewed. There was a consideration of their primary purpose as serving seniors from the center, but also serving people from the community in general which includes being welcome to the homeless seeking heat relief.

The third theme had articulations of role in providing heat relief at this level of the network that were for being mainly a hydration station due to the nature of a parks and recreation facility. The manager of a large parks and recreation area had articulations of their experience that was different in terms of being primarily a hydration station

rather than an indoor cooling center. He said that their ranger office is away from most

of the park, so they don't get many visitors there at all. Rather, most park visitors are out

on the trails, getting water handed out to them by the rangers, and using the park habitat

itself as a means of cooling themselves off, like standing under trees rooted in riparian

areas or being on trails in cool river bottoms. This cooling center example is supported

by evidence from network attribute two that describes how the outdoor park gets some

homeless trying to seek relief from the heat in shaded parts of the park, and how they

meet that need by checking on the homeless and bringing them water. What was similar

to articulations of other managers was that their mission was to keep people safe in the

heat by giving hydration, which is appropriate given the nature of their large park.

   Research Question 3: Do managers indicate first or second loop thinking in

their responses? The idea of first or second loop learning in an organizational context

has to do with learning respectively for daily operations versus overall norms and values.

For organizations serving either community members in general, or the poor and

homeless, the managers of such facilities main role is to generally make sure that daily

operations run smoothly. Hence their thinking generally reflected this focus on day to day

operations, and therefore focuses on first loop learning thinking. Also, many of the

organizations operate under finite budget constraints that causes them to focus their

limited resources on daily operations. As a result it is not surprising to report that in the

first theme of first loop learning type thinking, thirteen of the sixteen interviews had their

thinking as first loop and focused on daily operations. For the second theme, there were

only three interviews that had managers displaying thinking that indicated learning in

terms of norms and values, or second loop thinking. This overwhelming focus on daily

operations makes sense in that the environment in which senior, or poor and homeless, needs are met is relatively unchanging – the same interventions are proven to work year after year. Of course there is room for innovation, which is what is indicated by the examples of second loop thinking in the second theme that follows.

The first theme under this research question is of first loop thinking from the manager of a family homeless shelter and is supported by evidence from network attribute two (responsibilities of individual facilities). Most of the thinking is in terms of first loop learning to adjust to variations in daily operations, such as holding supply drives for water bottles for heat relief. In addition, they focus on supply drives for the homeless families they shelter such as getting clothes and school supplies for children depending on the time of year and need. Second loop thinking in terms of shifting values was not indicated, but stable adherence to their primary mission and achieving that was indicated by first loop learning. For another cooling center, the manager of a poor and homeless services organization, like many organizations, operated on a very limited budget and set of resources. The results from network attribute five (external forces in the network) gives the following supporting evidence for a poor and homeless services organization that is only open three days a week. This contributed to much of their thinking being related to first loop learning regarding daily operations. Because their funding level limited them to being open three days a week, they wished they could be open all five business days of the week to help more people. This indicates that their constrained resources makes them focus on their primary mission of helping the poor and homeless, and likely less time about thinking about shifting their norms or values since they have been serving a core need of indigent people in their locality since 1976. When

91

the environment is relatively static in terms of what the homeless needs, focusing on first loop thinking rather than second loop thinking is likely helpful in being consistent with their primary mission.

In the second theme, there are only three examples found that qualify for second loop type thinking among the participant interviews. The first example comes from a cooling center manager that was once homeless, so there is a shift in normative thinking on her part to have a change in norms and values based on prior homeless experience and what might actually help someone in that position. This is supported by the results from network attribute six (unlimited resource access) that refers to the mobile water outreach idea from a recovery facility manager. The manager commented on ideas about doing mobile water and heat relief kit delivery outreach and the nature of leadership and implementation that would work best when approaching groups of homeless living in parks and other informal areas with heat relief supplies. This thinking was indicative of wanting to shift the norms and values of the kinds of operations that their organization performed, and hence was akin to second loop learning type thought. This is because the recovery facility does not have standard norms for doing outreach to the homeless, so this represents a value shift relative to the organization's primary mission of recovery assistance. She said, "*It could make a big impact, a big one, because not all of the homeless are willing to do their own outreach for help, so having somebody immersed in that culture that's willing to go there and be part of it and build a rapport and trust I think would be essential. ... and familiar figures that people know, trust and believe in.*" The manager also mentioned, "*I think the best folks to be driving around [giving out water] is peers, people who have been there and done that, so they can have really an*

understanding of what the folks on the street are going through, and really be able to provide that inspiration."

Another example of second loop learning type thinking came from the manager of a cooling center of a thrift store that did outreach and worked with the homeless for additional services, extending what they offered far beyond what a normal thrift store would. This result is supported by evidence from network attribute three (flexibility to adjust role or behavior), relating to doing outreach to homeless needing heat relief outside of the Christian ministry thrift store. That manager of a Christian ministry thrift store generally thought in terms of first loop learning for daily operations since they help meet the needs of the poor and homeless. However, there were instances of second loop thinking where due to the extended norms associated with their Christian ministry, there were aspects of thought that resembled second loop learning because it embodied a shift in values from what a normal retail operation would have in mind for goals — normal retail operations don't do homeless heat relief outreach. The manager said, "*I think that we need to take care of each other on this planet, regardless of your religious background you should still take care of each other on this planet*."

A final example of second loop learning type thinking comes from network attribute six (unlimited resources) that discusses the point of view of a senior center manager. That manager had articulations of wanting to change the types of services offered to homeless people if they had unlimited resources. The senior center usual normative approach is to give services to seniors but to give hydration and heat relief to the homeless who aren't part of their normal client base. In this instance, the manager indicated that she wanted to create showers and hygiene supply kits for homeless people

93

that are in need of heat relief, which represents a normative shift in thinking from caring about seniors primarily, to also thinking and acting on the needs of the homeless.

Research Question 4: What insights does this case bring to bear on climate adaptation and institutional resilience? The specific type of climate adaptation brought to bear by cooling centers is increased resilience to extreme heat that is provided through access to cool space and water, as well as other services. Here resilience is defined as, "… a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables." (Holling, 1973, p. 14) This means that resilience could be increased to the HRN system, or an individual's resilience depending on the contribution a cooling center makes to heat relief.

The most frequent first theme of institutional resilience found in the interview data was multi-year participation in the HRN which gives a consistent presence to the network of cooling centers — supported by network attribute eight (cooling center public awareness) for the word of mouth communication strategy that most cooling centers rely on for public awareness of the cooling center. This is important because word of mouth is the primary way public awareness among the homeless and other populations spreads about a facility being a cooling center. Hence being there year after year increases resilience of the HRN through increased awareness for the neighborhood they serve by being there annually. The second theme for institutional resilience was the ability of several cooling centers to increase the amount of space or open hours they had available in the event of an extended heat emergency where many people in an area were without power and needed refuge. This second theme is supported by results from network

attribute three (flexibility to adjust role or behavior) that discusses the ability of some

cooling centers to open up additional space for heat relief should there be an emergency.

This could occur when a certain part of the city has lost power and emergency plans were

put in place to give the residents heat relief at the cooling centers. The final theme was

an individual's resilience increased as the result of institutional programs, such as

assistance with utilities and air conditioning repair, or food programs that increase

resilience in individuals for food security. In other words, people experiencing poverty

or homelessness have their personal resilience increased by ancillary social programs and

support offered as primary client services by poor and homeless services organizations.

This final theme is supported by network attribute five (external forces in the network)

that describes extensive ancillary services provided by poor and homeless services

centers to increase individual resilience by giving social services.

 Multi-year participation as a cooling center often extended much further back in

time beyond the initial formation of the HRN in 2006. For example, a manager of a poor

and homeless services organization said that they had been operating as a cooling and

hydration center informally for many years — since 1976 — long before the HRN was

officially formed in 2006. This institution's persistence shows a continual source of

institutional resilience for the homeless and poor they serve with all types of services

beyond just cool space and water. This is because providing shelter from the heat and

giving water is part of their core mission to serve the homeless, which also adds

resilience to the community by helping avoid heat related mortality and morbidity.

Another facility had a pastor of a poor and homeless outreach ministry who indicated that

they had been serving the homeless showers, food and water for over twenty years in

95

their current location, hence they were continually adaptive in a challenging funding

environment to persist over time. This long-time participation as a cooling center, even if

informally before the HRN inception in 2006, means that this institution has been a

source of resilience to the community where homeless can come and get some of their

needs met while getting respite from the heat. This year after year participation in the

HRN is an important aspect of community resilience since it becomes a regular fixture

for homeless and others to seek aid year after year, increasing consistent awareness of the

cooling center's existence through spread by word of mouth.

In the second theme, there were a variety of ways cooling centers showed

resilience in terms of having extra space available in an emergency, or by offering food to

increase food security and improve hydration through electrolytes. The manager of a

recovery facility gave comments that were indicative of their facility adding to

institutional resilience since she indicated a willingness and ability to open-up additional

space in their facility in the event of a widespread heat emergency such as power loss in

another part of the county. She indicated further availability of offering food from the

lunch they serve to anyone who came in off the street for heat relief. This is a modest

case of ability to adapt to a climate of extreme heat through the willingness to be flexible

and address those in need should the occasion arise by offering extra space for heat relief

in the event of power loss in another part of town. In another instance, a manager of a

Christian ministry said their thrift store was attached to an integrated foodbank in the

back of the store to provide resilience to the local residents in terms of both access to cool

space in the thrift store and food security through the food bank. The thrift store and food

bank have access to many sources of public and private donations to support their

operations, making them resilient to funding fluctuations from any single source. The thrift store and integrated food bank is able to offer consistent services through their resilient funding sources to the people it serves by increasing their resilience to extreme heat and food security. In this way, one form of resilience in funding allows provision of other services that adds resilience to the community.

The third theme indicated there was use of a case worker to assist their clients with utility bills and air conditioning repair costs. This adds general resilience at the individual level allowing people in financial distress for example to get benefits from public assistance and other programs. One senior center manager mentioned an instance where they were a source of institutional resilience to their regular senior center members by having a case worker help them with expensive utility bills and HVAC repair. The manager said, "*A case worker, often times what happens with him is that we have individuals who need help with their utilities ... paying the bill, oh well sometimes repairs too and we're making referrals to ... other agencies or nonprofit organizations that have the where-with-all to repair AC units, evaporative coolers, insulation — those kinds of things. So, of late we've been having individuals coming in wanting assistance with their utility discounts, signing up for them or renewing the discount. Because AC can be pretty expensive especially if you are on a limited budget. And we've had a lot of people, lot of people, looking for those discounts.*"

Discussion

The awareness of cooling center managers relative to other parts of the HRN system is important because it affects how they interact with other cooling centers and the larger HRN coordinators. These interactions could be only with the higher level HRN coordinators which was the majority of cases; it could also be horizontal interactions with other cooling centers (direct or indirect) such as indirect referral of clients to other cooling centers as was shown in one exceptional example in the interview data. The way that cooling center managers perceive the position and role of their organization in the HRN is from intra-organizational level perspective of network interaction (Yih-Tong Sun & Scott, 2005). Some of the organizations in the HRN function with heat relief as a secondary function after they serve their primary population, senior centers for example, while others are highly constrained by resources and therefore must focus narrowly on daily operations to serve their clients. The fact that interaction with other HRN members requires an investment of time and energy, when both are often scarce, means that there is little opportunity to invest in relationships across the HRN with other cooling centers. For this reason, this ad-hoc network has few horizontal connections among cooling centers, and mostly vertical hierarchical network connections with the higher level HRN coordinators.

In the HRN opportunities for horizontal network communication may not always be taken advantage of by members and could default to a hierarchical communication form as has been shown in other cases of organizational internet communication (Oberg & Walgenbach, 2008). In the case of the HRN, it is not surprising that there is little if any horizontal interaction among cooling centers. This is due to their focus on their

primary organizational function besides heat relief and the lack of investment in coordination and communication opportunities by the HRN coordinators for cooling centers, such as a digital communication platform online. As a result, there is little horizontal contextual awareness of the nodes of the HRN (i.e. cooling centers) of one another, with only a vertical contextual awareness of the HRN coordinators for annual HRN sign up, and water bottle donation requests.

There is a widespread pattern of cooling centers operations focusing on interactions with their local year-round network partners, rather than interacting with other cooling center managers facilitated by being part of the HRN. The reason for this seems to be little awareness of the rest of the HRN and little perceived need to generally interact with other cooling center managers since all organizations have a primary purpose other than being a cooling center, which is an ancillary function. Most facility managers are focused on daily operations and usually do not have extra staff time to reach out to other cooling center managers. If a cooling center did need extra water bottles when running out, they were more likely to contact the HRN directly rather than coordinating with other cooling centers. Even the single instance of a cooling center manager saying that they referred their clients to two other cooling centers on days they were closed was the result of their internal local network interactions, rather than being facilitated by the HRN. This lack of interaction with other cooling center managers suggests that such interaction may not be a critical aspect of being a cooling center, and that interaction with the HRN coordinators for extra water bottle donations could be a more critical strategy. One benefit that would help those seeking heat relief would be an

increased awareness of other nearby cooling centers to refer clients to even if the cooling center managers didn't interact with one another directly.

Communication has been shown to influence organizational culture as a means of shaping such culture where vertical upward communication has a positive effect on organizational performance and its perception (Garnett, Marlowe, & Pandey, 2008). This suggests that improved vertical communication in the HRN between cooling centers and HRN coordinators could improve organizational performance and its perception. A useful attribute of several cooling centers, particularly senior centers, is having a central coordinator pass information from the HRN along to the different cooling centers. This helps streamline communications and appears to make it more efficient with less overhead on the organization. Therefore it is helpful for communications in such situations that the meta-coordinator is there to facilitate two way communication between the HRN and a cooling center when needed. The ability to request more donated bottled water from the HRN is an important type of communication from cooling centers to the HRN that should be maintained to keep supply of water flowing. Other one way communications from the HRN to cooling centers can simply be passed on by email or other means to the facility managers.

The majority of cooling centers reported not having any regular communication with the HRN beyond their initial sign up, and sometimes an initial water bottle donation to the cooling center from the HRN. Improved two-way communication and information transfer is one potential way to meet needs at the community or urban level (Sheppard et al., 2011). Hence improved two-way communication in the HRN between cooling centers and HRN coordinators is likely to help meet community needs in the urban

100

environment of Maricopa County. These are instances where improved communication between the HRN and cooling centers could facilitate more efficient distribution of needed donated bottled water and updates with cooling center related information such as when Excessive Heat Warning days are forecast. There was only one example of positive regular communication between a cooling center and the HRN, and this was found to be satisfactory by the facility manager because it allowed them to get the donated bottled water they needed from the HRN. In general, improved communication would be helpful to improve water bottle distribution and keep cooling center managers up to date on events happening relevant to the HRN. This could be achieved by getting and using email contact information for the cooling center facility managers in instances where there is no meta-coordinator to manage communications with the HRN.

The motivation for being a cooling center from most facility managers was because it was part of their core mission to take care of those in need, and they indicated they would be doing the same heat relief work whether the HRN existed or not. This type of motivation across an organization is an example of how organizational culture can manifest itself to affect patterns of behavior (Martin, 1992; Schein, 1983). This motivation was found with nearly all poor and homeless service organizations, and with some senior centers. In fact, several of the cooling centers had been doing their work acting as cooling centers for long before the HRN was officially formed. This means that there is a high degree of internal motivation among these organizations to meet the needs of the poor and homeless in terms of heat relief by volunteering their space and resources without any compensation except water bottle donations. Their participation in the HRN only increases their visibility to the public with the online MAG maps and makes them

easier to refer clients to other cooling centers since they are known from those MAG maps. An additional value added for an organization to be part of the HRN is this ability to spread information about other cooling centers and the allocation of donated water from the HRN to cooling centers that would otherwise rely entirely on internal network donations.

The results from looking for first versus second loop learning type thinking in these interviews was highly skewed toward first loop learning thinking (Argyris & Schön, 1996). This makes sense since most managers responsibilities are to maintain the day to day operations of their facilities primary function, with ancillary service as a cooling center. Further, it is known from the literature that a properly functioning first loop learning cycle is required for any second loop learning, and examples of second loop learning are rare (Schimmel & Muntslag, 2009). Hence *a priori* one would expect to find more first loop learning examples, not knowing anything else about the organizations. Because many of these organizations are on limited budgets and have clients that are experiencing social crisis, there may not be a lot of incentive for these organizations to question their norms or values for second loop type thinking. This is because the environment for those with heat health risk is relatively unchanging, occurring year after year with a chronically hot climate. As a result, many of these organizations focus on first loop learning and manage their day to day operations with care. This is especially important when the cooling center operates, as many do, under significant funding constraints that limits the amount of creativity and expense they can spend beyond their primary mission. There were only three examples of second loop learning type thinking that are indications of thinking about changing norms and values and were much more

rare that the commonplace first loop learning examples. These were second loop examples where the cooling center managers were thinking beyond traditional norms for their organization, for the mobile water delivery example from a previously homeless manager. There is no specific indication that there are attributes that distinguish managers who exhibited first loop learning from those who exhibit second loop learning.

The cooling centers represent an example of increased climate adaptation and institutional resilience because they offer refuge from the heat by definition. This is an example of urban resilience that can "… maintain or rapidly return to a desired function in the face of disturbance, to adapt to change, and quickly transform systems that limit current or future adaptive capacity." (Meerow & Newell, 2016, p. 7) That is to say cooling centers provide heat relief that allows moderation of heat health risk in the face of a disturbance caused by extreme heat events in Maricopa County. These organizations however have additional aspects of institutional resilience that go beyond just offering cool space and water in any given year. Most importantly, year after year participation by an organization increases the resilience of the HRN because of the consistent word of mouth spread of awareness that their facility is a cooling center. This means that for a new cooling center in a given year, there is likely a learning curve over time for the homeless to learn about what new facilities offer heat relief. This is because a new cooling center's existence in its first year of participation is not part of the existing word of mouth awareness in the minds of those who need heat relief. Since the homeless learn about cooling centers by word of mouth, they are most likely to know about cooling centers that have consistently been part of the HRN rather than a new organization volunteering in a single year for example. As a result, this year after year participation is

more effective than an organization just participating sporadically across years. In addition, year after year participation increases the climate adaptation of the local area they serve in terms of consistent heat relief in a given neighborhood. Other types of institutional resilience that were important included the ability to open-up extra space to cool hundreds more people in areas usually not used as part of the cooling center in the event of a large emergency. This gives the county resilience in keeping large numbers of people cool in the event of such an emergency like a power outage in a certain part of the county. Also, there are ancillary programs that the cooling centers offer that help poor clients cope with poverty that increases individual resilience.

Conclusion

Cooling centers offer reduced heat related mortality and morbidity risk to those that seek heat refuge by using latent organizational resources to from this ad-hoc network (Berisha et al., 2017). An important finding is that there is little to no horizontal network communication between cooling centers, and the majority of communication is hierarchical between cooling centers and the HRN coordinators. This means that although the HRN is an ad-hoc network with some self-organizing features (such as cooling center self-selection of open hours), it retains some features of a hierarchy due to lack of horizontal communication. Also, second loop learning type thinking was found to be rare given the exigent circumstances that most of the volunteer cooling centers operate in by helping those in need of heat relief. On the other hand, first loop learning type thinking was common and was expected to be the larger share of learning type thinking

found in the interviews. This is because even though climate change is slowly increasing heat wave frequency and intensity, from the cooling center manager's perspective the environment is chronically hot during the summer most of the time and so they offer the same services year in and year out. This means that they likely focus on stabilizing strategies with respect to their current operations which lends itself to first loop learning type thinking.

There is a great diversity of perspectives across the interviewed cooling center managers, but some consistency in the experience of different categories of cooling centers. One important difference among the cooling centers to note was the central coordinator for the senior centers that helped with communication, where private non-profit organizations did not generally have central coordinators to communicate with the HRN. Having a central coordinator for different regions of the HRN may be one way to improve two way communications between cooling centers and the HRN, especially to request bottled water when needed. There was also an indication by some facility managers that public awareness could be improved through increased signage and handing out HRN maps to help spread the word of cooling center locations. Ultimately, addressing the root causes of homelessness and poverty by having social services that alleviate these causes can be an important means to remove an individual from heat health risk. As a consequence, social services for food, utility and rent/mortgage assistance are underscored as being critical to supporting people on the edge of homelessness especially toward the end of the summer in August. This is because many living in poverty are pushed to their budgetary limits due to high summer electricity bills from air conditioning costs and paying food costs for children that are normally in

reduced fee lunch programs during the year. Importantly for the homeless, case workers are a critical element in connecting them with resources to find housing, employment and treatment for underlying mental illness or addiction. These last few suggestions can be a large source of support in keeping someone from becoming homeless in the first place, or help someone out of a homeless situation and hence reducing their heat health risk.

CHAPTER 3

PROTOTYPE MODEL DEVELOPMENT TO ENABLE

LOCAL INNOVATION THROUGH COMPLEXITY GOVERNANCE

Introduction

The previous second chapter of this dissertation evaluated the perspective of

individual managers of cooling centers, which refers to both heat refuge (cool space and

water) and hydration only stations in the Maricopa County Heat Relief Network (HRN).

This third chapter on the other hand looks at the larger network level, uses the concept of

complexity governance, and describes a participatory modeling approach using simple

agent based model to represent the Maricopa County HRN. The first part of this chapter

considers opening governance to a complexity governance perspective. This first part is

then followed by a discussion of enabling local decision making and innovation through

complexity governance. There is a subsequent discussion on participatory modeling in a

complexity governance context.

Complexity governance can be defined as "… an emergent, self-organizing

process and structure in which a wide range of actors including the public, government

agencies, nonprofit organizations, for-profit organizations, and/or international

organizations voluntarily and dynamically interact with one another on a relatively large

scale to resolve complex social problems in an innovative and collective way and

ultimately advance the common good by using information and communication

technologies." (Park & Johnston, n.d.) The research question being asked in this chapter

is: *can the HRN be viewed as an example of complexity governance*? The methodology

used in this chapter to answer this question relies on a literature review of different types of governance theory and participatory modeling from past studies. For example, hierarchical governance versus network governance. Conclusions will be drawn based on these literature examples in the context of the HRN and how well the HRN case fits within the definition of complexity governance. The HRN case allows consideration of how to take advantage of complex systems theory in a governance context. The following discussion goes between theory and participatory modeling to aid in a complexity governance approach to the HRN.

Societies are addressing increasingly complex governance challenges that necessitate collaboration between many organizations. Harnessing the emergent abilities of these collective efforts requires new administrative strategies and techniques, but if done well also provides promise for addressing important social challenges. In Maricopa County Arizona the Department of Public Health reported 632 confirmed heat-associated deaths from 2006 to 2013 (MCDPH, 2014). In response, public health and other organizations coordinated across the County with a collection of public and private organizations and non-profit groups to provide services for heat relief as cooling centers starting the summer of 2006, also known as the Maricopa County HRN. Here we show how development of a prototype model for future use in participatory modeling can be used as a tool to enable this ad-hoc collaborative network to self-organize to provide more efficient service. The voluntary nature of the network imposes a structure on cooling service provision, such as the locations and open hours of centers are largely based on other ongoing operations of organizations that volunteer their space and resources. There are consequently both gaps and redundancies in spatial and temporal

cooling center availability that exist when the network is examined from a system perspective.

During late 2014 and early 2015 a simple prototype agent based model was developed that visualizes relevant components of the regional Heat Relief Network's function. The intent is to use the prototype agent based model in future participatory modeling exercises, described further below, with stakeholders to improve the model and overall systems thinking among other benefits. Through this process, it became clear that such a model could contribute to increased systemic awareness of HRN participants for both challenges and opportunities of coordination across the network. Further, this effort could help network members begin to see cooling centers from a systems perspective, leverage their ability to see dynamic cooling center availability spatially and temporally and thus increase opportunities to align services along both dimensions. The intention for developing this prototype model was future collaboration with the Heat Relief Network in central Arizona using subsequent participatory modeling approaches. The approach used here highlights development of a simple prototype agent based model for participatory modeling as an innovative means for translating evidence to practice and facilitating knowledge dissemination, two important elements for successful applications of complexity governance.

Participatory modeling involves stakeholders where meaningful stakeholder participation (King, Feltey, & Susel, 1998) can improve local policy innovation because those on the ground have expert local knowledge (Cinderby & Forrester, 2005). It has also been shown that public participation that links technical analysis with public deliberation iteratively can aid in dealing with difficulties in resolving conflicts among

perceived facts and values (Dietz, 2013). This approach has been successfully applied to other complex public health challenges. An example of this is a participatory modeling process to evaluate the complex system of the polio virus to try and build a useful model for policy analysis, allowing for iterative reframing until the "right" questions are asked (K. M. Thompson, 2015). An analog in the HRN involves the potential discussion about providing heat relief to homeless individuals in Maricopa County. Whereas the conversation would begin by considering the spatial distribution of cooling centers relative to known locations with high density of homeless individuals, it could evolve to a deeper consideration of other barriers (besides distance) that might discourage or inhibit a homeless person, for example, from seeking and obtaining relief from the heat in a facility that officially participates in the formal HRN.

The ultimate goal of the HRN is to reduce preventable illnesses and deaths. In particular, it is of interest to answer the question of how to best leverage available public and private resources to yield the greatest reduction in the public health burden associated with extreme heat. The participatory modeling approach offers potential benefits of matching the solution to the scale of the problem, facilitating a systems approach, and directly motivating local innovation.

Maricopa County HRN case. Our case study for participatory modeling represents a geographical and contextual setting in which a process innovation (potentially derived from participatory modeling) could lead to significant improvements in addressing a variety of public health challenges. Maricopa County, Arizona is home to one of the largest and rapidly-growing metropolitan areas in the United States, and faces extreme heat conditions each summer that have been linked to heat-related morbidity and

mortality (Petitti, Hondula, Yang, Harlan, & Chowell, 2015). The more than four million

residents from two dozen cities and towns that comprise Maricopa County, including the

city of Phoenix, consistently face the highest summer temperatures observed of any large

metropolitan area in the United States. Over the 2009–2013 period the Maricopa County

Department of Public Health reported 632 heat-associated deaths (MCDPH, 2014), as

well as hundreds of extreme heat-related hospitalizations and emergency department

visits. These impacts occur against the backdrop of increasing population, urbanization,

and observed as well as predicted temperature increases associated with global- and

regional-scale climate change (Georgescu, Moustaoui, Mahalov, & Dudhia, 2011;

Hondula, Georgescu, & Balling, 2014). As other large cities around the world with

vulnerability to heat continue to face increasing temperatures, they will likely benefit

from lessons learned in Maricopa County.

   A range of public health strategies are in place to minimize heat-related health

impacts in many jurisdictions around the world. In Maricopa County in particular, many

of the components of an effective campaign to combat heat-related illnesses and deaths

would seem to be in place including extensive research documenting heat impacts in the

region and variability across spatial, demographic, and occupational dimensions (Harlan

et al., 2013; Hondula & Davis, 2014; Petitti, Harlan, Chowell-Puente, & Ruddell, 2013).

Regular communication between state and local public health agencies, university

researchers, and other stakeholders is maintained by the HRN in addition to a public

warning system for extreme heat operated by the National Weather Service. Each year,

HRN public health efforts include information campaigns about the health risks of

extreme heat and water bottle donation drives. The continued heat-health impacts in

Maricopa County even with such preparedness and intervention activities in place suggest that there are opportunities to improve outreach and relief efforts. We propose that participatory modeling is a useful means of identifying opportunities to improve the coordination of current service provision within the HRN to further increase effectiveness of one of many interventions for heat relief in Maricopa County. The future use of prototype participatory modeling mode of engaging HRN stakeholders was chosen because it presents both spatial and temporal cooling center availability in a visualization format that is relatively easy to understand. Further, this modeling approach provides a simulation experience where stakeholders could interact with the model by changing parameters in real-time, such as cooling center coverage radius.

The co-learning process, or joint learning between the modeler and stakeholders, is helpful because it allows through participatory modeling a better understanding of the different perspectives from different members of the HRN. The approach used by this dissertation is designed to leverage existing heat relief resources through coordination and communication at the intersection of historical heat impacts and cooling center availability in space and time, including HRN annual variability. This is especially important because although the location and availability of cooling centers is published by the Maricopa Association of Governments (MAG), the daily operations and logistics for most cooling centers are determined on a facility-by-facility basis largely independent of the other cooling centers. The exception occurs where there is a cluster of community centers managed by a single administrative agency where an intermediary coordinator aids in connecting their cooling centers to the HRN.

Effective governance of regional challenges facing the residents of Maricopa County spans many formal and informal jurisdictional boundaries and networks, with twenty-four nearly contiguous yet distinct municipalities. Minimizing health impacts associated with extreme heat is a challenge shared across the County and is not unique to any jurisdiction. Coordination at a county or regional level potentially enhances the effectiveness of various intervention measures via shared resources, knowledge, and practices. MAG and City of Phoenix are primarily responsible for coordinating the HRN activities across the County. MAG also supports the HRN operation through annual recruitment of cooling center volunteers, and provides online maps of cooling center locations and open hours.

At the beginning of each year, HRN coordinators solicit participation in the network by reaching out to past participating organizations and other potential partners directly or through broader advertising efforts. The network is voluntary, and most organizations that participate as cooling centers would offer air conditioned space and water even if the formal HRN was not present. The HRN does engage in recruiting new organizations to participate as cooling centers, however most HRN organizations volunteer as cooling centers every year. In this sense, these cooling centers are self-selecting in their annual participation in the HRN, although central coordination of the formal HRN is top-down in approach. One objective of this research is to determine if and how cooling center facility managers and other stakeholders could enhance coordination with each other. Volunteer organizations for the HRN can register to be a cooling center using a MAG online registration form. Figure 4 shows the 2013 Maricopa County area cooling centers. The prototype model coding was begun in 2014 before that

year's HRN map had been published, hence the prototype uses the 2013 HRN data. Because most HRN members participate year after year, there is very little difference between the structure in 2013 versus 2014.

There is an impact of path-dependency (Sole & Goodwin, 2002) such that historical patterns of where organizations have chosen to locate their primary service delivery determines where cooling centers are located in the present. Cooling center spatial location and open hours are almost exclusively driven by this historical development path of where volunteering organizations reside. This development path that has not been specifically designed for heat relief efforts, now constrains the HRN's spatial structure each year when new and returning HRN organizations volunteer. The benefit of this path dependent voluntary network of cooling centers is that it leverages existing latent resources. However, the HRN itself has not been deliberately optimized for heat relief. This path-dependent spatial aspect is superimposed on a similar temporal constraint in which the open hours of cooling centers are driven by organizations' normal operating hours. The traits of cooling center location and open hours add together to yield both redundancies and gaps in the distribution of cooling center availability along these dimensions. In addition, facility manager interviews from a 2014 cooling center evaluation project indicate that once the summer season begins, relatively few cooling centers remained in close contact with other HRN participants to coordinate and share resources (Berisha et al., 2017). The majority of cooling centers were found to generally operate independently of the larger HRN. The HRN organizes cooling center location and open hours that bridges several municipal jurisdictions at the regional scale.

However, daily operations and resource distribution of cooling centers most often operate independently or with their familiar local networks that are not part of the HRN.

The process of these public health organizations participating in the 2014 cooling center evaluation project (Berisha et al., 2017) led to idea exchange and relationship-building information between these public agencies and cooling center program managers. The idea is to provide conditions for the network to find the best ways to leverage existing resources to reduce heat health risk. In addition, the hope is that this process will reveal where the most productive areas would be for investment of additional resources to reduce heat health risk without increased effort and burden on a central organizing authority. For example, communication across the HRN is presently mediated by MAG, with individual voluntary cooling centers not generally having direct contact with facility managers at other cooling centers in the network. This network structure restricts communication through the central organizers at MAG, rather than creating a means for cooling center facility managers to communicate directly with one another, for example, to optimize resource allocation. This would likely have benefits for the HRN, and reduce the burden on MAG to pass on communication as the central communication node in the network. Benefits manifest largely because decision making occurs through co-location of general and specific knowledge (Ojha, 2014). Hierarchical organizational structure relies on central information distribution, reduction of complexity and separation of thinking and acting; network organizational structure on the other hand is reliant on coalition building and communication, enlarging multi-issue complexity, and the linking of thinking and acting (Koffijberg, De Bruijn, & Priemus, 2012).
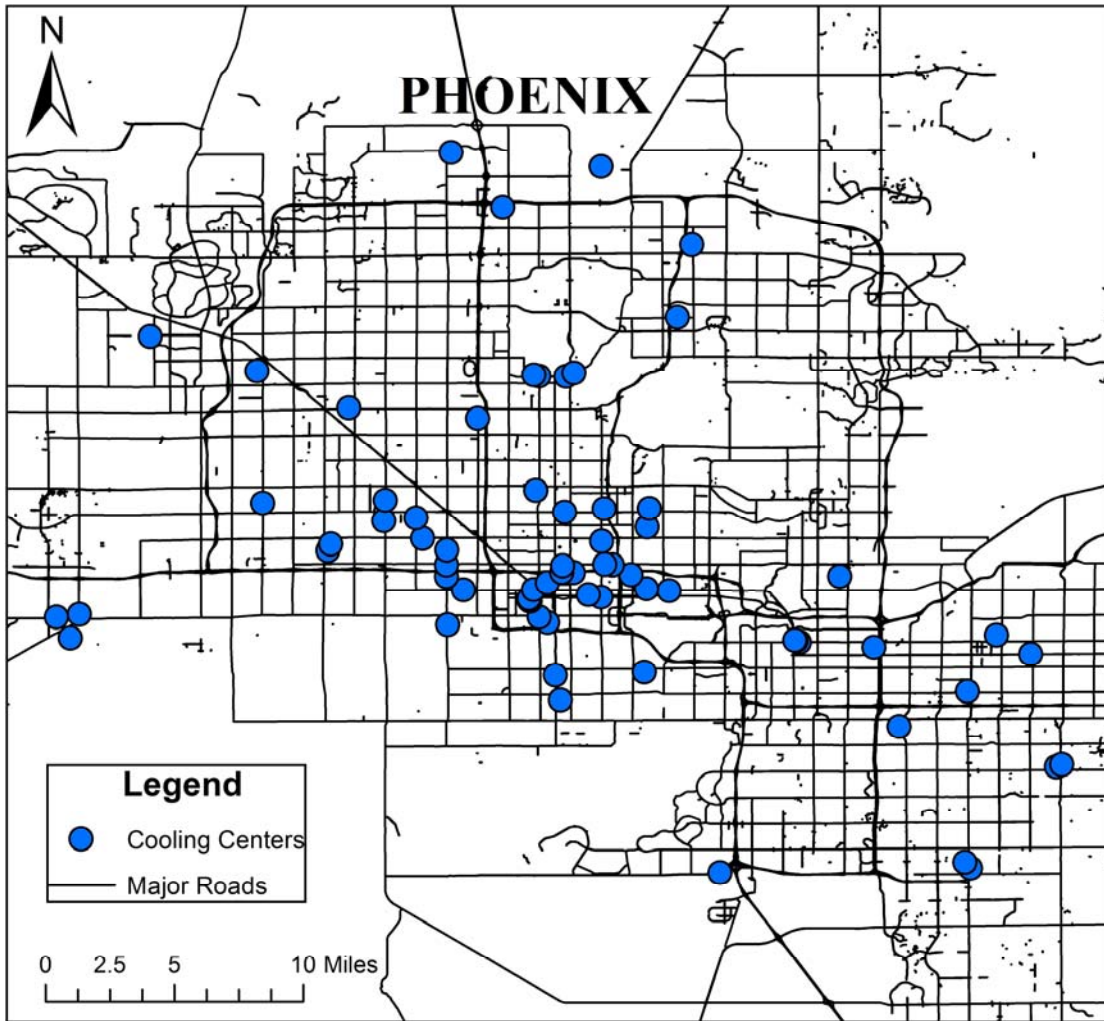
Figure 4: 2013 Maricopa County Heat Relief Network cooling centers map.

Complexity Governance: Enabling Local Decision-Making and Innovation

Many of the challenges that face society are often dealt with by governmental and non-governmental organizations, both of which are often addressed by organizations within communities without central coordination. These distributed organizational resources from the HRN are not necessarily optimized in their deployment across the system, but it is possible to employ various approaches for improving network optimization. Improving network coordination and communication, by harnessing new

technologies for example, can aid in ensuring exchange of optimal resources and best practices as well as cooperative referral (Innes & Booher, 2004). As the functions of governance spread beyond traditional government institutions, new forms of organizing around shared problems to achieve social change are possible because of new data availability, advances in computation, and communication options that constitute necessary conditions to leverage collective action (Johnston, 2010). Bridging the gap between this possibility and the current reality requires innovative approaches to realize the potential of open and effective complexity governance.

This chapter, grounded in the example of heat relief in Arizona, articulates an approach that develops a participatory modeling approach to be used in chapter four with a prototype agent based model (Cinderby & Forrester, 2005; Yearley, Cinderby, Forrester, Bailey, & Rosen, 2003) as an instrumental process used to strategically translate evidence to practice, provide system awareness to practitioners, and build healthy collaborations. Future participatory modeling will be used with relevant stakeholders where they can contribute their knowledge of local conditions on the ground into constructive changes to the model for further stakeholder consideration. This enables self-coordination of multiple efforts to more effectively address social challenges (Johnston, Hicks, Nan, & Auer, 2010; Pahl-Wostl, 2002).

Hierarchical versus complexity governance. There have been substantial changes in the ways in which the public engages in the process of governing over the last several decades, with accelerated change accompanying technologic advancement. Information transfer and communication using a variety of new technologies has improved overall social connectivity and created the potential for new governance

arrangements. The traditional hierarchical model of public administration with top-down

command and control approaches is no longer the dominant form in many policy systems

(Fung, 2006a). A wide variety of organization network combinations are increasingly

capable to perform governance functions (Booher & Innes, 2010; Leong, Emmerson, &

Byron, 2011). One of the benefits of ad-hoc networks is that they can leverage flexible

jurisdictions, which are appropriate to the scale of the problems forming a new 'public'

(Koppell, 2010). For these reasons, the opening of governance to extend beyond the

hierarchical bureaucratic model to include a mixture of government and non-government

organization has benefits of civic engagement among stakeholders and scientific experts

(Bäckstrand, 2004).

Coordination of information and action across different spatial scales and political

jurisdictions (Leong, Decker, Lauber, Raik, & Siemer, 2009) is not cost free and requires

effort, yet is critical as the hierarchies loosen and new emergent forms of self-organizing

governance arrangements are used. These types of interactions often represent complex

governance systems with multiple levels of interaction (Liesbet & Gary, 2003) and

system feedback via information transfer and decision making (Duit & Galaz, 2008). An

important aspect of complex systems is self-organization, often through simple decision

heuristics, where agents exhibit non-linear responses to changes in the environment

(Miller & Page, 2009). An important trait of complex adaptive systems is the

phenomenon of emergence where agent decision making leads to outcomes that could not

be predicted based on the sum of the component parts. This type of approach to

governance represents a substantial shift from the dominant hierarchical forms that

predominated the 20th century in the U.S. Now there are increasingly myriad ways for

governance to take shape, communicate, and interact through new technology. This dramatic expansion of the possibilities of the forms of governance is discussed here in this chapter in the context of the Maricopa County HRN case of heat relief.

There is a long history of hierarchical governance structure through the mid-20th century (Cleveland, 1985). Neoliberal market governance arose in the mid-1970's and continued to grow through the 1980's focusing on privatization, outsourcing, and financial commodification (Harvey, 2005). New Public Management (Lynn Jr., 2001) often took on aspects of both hierarchical control and market based governance, while network governance gained prominence in the 1990's with interdependence, trust, and empathy as key features (Meuleman, 2009). The way governance has traditionally been described represents an imperfect caricature of government archetypes that focusing on predominant features (Meuleman, 2008a). Different approaches to describing governance have often focused on the dominant form employed, such as hierarchy, market, network, or a composite of these forms (Meuleman, 2011). While such typologies have some practical value in understanding governance arrangements, they do not capture the full spectrum of realized forms of governance. Using such typologies focuses on salient traits of different types of governance rather than seeking a more general complex adaptive systems theoretical governance framework. For example, it may be important to consider how information flow and feedbacks across different parts the network exist that enhance its function and where encouragement of additional flow and feedbacks could further enhance operations.

There have been concerns with maintaining democratic accountability under these new forms of governance (Sørensen & Torfing, 2005). The concept of meta-governance

(Meuleman, 2008b), defined as governance of governance, has been described as a way to help retain values, norms and principles (Kooiman & Jentoft, 2009). Complex adaptive system theory applies to economics (Arthur, 1999), public health (Haffeld, 2012; McDaniel & Anderson, 2009; Paul E Plsek & Wilson, 2001), public administration (Marks & Gerrits, 2013), and holds that these systems are nested in other systems that co-evolve (Furnas, 2000; Sole & Goodwin, 2002). While, the concepts of democratic meta-governance, or, "the regulation of self-regulation" (Sorensen, 2006), and complexity governance are similar, the former is described by the scale position of higher level management of governance while the latter uses a scale-free complex adaptive systems theoretical underpinning. The co-evolving aspect of nested systems suggests that complexity theory applied to HRN governance is useful in that it allows bi-directional multi-level influence of nested systems. This conception of complexity governance is thus distinct from meta-governance, and is more generalized as further described below.

Complexity theory and equity. We approached improvements to heat relief from a complex systems perspective. This is appropriate due to nested levels of sub-systems interacting across the global climate system, including local public health agencies, the HRN, and individual decisions of those at risk. A complexity governance approach then accounts for these nested systems that interact and hence is an appropriate description of the HRN. Reducing heat health risk through the HRN is one component of broader public health efforts, though there are other important feedbacks within the system. Consider, for example, that in Phoenix, use of air conditioning became widespread after 1950 (Chuang, Gober, Chow, & Golden, 2013). This adaptation from air conditioning represents a high degree of technologic adaptation in the residential housing stock for

120

coping with high heat relative to most other large U.S. cities. A small portion of the

Maricopa County residents, predominantly those with lower incomes, are likely without

regular access to air conditioning (Goodin et al., 2015). This has the potential to lead to a

situation where as the proportion of central cooling increases, those that are left without

access are likely to represent an increasingly socio-economically marginalized share of

society. Hence there is the likely ironic emergent feature that although the share of

people with air conditioning in greater Phoenix has increased, those without access

represent an increasingly marginalized share of society. This effectively decreases the

political strength of those who most need heat relief over time as overall societal climate

adaptation potentially improves as more individuals have access to cool space. This

progression is generally seen as a positive outcome since air conditioning is protective

against heat health risk (O'Neill et al., 2010), but there may be the unintended

consequences of social marginalization of those without air conditioning. In this way,

feedback across this complex HRN system can result in substantial equity concerns.

A framing of complexity governance would consider complex systems attributes

and social equity, especially in the context of equity concerns articulated in global

climate adaptation policy (Morgan & Waskow, 2013; Ngwadla, 2013). In this context,

an important aspect of heat risk reduction resources such as HRN volunteer cooling

centers is that they self-select to participate as HRN cooling centers each year. Most

these cooling centers are oriented toward community needs; they would be offering heat

relief regardless of the existence of the official HRN. In fact, many organizations have

been doing what they do now for heat relief for many years, decades in some instances.

The motivation in this chapter is to find opportunities using complexity theory to assess

system feedbacks to moderate the inequitable distribution of extreme weather impacts. This framing could reveal opportunities to improve the functioning of the HRN. Improving the ability of networks to self-organize with a blend of some centralized organizing authority to list each year's organizational HRN volunteers with autonomous daily operations of independent cooling centers could do this. The increased ability to communicate has likely benefits of coordinating interactions across the network, among cooling center facility managers for example, related to increased efficiency and flexibility. Such a service could be implemented by MAG or could be developed among cooling center managers and public health agencies.

The Heat Relief Network Prototype Agent Based Model

   A simple prototype agent based model for future participatory modeling. A simple prototype agent based model was developed as the basis for future participatory modeling intervention. Participatory modeling can be defined as, "the process of incorporating stakeholders, often including the public, and decision makers into an otherwise purely analytic modeling process to support decisions ..." (Voinov & Bousquet, 2010). The approach presented here seeks to focus the expert knowledge of cooling center facility managers, other HRN members, and stakeholders on developing the most important questions to reduce heat health risk and different approaches to answering them. This includes use of a simple prototype agent based model (ABM) of the HRN designed for future participatory modeling and problem solving among cooling center and HRN managers, and stakeholders as an intervention. The benefit is a dynamic view of realized heat health risk and cooling center availability combined with local expert

knowledge of operations on the ground from HRN members that leverages a system perspective.

The approach used here seeks to evaluate available cooling centers in space and time relative to communities with the greatest need and/or historical heat-health impacts. The benefits of future participatory modeling with the prototype model are inclusion of HRN participants and stakeholders in the model design process and has the potential to add local knowledge to the larger system leveraging existing resources. For complexity forms of governance to function well there need to be opportunities for information transfer, local decision making, and non-linear responses among coevolving nested systems such as the HRN. The structure of these nested interactions form a complex network (Castells, 2000). Network organizational forms have also been shown to foster learning (Podolny & Page, 1998b), though a network structure itself facilitates rather than guarantees such learning. Complexity governance, like network governance, relies on trust and empathy to reinforce social connections (Meuleman, 2009). The distinction is that complexity governance understands and leverages complex adaptive systems theory of how emergent features could arise from variation in individual decision making.

Development of a prototype model for future participatory modeling allows refinement of different organizational network features, such as cooling center recruitment strategies, and resource optimization (e.g. water, volunteers), via innovation by locals with expertise in heat relief. We believe that valuable perspectives can be derived from all parts of the system, including cooling center visitors, cooling center facility managers and staff, as well as MAG, the Maricopa County Department of Public Health, the Arizona Department of Health Services, and university researchers studying

heat relief efforts. Participatory modeling, as one of the tools of effective complexity

governance, is a process for creating systemic awareness and the conditions for increased

self-organization (Pahl-Wostl, 2002a). This allows for the transmission of best practices,

and creating organic jurisdictions for addressing problems at the appropriate scale. As a

result, the focus of such a future participatory modeling effort is often as much about the

social learning and trust generation among HRN members as it is specific model

developments.

Model description. A prototype model was developed of the 2013 HRN to be

used in future interactive participatory modeling sessions with stakeholders shown in

Figure 5. Because a vast majority of cooling centers volunteer year after year, the fact

that the 2013 HRN was used as the template for the prototype model, as opposed to the

2014 HRN, makes very little if any difference when considering the network from a

systems perspective. This overall approach was intended to help enhance systems

awareness, promote complex systems thinking, translate evidence into practice, and spur

innovation. We constructed a prototype visualization model using cooling center location

and availability data that shows an hour by hour visualization of cooling center

availability and observed hourly peak heat index over the course of a typical summer

week in 2013. The model was written in Netlogo (Almeida, Kokkinogenis, & Rossetti,

2012; Tisue & Wilensky, 2004) for use in future participatory modeling exercises with

HRN coordinating agencies. This model also allows for potential additional layers to be

suggested by HRN members such as population demographics and observed intra-city

patterns in heat mortality. This research is ongoing and future developments could
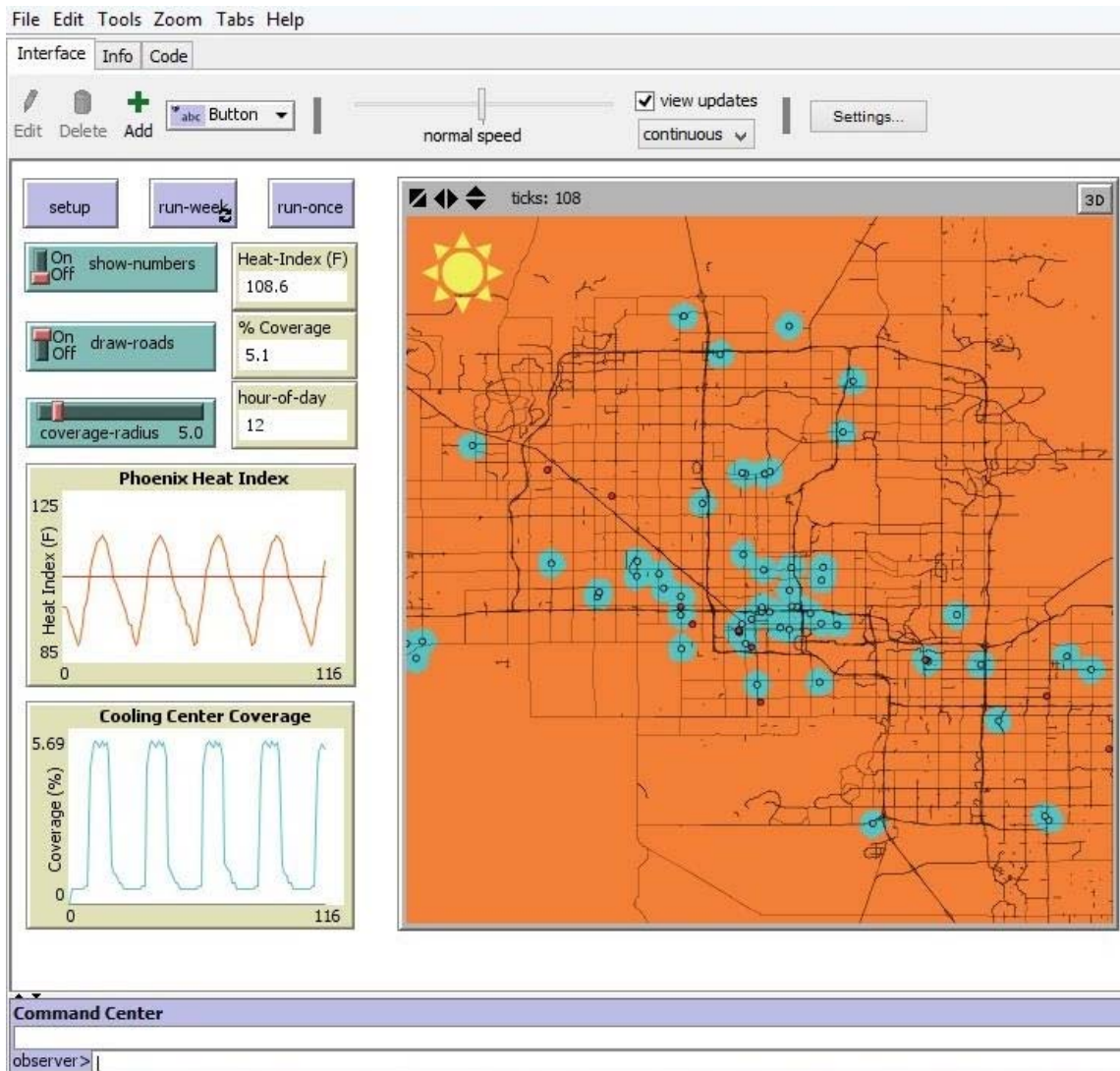
Figure 5: The prototype model interface with circles indicating coverage of open cooling centers for a typical weekday at noon time.

include addition of independent agents (individuals seeking heat relief) that interact with the environment (heat index and cooling center location/availability) to learn more about the dynamics of temperatures experienced by those without access to air conditioning. For example, recent data collected using an approach developed by Kuras, Hondula, &

Brown-Saracino (2015) measured individually experienced temperatures (IETs) in Phoenix from different communities. This offers additional possibilities for agents seeking heat relief to provide IETs within the cooling center prototype agent based model. Strictly speaking, the prototype model presented here is a very simple agent based model because although it does have cooling centers as agents with their own individual hours of operation, these are fixed for a given year under consideration – in the case of the prototype the year is 2013. This is also a simple model from the standpoint that there are no agent individuals seeking heat relief, only the agent cooling centers. Adding individual agents seeking heat relief would add another layer of complexity and the types of questions that could be explored with the model in the future.

The prototype model is a map of greater Phoenix with each cooling center's location represented by a point. The coverage area assumed for each cooling center is selected by the user. Users can pick a radius of access around each cooling center indicated by a blue circle extending from a point representing the cooling center position of a given radius filling a coverage circle; the points turn red with no extended radius when closed. The model initiates a run for a hot week in the summer of 2013, with the peak hourly observed heat index for 2013 repeated for each 24-hour period over the course of a week. This consistent daily heat index profile across the week allows consistent comparison of cooling center availability across the week. This is the primary focus of this research as opposed to evaluating heat index variation, because the focus is on the institutional arrangements in the context of heat health risk and not the other way around. Heat index is a parameter that represents the apparent heat experienced by a

person as a function of both temperature and humidity, accounting for reduced ability of the human body to dissipate heat through perspiration as relative humidity increases. In other words, the more humid it becomes, the less able the body can cool off by perspiring. The run begins Sunday at midnight and steps through each hour of the week through the end of the following Sunday to capture the week's profile. This allowed an hour by hour comparison of risk — how dangerous the weather is — and spatial as well as temporal cooling center availability to mediate such risk.

The model is stopped at peak cooling center coverage for a typical weekday, in this case Friday, for the 2013 HRN in Figure 5. This shows a good deal of relative coverage during normal business hours in Figure 5, but as soon as 5pm arrived each business day, nearly all the cooling centers close at that time. The situation is similar yet more pronounced on weekends, with a similar relative increase in coverage during the day on weekends, and significant decrease over the afternoon and into the evening on weekend days. Figure 6 shows the prototype model stopped at peak coverage for Sunday afternoon peak cooling center availability, which is only about 25% of the coverage at the same peak noontime as during the weekdays. Figure 6 underscores how variable the coverage can be in time, with very little cooling center availability after 5pm in general and on also much less coverage on weekends than weekdays.

Early observations from model development show that there was almost no cooling center availability on weekday evenings after 5pm and on weekends. In addition, the results from chapter two for facility manager interviews showed that node-to-node direct communication was not a regular feature of the current cooling center network.

Increased ability to easily communicate with other cooling centers for resource

optimization is a strategy that allows organizations to transfer items they have in excess,

while gaining supplies they have in short supply. On the other hand, any communication
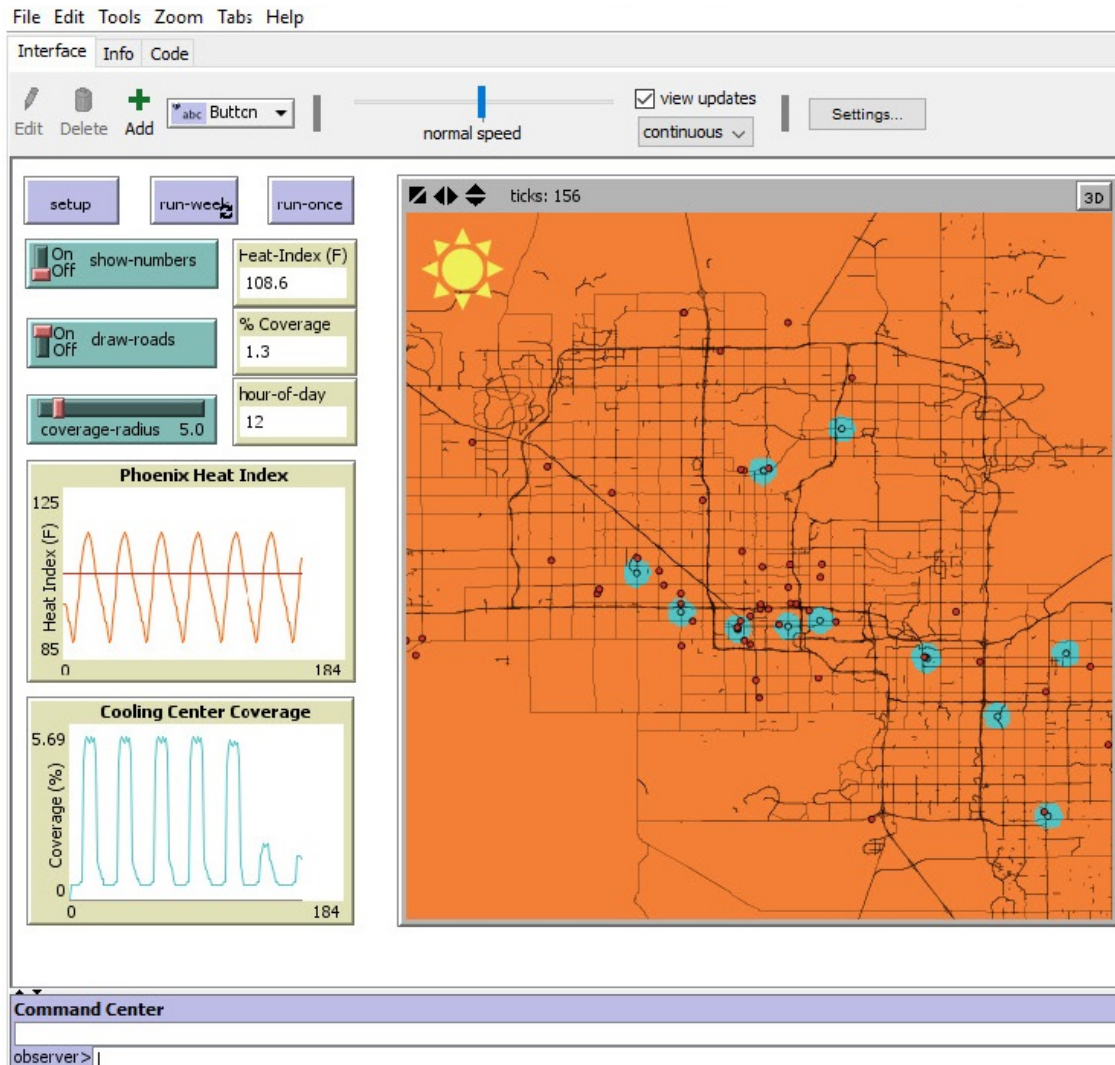

Figure 6: A run of the prototype model stopped at noon on a Sunday afternoon to show

that coverage is reduced on weekends and evenings relative to weekday times.

strategy would have to be efficient since may cooling center managers operate under time

and resource constraints (Mintzberg, 1973), hence HRN communication would need to

add rather than detract from effective operations. Other aspects of the system that the prototype model revealed include the potential gain from expanded coverage during evening hours and on weekends. It is the potential for change in perception and ways of thinking that is one of the greatest strengths of using this prototype model in future participatory modeling by allowing participants to discover a new understanding of the HRN.

Model captures institutional dynamics. The endeavor of collaborative model building requires participants to reevaluate aspects of the system in which they are participating that they had previously taken for granted or never fully considered (Johnston, Kim, & Ayyangar, 2007). For instance, asking practitioners the criteria for recruiting new members in the network can reveal the difference between alternative strategies, alternatives that can have significant consequences on the outcomes of the collaboration (Kim, Johnston, & Kang, 2011). Additionally, in building a model that captures the different dynamics of the system, participants can learn about their relative position in the system, which provides context for how their actions can have far-reaching consequences as parts of the system in ways they were previously unaware. For example, they could see how each cooling center chooses its own hours, but that despite this fact there is a large amount of inadvertent coordination where normal business hours are the dominant availability of cooling centers. Overlaps in availability or closure, as well as unexpected schedule changes could cause unnecessary difficulty for individuals to access cool space. This would be true for both a facility that faces unusually high demand, as well as for individuals seeking heat relief, who are challenged to find the

services that they need within a distance they can travel to or fit within a routine they may have established.

Information about how institutional practices evolve to address the extreme heat public health challenge is important to consider, where novel means of serving at risk populations are often developed locally. While the perspective of those seeking relief from heat is important to understand how they can best be served, institutional rules and practices are also important, as they can significantly impact the effectiveness of service delivery and provide information to individuals seeking heat relief. An important benefit of participatory modeling is to work with the local HRN to discover the range of strategies, rules and behaviors used by its members. Connecting different parts of the system by investing in approaches such as future participatory modeling, and potential developments such as virtual participatory commons for HRN members can increase the level of competition among HRN institutional rules and best practices for different local circumstances. This is important because micro-level processes have been indicated to be responsible for evolution of institutional rules that are novel or extant rules that are retained (Colyvas & Maroulis, 2014).

One of the major challenges of governance in the modern era is that there are mismatches between the problems that need to be addressed and the scale of the governments that are in place. There are over 87,000 governments in the United States alone and few problems fit neatly into predetermined containers. Many of the problems that need to be addressed fall between, within, across, or overlapping multiple jurisdictions (Johnston, 2010). Some of these challenges can be addressed, in part, by

using participatory modeling as a way of building appropriate scale jurisdictions organically. To represent the full and appropriate dimensions of a system, key stakeholders in the system need to be included, though not necessarily at the same time. By intentionally including these disparate participants in the future process of building the model beyond the prototype described here, they can experience their voice being heard authentically and they develop a shared representation of the system in which they belong. Participatory modeling activities are also beneficial in building empathy and trust that are necessary components of successful organizational networks. This is even more important when bringing together different types of network members who are likely to have different perspectives and values.

Discussion

       Future participatory modeling. An implicit goal of the HRN is to provide a certain type of coordinated behavior that advances social good — making cool space available for those in need — by preventing illnesses and saving lives. Such behavior emerges when considering the entire network since one cannot predict emergent features of complex systems easily based on the sum of constituent parts. Close examination of the network's operation reveals that there is no single actor operating in rigid hierarchical structure that brings such behavior to life. Although there are coordinating players within the network associated with formal government entities, the role these actors play might be more appropriately described as coordinators and independent facility managers making decisions within the system. Through future participatory modeling using a prototype agent based model and employing a complexity governance framework, we can

begin to better understand how to optimize new HRN facility recruitment, information sharing, and important network characteristics such as the location and open hours of each facility. The relief-providing behavior, however, such as the places and times where heat relief is available, largely emerges through the independent facilities that participate in the network making their own choices and actions. This is superimposed on the actions and preferences of individuals who seek cooled space within HRN facilities.

Offering complexity governance, such as through participatory modeling, as a framework for understanding and improving the HRN for its participants and stakeholders underscores three affordances of such a framing: contextual awareness within the system, a platform for communication and transmission of best practices, and jurisdictional flexibility to address a social challenge ignorant of municipal boundaries. In addition to these benefits, complexity governance allows flexibility to consider the interactive elements of a given system. For example, complex adaptive systems often exhibit non-linear, and potentially unanticipated, interactions where small changes in signal magnitude can translate to exponential increases in response. These dynamics occur across interacting levels of co-evolving nested sub-systems — an important element of complex adaptive systems (Plsek & Greenhalgh, 2001). The hallmark characteristics of the complexity governance framework are appealing when considering a wide range of other public problems and pursuit of societal goals. Here we have examined just one aspect of a larger social system, a network of cooling centers within the context of health risks associated with extreme heat exposure, as a complexity governance entity itself within a much larger complex governance entity aiming to minimize adverse health outcomes for the public at large.

The complexity governance framing of the HRN is academically appealing because it is helpful since it opens the door to a new set of perspectives (e.g., complexity theories) and tools (e.g., agent-based models, participatory modeling) that can enhance the network's ability to achieve its goals. It is not simply defined by its organizational forms, but also by the new processes necessary to realize the affordances of such an approach. Participatory modeling is a process of building a systemic representation of a challenge, for example managing the Chesapeake Bay (Learmonth, Smith, Sherman, White, & Plank, 2011), or modeling a health care delivery system (Kim et al., 2011), with both modeling experts and local practitioners taking part. Stakeholder inclusion in the modeling process is a fundamental instrument because complexity governance systems require dynamic information on both group and individual behavior. Participatory modeling also has the potential to capture local knowledge for decision making at the individual level where bottom-up decisions allows for coordinated governance to emerge. For example, agent based modeling has been used to systematically evaluate various sequences of local level actions that affect the larger system without explicit top-down or bottom-up constraints (Colyvas & Maroulis, 2014).

Scalable agent based modeling approach. A systems approach is important when engaging a continually evolving complex adaptive system with natural environmental and human social components. This allows better understanding of the wide variety of forms of governance that are possible with the dramatic expansion of agenda setting (F. L. Cook et al., 1983) in communication and social media (*sensu* Moser, 2010). The complex adaptive systems perspective is especially appropriate given the increasing rate of information transfer, individual cognition and decisions occurring at

multiple nested governance scales (Wyborn & Bixler, 2013). This is useful in focusing on opportunities to manage complexity governance, leveraging self-organized resources from the community to municipal levels and beyond (Cash & Moser, 2000). With respect to the particular context we examine in this chapter, it should be recognized that efforts to increase social resilience to climate change impacts, including extreme heat health risks, primarily occurs at the local level to achieve goals articulated at local, state, national, and international policy level (Derman, 2014). In this context, it is important to understand interacting parts of coupled system components at different scales to identify gaps in knowledge and understanding that are critical in reducing system vulnerability to perturbation (Turner et al., 2003). It is helpful in evaluating problems that operate at multiple spatial scales to have a scalable approach like agent based modeling where the technology design of the model can be made to fit the true scale of the problem.

Additional contexts that appear appropriate for a complexity governance approach toward intervention and prevention strategies include public warning systems, educational campaigns, water distribution, wellness check programs, emergency medical response, and healthcare system utilization. Scaling the approach we have described in this chapter by considering this system through prototype ABM development for future use in participatory modeling can help ensure that the proper resources for combating extreme heat health risks are available to those who need them. This can direct resources to those most in need at the times and places where they can leverage the greatest benefits. A prototype model at this scale can document the range of intervention and prevention measures currently in place. This approach also could allow rigorous consideration of the behaviors from another set of agents that represent individuals

seeking heat relief without access to air conditioned space as an extension of the prototype model. Their interaction with intervention and prevention measures is impacted by extreme heat to varying extents. Consider that both the "service providing" agents as well as the "service receiving" agents could help enable prioritization of the most effective points of intervention for reducing heat-related illnesses and deaths. Similar complexity governance frameworks may be appropriate for considering other environmental health challenges like air and water pollution. Indeed, the complexity governance framing is a useful strategy for addressing current and future challenges associated with extreme weather.

Global implications of complexity governance. Communities across the world can expect increased extreme weather events, including extreme heat in some instances, as Earth's global average temperatures continue to rise (Pachauri et al., 2015). Such increases in extreme weather events due to anthropogenic climate change are no longer just predictions, but rather are being experienced by many jurisdictions around the world. As temperatures in cities around the world continue to increase as a result of global (Coumou, Robinson, & Rahmstorf, 2013) and regional-urban forcing (Argüeso, Evans, Fita, & Bormann, 2013), global populations become increasingly urbanized (Matei Georgescu, Morefield, Bierwagen, & Weaver, 2014) and elderly (United Nations Department of Economic and Social Affairs Population Division, 2013), the frequency and intensity of extreme heat events as well as their societal impact may become an increasing public health concern. The far-reaching effects of climate change of unknown magnitude makes the area of complexity governance a fertile ground to look for unusual emergent system features that have important societal impacts. The challenge is to

consider what the future benefits of complexity governance could be in these contexts and others. This chapter adds to a growing body of evidence that the complexity governance theoretical framing can provide advantages for tackling public problems. More exploration of the applicability of the complexity governance approach to other contexts is certainly warranted, but we have been able to demonstrate its theoretical applicability to the HRN for heat relief in this chapter. The next step forward is showing through proofs of concept that this prototype model is useful in participatory modeling interviews with HRN coordinating health agencies, as well as using the complexity governance framework works in other contexts.

Beyond the proof of concept stage, where the framing and improvements to the HRN lie, the future could involve the uptake of complexity governance principles and tools as regular components of the greater Phoenix HRN's functioning. This development path may lead to the identification of the appropriate application of complexity governance as a useful framework for approaching the region's heat relief efforts more generally. Ultimately, we envision this engagement with the HRN in central Arizona as an interesting field case to contribute to widespread understanding of the applicability of complexity governance and its associated perspectives and tools to other forms of organizing around significant public problems.

Conclusion

In an answer to the question asked in this chapter, it has been shown that the HRN is a useful example of complexity governance when approached from a participatory modeling standpoint. The traditional forms of hierarchical governance are no longer the dominant form and so embracing approaches like complexity governance is useful

because it is not dependent on one structure or another, and can be applied to a wide variety of circumstances. The HRN fits squarely within the context of the definition of complexity governance, and so is a good example. That is, the HRN is part of an emergent self-organizing structure and process that involves a range of actors from public to non-profit organizations. These institutions and actors volunteer to interact dynamically with one another where the individual components of the HRN cooling centers sum to yield a larger emergent outcome than the sum of individual parts. This is done on a relatively large scale, county wide, and the agent based model brings an organic large scale multijurisdictional approach to the modeling in the agent based model. Finally, the HRN is an example of complexity governance because the approach articulated in this chapter aims to use innovative means to resolve complex social problems using information technology in the participatory modeling process.

The next chapter uses a prototype model in participatory modeling exercises with HRN coordinating public agency members. The purpose of these exercises is to increase HRN member systems level awareness about how the HRN functions both over space and through time. This is in addition to learning about what system attributes HRN members think are important to answer to improve the HRN within the modeling framework.

Introduction

Each year the Maricopa Department of Public Health (MCDPH) reports that there are dozens of avoidable heat related deaths in Maricopa County Arizona (MCDPH, 2015a). This is due in part to regular exceedances of temperatures of over 100° F from May through September in the greater Phoenix metropolitan area (Harlan et al., 2014a). One of the public health interventions to reduce this heat health risk was the implementation of cooling centers where people can go to get relief from the heat (Berisha et al., 2017). Cooling centers are comprised of both heat refuge stations where one can go inside for air conditioning and get water, and hydration only stations where only water is given out. These cooling centers comprise the Heat Relief Network (HRN), which consists of non-profit and government organizations who have volunteered their resources to be a cooling center. These voluntary organizations could be community centers, senior centers, poor and homeless services, religious, or parks and recreation facilities generally.

Within the HRN there are different types of public agencies that help monitor and coordinate different parts of the system. The Maricopa Association of Governments (MAG) and the City of Phoenix has the lead on organizing and implementing the HRN each year, coordinating volunteers, water distribution, and generating maps and schedules of the cooling centers each year. MAG also holds a regional heat relief planning meeting

each year with other HRN coordinators and cooling center facility managers. The

MCDPH monitors the mortality events and epidemiology of heat related deaths, and

works with the other agencies like the Arizona Department of Health Services (ADHS)

and National Weather Service to respectively monitor these mortality events and

associated extreme heat events. The National Weather Service issues Excessive Heat

Warnings when heat levels reach a consistent dangerous threshold to warn the public,

helping people become aware of the danger. MCDPH and ADHS also partnered with

university researchers to complete a program evaluation of the cooling centers in 2014

(Berisha et al., 2017). Generally, each year most of the same cooling centers volunteer to

participate again annually, though there is some variation year to year in which

organizations volunteer as cooling centers. Hence this is an ad-hoc voluntary governance

network that provides relief from extreme heat by providing access to cool space and

water.

The true nature of the functioning of the HRN in over space and through time is

difficult to see without use of a simulation like an agent based model, using a complexity

governance approach. For example, each year MAG organizes the HRN and publishes a

set of maps and schedule of cooling centers that can be viewed online or downloaded for

offline viewing. This map and schedule shows the location of each cooling center, and

off to the side of the map it shows as schedule of when each cooling center is open. It is

very difficult looking at the static maps to tell how the cooling centers collective

availability adds up at certain parts of the day versus others. Taking a complexity

governance approach by building the system from the ground up in a modeling

environment is one way to understand how the component elements of the HRN combine

to yield emergent outcomes that cannot be easily predicted from the sum of its parts. The approach taken in this chapter is to develop just such an agent based model where individual cooling centers are agents that are fixed in space for a given year and have their own self-selected scheduled open hours for the cooling centers. The goal is to show the model to members of HRN coordinating agencies and learn from their expertise what lessons and improvement recommendations can be learned from viewing the dynamic simulation of the cooling center's availability in both time and space along with observed peak heat index from the meteorologic record.

The research in this chapter seeks to understand one overarching research question: how can participatory agent based model intervention act as a catalyst for co-learning and ideation for problem solving in a complexity governance context? A complexity governance perspective uses emergent and self-organizing structures with a wide range of actors to dynamically interact on a large scale to solve social problems using information technology. Participatory modeling is a way of engaging a diverse set of stakeholders in a governance system to learn from their expertise. The research in this chapter is interested in learning how members of different HRN coordinating agencies approach the cooling center system as a whole and how the model acts as a catalyst for bringing together new ideas and suggestions to improve the HRN.

The prototype agent based model used here is the same model described in the previous chapter three and represents a complexity governance approach to the HRN, with a more complete description of the model given in the research methods section. The model is a map of the greater Phoenix area, Maricopa County Arizona, that shows the location of cooling centers in space. The model steps hour by hour through an

extremely hot week in the summer of 2013, showing for each hour which cooling centers

are open and which are closed. The observed peak hourly heat index from the

meteorlogic record from the summer of 2013 is also shown for each hour so that viewers

of the model can see the heat risk alongside the cooling center availability. The model

shows how the HRN functions in aggregate rather than as single elements that are listed

in the schedule and gives a top down systematic view of how the cooling centers function

to cover heat health risk. This allows viewing of emergent features within the HRN

system.

Traditional conceptions of governance and advisement often have a template that

has experts deliver to those who are governed recommendations based on an outsiders

perspective rather than the expertise of local actors (*sensu* Skogstad, 2003). The

approach used here in this chapter turns this approach on its head. Rather than bringing

conclusions to stakeholders after studying the system, those with modeling expertise

bring the model to stakeholders to allow their on the ground expertise develop solutions

to the problems at hand. The idea is to allow people to discover the answers for

themselves by seeing elements of the system in new ways through modeling and other

means. The participatory modeling approach is one such way to bring local experts to

find answers for themselves in the model experience rather than being told what aspects

of the system are important. "These issues can be captured with agent based modelling

techniques and participatory model building processes where decision making is

perceived as a process of social learning. Agent based models are particularly suited to

participatory model building." (Pahl-Wostl, 2002 p. 405) Participatory modeling as a

social learning process allows a two-way interaction between consulting modeling

experts and those that are expert in operating in the local governance system. This chapter uses an agent based model as part of the participatory modeling process to help participants see emergent feature of the system from a complexity governance perspective as previously described.

The social learning process of participatory modeling can be useful in overcoming learning barriers in organizations by letting individuals learn from their own experience with a model how the system works. This can aid in overcoming learning barriers, such as first loop learning barriers or second loop learning barriers. Here, first loop learning has to do with adjusting organizational behavior based on a fixed normative reference point mostly related to daily operations; second loop learning is learning that leads to a change in norms or values against which daily operations are measured against (*cf* Argyris, 1976). Participatory modeling can aid in overcoming barriers to both types of learning in organizations, though any second loop learning requires that first loop learning cycles are functioning properly (Schimmel & Muntslag, 2009).

Another benefit of the participatory agent based modeling approach is that the model can be constructed at the scale of the problem, that may extend beyond traditional political boundaries hence avoids the problem of model scale mismatch to the scale of the problem at hand (Hare, Letcher, & Jakeman, 2003). There are many examples of agent based models being employed of integrated regional land use and climate policy (Downing, Moss, & Pahl-Wostl, 2000; Walz et al., 2007), often being used for environmental management problems (Hare & Deadman, 2004) since those problems tend to span traditional political boundaries. The application in this chapter uses both institutional and environmental data in the agent based model and so does fit within the

realm of environmental management applications in terms of managing extreme heat health risk exposure. What is useful in the application of this chapter is the combination of institutional and environmental factors to view the supply of cooling centers in space and time, against the temporal risk of observed heat index from the environment.

Research Methods: Qualitative Analysis of Participatory Modeling Meetings

  Epistemology and methodology. The worldview of my research epistemology is pragmatism, focusing on the situations, actions and outcomes rather than on preexisting conditions (Creswell, 2009). This means that the approach is not restricted to one research ideology or another, but rather draws on methods that fit the problem at hand (Rossman & Wilson, 1985). Hence the research methods chosen focus on approaches that work in a practical sense on the problem with likelihood to yield solutions (Patton, 2002). In this epistemological worldview, social phenomena are seen as existing outside my perspective or understanding, and an attempt is made to use practical approaches to data analysis that provide a deeper understanding of the processes at hand. Hence pragmatism is not anchored to any one system of philosophic investigation, where the external world exists independent of the mind but is also perceived by the mind (Creswell, 2008). The research used here is both qualitative in terms of the participatory modeling interviews given, and quantitative in terms of the prototype agent based model used in the interviews. Hence this is a mixed method approach and is described further below.

  The approach used in this chapter uses case studies of individual or focus group interviews that explore their perspective on the participatory modeling process. Case

studies are the preferred approach when 'how' or 'why' questions are being asked within a contemporary real-life context (Yin, 1994). This is an exploratory case study analysis that does not have a good deal of literature representation of this type of participatory modeling of a complex governance system. Hence *a priori* inductive codes were not used, but rather inductive coding based on the data was employed. Where possible, categories were developed to help organize codes under common themes to aid with thematic analysis of the interview results (Friese, 2014; Saldaña, 2015).

Researcher perspective. Qualitative analysis is interpreted by the researcher, hence that individual is akin to a research instrument whose biases should be known to understand how the researcher's interpretations might skew based on such bias. Hence my perspective and experience is relevant to my role as interpreter of this qualitative data. I have a background in quantitative analysis and experience developing the prototype agent based model used in this study. My undergraduate degree and M.Sc. degree are in the fields of biology and ecology respectively, giving me additional quantitative background. This prior training is bolstered by my doctoral experience that has coursework and field experience in qualitative data collection and analysis, focusing on reducing extreme heat health risk. I do not have the same perspective of those I interviewed, but rather am attempting to interpret the expert experience of participants to derive meaning and understanding of the larger HRN system and their perspective on it. My biases may include focusing on model details as the person who built the model. This focus may bring attention away from other attributes of the system that are not related to the model such as use of the model as a communication tool across the system to show other members of the HRN the gaps we discovered. This is not to say that I

ignore purposefully one aspect of the interview discussion or another, but rather my background influences my perspective and the types of follow up questions I might choose during an interview. Together, my biologic science background brings a quantitative perspective, and public administration and policy background brings a qualitative perspective that mix together to yield the mixed method approach used here in this chapter.

Interview research questions. The participatory modeling approach used in this study was an open-ended interview format. The participants were asked two starting questions about how to approach the participatory modeling interview, and then the discussion was allowed to flow naturally after that point with follow up and clarification questions being asked along the way. The two questions initially asked of participants was: 1) what are the important questions to answer to improve the HRN? and 2) how can these questions be answered in the modeling framework? The goal was to have responses to this question reveal indications about the overall research questions being asked in this dissertation, namely: how do HRN members see themselves as part of the system? and once aware of their position within the system how to do they respond? The awareness to their position within the system likely increases when viewing the model since they can see the entire HRN work together and consider their role within it. The participant's responses to the participatory modeling indicates how they react once they are aware of their relative position within the system in terms of recommendations for improving the HRN. There were nine interview research questions that were asked when analyzing the recorded interview data to help structure the results in a meaningful way shown in Table 2. That is, these interview research questions were used to interrogate the

interview data for meaning but were not asked directly of the participants during the interview.

Table 2

Chapter 4 Interview Research Questions

Chapter 4 Interview Research Questions
1) How do organizations articulate their role in mitigating heat health risk?
2) How do organizations frame their responsibilities?
3) How do organizations articulate awareness, or lack of it, to the rest of the system?
4) How do organizations understand their capacity to adjust their role or behavior?
5) How do organizations interact with adjacent lower-level HRN managers?
6) How similar are the articulations across those interviewed?
7) How did participatory modeling give suggestions to improve the model?
8) What insights does this case bring to climate adaptation and institutional resilience?
9) Do HRN members show first or second loop learning thinking in their responses?

Prototype model description. The prototype agent based model is written in Netlogo software version 5.2 (Tisue & Wilensky, 2004) and is structured as follows. The model shows a map of the greater Phoenix area of Maricopa County Arizona, and it initializes by showing on the map the 2013 cooling centers, which is comprised of both heat refuge and hydration only stations. Heat refuge stations are where people can get water and go inside to cool off in air conditioning, whereas hydration only stations give

out water only and do not provide access to cool space. The prototype model did not distinguish between heat refuge and hydration only stations and modelled them together collectively as cooling centers. The model run steps through each hour of the day over the course of a week, hence 24 diurnal time steps times seven days yields a total of 168 time steps over the course of the week. The model display shows a circle with a user selectable radius of transit access distance around open cooling centers. This is a hypothetical radius of transit access to cooling centers and is not based on road networks. So, the model steps through each hour of the week showing which cooling centers are open or closed by putting a circle around the open cooling centers based on the user selected radius. The model also shows the heat index as a color in the background of the map as it runs, showing darker red colors when it is hot outside. The heat index data is the highest hourly heat index observed from the 2013 Phoenix Encanto weather station, so it gives an idea of the hottest possible day one could experience that summer at that station. It is possible that there were other weather stations in Phoenix with hotter or cooler temperature profiles, but this is relatively unimportant because we are looking at heat index as relative risk to cooling center availability. Heat index is related to temperature, except that it takes into account the effect of humidity on the apparent temperature that a person is experiencing — that is, it is less easy to cool off through perspiration the more humid it is outside (Delworth, Mahlman, & Knutson, 1999). The model initializes Sunday at midnight and runs through the course of a week showing graphical line charts of the percent cooling center coverage and heat index value for the current and previous time steps. This way people can see both when and where cooling centers are open, and when it is most hot outside.

147

Data collection, research setting, and interview approach. Interviewees were selected based on a snowball sample approach, starting with a member of an expert heat health risk reduction panel that made a presentation in the fall of 2014. The first person interviewed made a recommendation on who the next person should be interviewed should be, and so on. This led to the first three individual interviews performed sequentially using snowball sampling during participatory modeling sessions. The final interview was of a focus group of six individuals from various HRN coordinating agencies that was recommended by the third individual interviewee. These total three individual interviews and one focus group. The interviews were open ended in format (Bernard, 2011), asking the participants at the beginning two questions: 1) What are the important questions to ask to improve the HRN? and 2) How could those questions be answered within the modeling framework? These were the two questions asked directly of the interviewees, whereas the nine interview research questions were asked results to interrogate their responses.

One of the people who participated in an individual interview also participated in the focus group, hence the total number of independent people in all the participatory modeling was eight. The individuals who participated in the snowball sample in order of participation were a university researcher, an MCDPH geographic information system (GIS) analyst, and an MCDPH epidemiologist. The focus group was recommended by the MCDPH epidemiologist as the next and final snowball sample with multiple individuals. This MCDPH epidemiologist also participated in the focus group and hence was effectively interviewed twice. The focus group participants included: a MCDPH epidemiologist, City of Phoenix homeless program manager, a MAG representative,

NASA employee, MCDPH epidemiology data services manager, and Centers for Disease Control public health associate. Interview audio data was recorded for later analysis and evaluation. This study was approved by the Arizona State Institutional Research Board for human study (#1702).

The research setting was generally at the office locations of those interviewed, with the exception of the focus group that was held in a conference room at the MCDPH. The interviews began with getting permission to record the interviews, then asked the above two interview questions. The following discussion was allowed to play out, where I tried to let the conversation flow naturally without guiding the discussion to my own ends. I attempted to clarify and offer suggestions as the interviews proceeded, but tried to not lead participants toward any predetermined discussion points. Most importantly, the participants interacted with the model and made adjustments to it to gain familiarity with it to better understand the system while it ran. The most interactive part of the model was the user's ability to adjust the radius of coverage each open cooling center had in the model display when it was open. That is, the user was able to increase or decrease the radius of cooling center coverage under assumptions of different types of transit being used to access the cooling centers. Increasing or decreasing this access radius increased or decreased the percent area that the cooling centers covered on the map since greater radius created larger circles that covered more area. This gave participants an idea of the effect different transit mode could have on cooling center coverage, where radius for public transit cooling center access covered a greater area than radius selected for walking for example (Fraser et al., 2016).

Audio coding and interpretation. The method used to code the audio recording data of the interviews and focus group was the oral coding technique of Bernauer (2015), modified slightly as described below. The approach used in the oral coding method has the analyst repeatedly listen to the audio recording over the course of several days to establish great familiarity with the data. Here, subsequent audio quotes were taken from the raw audio data and processed using the Atlas.ti software version 7 (Friese, 2014). In the original method by Bernauer (2015), research memos from audio quotes were recorded as audio by the researcher and used to develop later analysis and results. In the approach used here, written research memos were recorded by the researcher as a modified method from the original which allowed an easier translation of the written research memos into results. The benefit of the oral coding technique is that it keeps the analyst deeply embedded in the voices of those interviewed, allowing the researcher to become familiar with tonal inflection of meaning and subtext of the conversation (Saldaña, 2015). This oral technique then has the benefit of not losing the verbal richness of the discussion that would be lost when converting the interview to text before proceeding with coding and subsequent analysis. Results were interpreted from the written coding output of the oral interpretation. In addition, research memos were developed for each of nine interview research questions described in the introduction that were used to interrogate the open-ended responses for meaningful results.

Qualitative Analysis Results

The overarching research question result is outlined below, followed by the thematic results of individual interviews that are of interest, and then results that are

organized by interview research questions. This is because individual participants often had comments that were relevant that extended beyond the individual research questions that helps shed light on the modeling process. The nine interview research questions were not asked directly, but rather are being used to interrogate the responses to the two open-ended interview questions. This is followed by a brief description of a revised model based on interview input. The coding of the three interviews and focus group yielded 69 different codes shown in Appendix C from quotes tagged for extracted meaning.

   Overarching research question. The main overarching research question asked in this chapter is: how can participatory agent based model intervention act as a catalyst for co-learning and ideation for problem solving in a complexity governance context? There are several answers to this. **1)** The participatory modeling process brought out the individual expertise for comparison and integration into ideas on how to improve the model and the HRN in general. **2)** Modeling participants had an increased awareness of the system and the interdependence of how the HRN functions collectively rather than considering one isolated node at a time — they see the whole HRN work together in the simulation. This allows them to see the system differently after viewing the model in a complex and dynamic view of the HRN system rather than a static view of a simple map. **3)** The model simulation allows the viewer to step into the role of someone seeking heat relief as they ask questions about the gaps in coverage and difficulties a person might have in traveling to a cooling center when it is hot out in the evenings and most of the cooling centers have closed after 5pm. **4)** Co-learning is encouraged during participatory modeling where the model designer and local expert explore the model together to

generate new knowledge that could not have been made working separately. This co-learning was further enhanced in the focus group since there were multiple local experts joining in the group co-learning process and so that yielded more insights than the individual interviews. **5)** The participatory agent based modeling process fits within a complexity governance context because it is an emergent process with a range of stakeholders that interact dynamically viewing the problem at a large scale to solve social problems using information technology.

   Three ways to use the model: gaps, networking, and end user kiosks. It was mentioned by an epidemiologist for MCDPH that the model could be useful to different levels of the HRN system. She said, "*I thought it [the model] would be used by several levels. First of all whoever makes the decision to have the cooling center open and maybe they have a say in you know what your schedule is going to be as a cooling center. I was thinking in that level you know when the cooling centers are open where hopefully we can do something about the gaps and so on. Number two, I was thinking that it's a good tool for people, managers as they work, as a networking tool so they know okay this center is [open], and sometimes to make adjustments in the schedule and so on. Number three, I was thinking who are the users, people that they need to go to those cooling centers, where can we place this tool that you are at the bus station and you click on some type of kiosk or I don't know, and then you find out where these places are [located]*" This represents three different ways the model could be used: to identify gaps in cooling center coverage, as a networking tool among cooling center managers, and as a tool for consumers from kiosks to find nearby open cooling centers.

Transit perspective and informal cooling centers. A university researcher had research activities that focused on using an assessor database to determine what commercial buildings are available to the public to serve as informal cooling centers. This could include stores and restaurants where people can stay longer than 30 minutes to cool off. The researcher also has experience with transportation considerations to get to formal and informal cooling centers. Here, formal cooling centers are the HRN, and informal cooling centers are other places where people can go inside to cool off. Hence the built environment and transportation considerations influence the university researcher responses to the open-ended interview questions based on his experience.

The university researcher commented that transportation access to cooling centers is a critical consideration when thinking about the formal HRN. He indicated that walking, or maybe using a bicycle would be the primary mode of transportation in trying to reach a cooling center for someone in need. He said, "*I think that from my perspective one of the issues with the network [HRN] as a whole is how do people access these places*?" He also said that, "*If the person is accessing the cooling center via public transit, why would they ever get off the bus*?" This indicates that public transit itself can act as an informal cooling center, and he suggested that many people seeking heat relief at cooling centers are likely to be walking or bicycling. The university researcher indicated that if a person has access to motorized transit, they could go to a variety of commercial locations to seek informal heat relief. He said, "*From a transportation perspective, if someone has access to motorized transit, there's a bunch of places they can go to get heat relief [besides formal HRN]. … They could go to the Scottsdale mall, they could go to other commercial centers that are low cost, like relatively cool movie*

theaters." This suggests that how people access cooling centers is a critical consideration since, if they can't get there then they can't benefit from the heat relief at the cooling center.

The university researcher indicated that there are some areas of Maricopa County of the greater Phoenix area where they are totally isolated in terms of lack of public transportation to access formal HRN or informal cooling centers. He said, "*There are pockets within Phoenix that are completely isolated [in terms of transportation] when I look at this in terms of where people live. … I think that potentially the most vulnerable people are the people that don't have transportation*." This presents a challenge for people living in isolated areas to reach formal HRN or informal cooling centers. Even when there is access to public transportation, people have to expose themselves to the heat in order to use the public transit to access the HRN cooling centers. The university researcher said, "*The idea of transportation to these places [cooling centers] is really important. … If for those people their air conditioning quits or something happens, they are extremely isolated, there is no planned transportation for this particular network [of cooling centers]. There is just the assumption that people will be able to get there*." This suggests that the transportation access of people seeking heat relief is a critical consideration, and that there are many areas in Maricopa County that are isolated areas and do not have public transit access that could hinder people accessing HRN cooling centers.

Informal cooling centers, such as libraries, are mentioned by the university researcher as a large source of informal cooling centers for the homeless and other populations in need of heat relief. The university researcher said, "*Libraries, I think that*

is a huge informal cooling center. Libraries is a public space, part of their mission is to serve the public, part of their mission is also to serve potentially underserved populations, so you know the homeless." Other informal cooling centers mentioned by the university researcher could be big box stores, grocers, and restaurants for example where individuals can go to stay for 30 minutes or longer to seek heat relief. However, not all individuals feel equally welcome in all types of formal HRN or informal cooling centers. An important consideration is different types of people seeking heat relief, such as homeless versus senior citizens, and how comfortable they would be going to a cooling center that did not serve their primary population. For example, there may be a reluctance for a senior citizen to seek heat relief at a poor and homeless services organization that is a cooling center because they may feel out of place. Likewise, a homeless individual may feel reluctant to go seek heat relief from a senior community center that was also a cooling center because they could similarly feel out of place. The university researcher said, "*I think that some people would be reluctant to go to a senior center and I think that seniors would be reluctant to go to some of the other types of places.*"

   Spatial and temporal gaps, and strategies to cover them. An MCDPH GIS analyst had observations of the HRN that were related to how the cooling centers acted as a whole rather than individually, and noticed certain times of day when almost all the cooling centers closed but it remained dangerously hot outside. When asked what his impressions were of how the cooling centers vary by time of day, he said, "*It's cool to see a visualization of like basically at 5pm that a lot close and so there's like only like only four or three [cooling centers] that are really open. … If you look at it on paper then*

you don't necessarily realize the effect of them all being closed and stuff. There's kind of like a two hour period [after 5pm] at least where it's still like really hot out, and that there's like, you know, really a lack of [cooling center] resources." He also made a few suggestions on how to address this gap in cooling center coverage in the evenings after 5pm. He said, "*For those ones that close at 5pm, then like it would be best for them to like stay [open] at least until probably 7pm or so. ... Or if these places closed and they have all water in their like services, is there like some kind of water dispenser or something like that. That way even if its closed I know I can go here and still get water, or something like that.*" These suggestions are intended to fill the gap left by many cooling centers closing at 5pm, that extends through 7pm when it is still hot outside, by having some stay open later, or leave cold water dispensers outside after they close.

The MCDPH GIS analyst mentioned the time of day coverage gaps in the evening hours from the perspective of a facility manager, saying, "*It does show that, like I guess, when we do close, there's potentially, it's still really hot out, and so. And when we're open at 8am its honestly not that much of a need [for heat relief]. In a perfect world, if we were open at like 10am and closed at like 7pm, or something like that, that would better meet the need of like people coming in for heat I guess.*" This suggests that cooling centers could shift their open hours from 8am–5pm to 10am–7pm to better cover the needs of those at risk for heat by shifting open hours to match the hours of the day that are hottest. The coverage and the gaps left by cooling center schedules is shown in Figure 7 that shows the count of cooling centers that are open during the week and on weekends, as well daytime (8am–5pm) versus evenings after 5pm. One can see from that figure that there is very little cooling center availability after 5pm and on weekends.

An epidemiologist at MCDPH also had observations of the model that increased her awareness of the drop off in cooling center coverage at 5pm when most of them close. This helped her view the high temperatures at 5pm in the model and also get an understanding that it was still hot outside when most the cooling centers close down. She also indicated that the spatial and temporal format of the model time sequence and map gave insight about the HRN as a system. "*What I see that this gives us an opportunity first of all to cover the area where the needs are full fell, because some areas it seems like they are not [covered with cooling center access]. People, if they are biking, if they are walking to those places, that's not — you know, there is a need for more [cooling] centers. It's nice to see visually that. The other thing that I like is the hours when they [cooling centers] work, you know when they are open.*" This suggests an increase in awareness after viewing the model about spatial and temporal gaps that could be helpful in addressing.

A suggestion offered by the MCDPH GIS analyst was to provide some type of support for people who arrive at a cooling center after it was closed by giving them information through signage where they could go locally to get heat relief, even if from an informal cooling center. He said, "*If maybe all the cooling centers had, on their doors or something like that, that says like 'If you're here to use cooling services, I apologize we're closed, but call or please go to this like nearest [alternate cooling center]', if they all had like based on geography a closest possible place they can go listed for each cooling center, even if it is a Taco Bell or like whatever.*" This suggests that cooling centers could still support those seeking heat relief after they are closed by giving

directions to the nearest cooling center that is open, or to an informal cooling center like a

retail establishment where the person could go in to get out of the heat and maybe some

cold water like a fast food restaurant. The idea is to not leave those seeking heat relief

stranded at times of day when it's still hot outside and yet nearly all cooling centers are
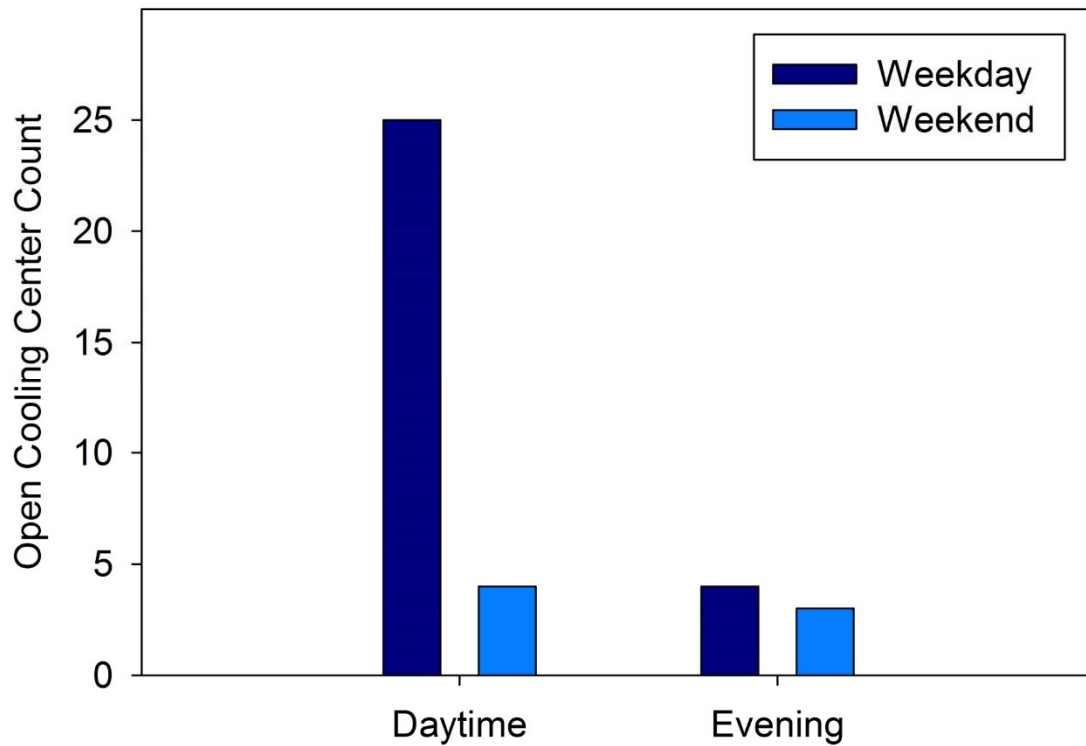
closed, specifically from 5pm to 7pm.

Figure 7. Heat Relief Network day of week and time of day availability (daytime < 5pm,

nighttime > 5pm).

The MAG representative described how her organization did not have an analysis tool that could be used to identify gaps in temporal and spatial coverage like the model showed, and suggested that the model was useful in part for this reason. She said, "*As for any type of tool that recognizes gaps or hours, or heat, we don't have anything like that. This looks like a very helpful tool, and I could definitely see it being used for the region for the heat relief efforts in terms of how to communicate this to the region as a whole.*" This also shows that the MAG representative thought that the model would be useful to communicate these gaps to the larger regional heat relief community at a planning level. There has not been an effort for strategic recruiting of cooling centers to fill gaps and get equal coverage in space or time, with the same cooling centers volunteering from year to year for the most part. The City of Phoenix representative said, "*I think historically it's been the same locations just kind of coming to the forefront [each year] 'okay we'll do it again, we'll do it again'. ... I don't think we've been really like strategic as far as where are the gaps and then how can we fill those. ... This [model] is helpful too in showing the need.*" Another thing that was mentioned was that the cooling centers themselves, as indicated by managers, do not have a lot of resource in terms of extra staff time and other resources to stay open later than 5pm to cover the heat gap until 7pm when it is still dangerously hot outside. The MAG representative said, "*I think a lot of providers were, you know there was only so much they could do, they have their hours, resources are very limited so in terms of — it was one thing to talk about it but it was another thing to recognize the actual gaps and how they affect services and those that need it the most.*"

As far as ways of filling gaps, the City of Phoenix does provide outreach teams that can be dispatched to where someone experiencing heat distress is located, hence this

is one way to fill the spatial and possibly the temporal gaps in coverage. The City of

Phoenix representative said, "*The City of Phoenix, we offer water to all of the outreach*

teams. Those aren't specific locations, those are basically individuals that get called out

if you see someone in crisis or a resident reports there's a homeless person on the corner

of 7th St and McDowell. … Again, we're not offering a cooling site but at least water is

available through one of our other programs through the City of Phoenix." As a result,

even though there are some gaps in the cooling center coverage, there are outreach teams

that can be dispatched with water to people experiencing heat crisis that do help provide

additional coverage for heat relief than the cooling centers alone. Another aspect of the

spatial and temporal gaps identified by the model is that there is a choice of which type of

gaps to cover — gaps in spatial coverage or evening gaps from 5pm to 7pm. The

MCDPH epidemiology data services manager asked the question to this point of whether

it would be better to improve existing cooling centers by extending their hours beyond

5pm covering the temporal gap, or if it would be better to recruit a new cooling center to

provide coverage for a spatial gap. This remains an open question but is critical to

determine if spending resources on one versus the other is more effective in providing

heat relief.

        Model as communication tool across HRN managers and end-users. A

MCDPH epidemiologist suggested that the model could be useful in the hands of cooling

center managers saying, "*Frankly, for [cooling center] managers this is a great tool for*

them 'oh, today this [cooling] center is open, these are the [cooling] centers that they are

open', they have [the model] handy and they can take a look at that." This suggests the

model could be useful in increasing awareness of the system by cooling center managers

to see what cooling centers are open around them and when they are open. There were

additional suggestions by the epidemiologist at MCDPH that included other uses for the

model such as making the it available to people at kiosks near public transit so they could

see where they were located relative to different cooling centers and which ones were

open. She said, "*It would be something in different like kiosks or whatever, that people*

are walking, coming from work, and they can take a look at this [model] and they say

'oh, I am here, I can go [to the cooling center] its open tonight, I can go.' … As a model,

if it's for somebody, I would like [the model] to be in the hands of the people that they

need it." She articulated an interest in trying to get the model into the hands of

consumers who could use it, or something like it, to find the nearest open cooling center

like a kiosk at a bus or light rail stop. She described the kiosk by saying, "*Consumers,*

that would be, I'm trying to think what would be the best way that this map, you just go

click at the bus station you are [located] or at the light rail, cooling center here by

clicking this you can find what cooling centers are open … I would like to see this to be

in the hands of the consumer, people that they need that, so how can we bring it to

them?" She also indicated that it might be helpful to get a version of the model into the

hands of 211 information phone operators so they could easily find out where the nearest

open cooling center is when someone calls for information.

There were several other observations that the epidemiologist for MCDPH had to

offer with regard to who the model could be useful for in supporting in terms of

decisions. This included a suggestion that it would be good to bring the model to a heat

relief planning meeting that the HRN hosts to help them see the cooling centers as a

system from the model's perspective as well. She said, "*So I think one place we can use*

this information would be really in the planning meeting of the HRN. I'm assuming that would be a place to start. ... I was thinking that this regional heat relief network [meeting], that I was there, and there were around 50 people, they are people from the cooling center sites, and you know, the collection of water donation sites, and so on. Maybe presenting [the model] to them, showing them, it would be — we would get better ideas." She thought that they might have even more creative solutions to the challenges faced by the cooling center networks, such as the gaps in coverage. This is because participants in the HRN planning meeting represent both HRN higher level coordinators and lower level cooling center facility managers. She thought both these stakeholders would benefit from viewing the model to see the systems level perspective. She said, "*I am just trying to think, so how can this be used, who can benefit from this? And two things are coming in my mind, maybe I'm wrong, one [is] regional managers that they work, and of course decision makers — whoever decides to open a cooling center*." Finally, she mentioned that the model was a good communication tool of how the system functions to cooling center managers themselves. She said, "*I think that having this information in the hands of managers, this is also good communication tool for them, because they can say 'oh, even if we close tonight, they are open, you know somebody else [another cooling center] is open.*'" She expresses in this quote the desire for cooling center managers to see when other cooling centers are open and closed so that they can coordinate their resources and maybe better cover some of the evening gaps after 5pm.

A member of MAG indicated that the model was a good communication tool that could be used to bring people together to talk about the gaps and redundancies shown by the model in space and time. She said, "*Through this you are bringing the visualization*

162

of a current issue that's going on in our region to sort of bring everyone together and say 'we're kind of talking about this but here is what's actually going on, here is the reason why we're not so efficient in our coordination efforts.'" This indicates that the model could be useful as a planning tool with cooling center managers and HRN coordinators.

A City of Phoenix HRN coordinator thought that the model could be a good tool for communicating the gaps in coverage to the cooling center managers. She said, "*We definitely could benefit from more communication. ... I think it would be more meaningful for all the participants whether a hydration center or cooling center to really hear this information and start again thinking strategically. It's more than us just providing water and a place to cool off. ... There's never such a bad thing as more communication.*" This shows that the model is a useful way of communicating complex information about the gaps and redundancies in the HRN based on the model simulation. Another way the model was envisioned to help with communication was to have the model show what nearby cooling centers were open and if they had capacity to accept more people for heat relief, if that capability was added to the model. An epidemiologist with MCDPH said, "*For example, 'God my facility is full today, so let me click there [on the model] and see what is the neighboring one [cooling center], like do they have enough capacity, can I send some people there and things like that. And then people that they are doing outreach, you know, if everyone can be [using] this communication tool.*" This shows the hope that the model could be developed into an information tool that allows cooling center managers to have better information about nearby open cooling centers to refer people to and their available capacity.

Another communication suggestion was to develop a separate software tool such as WebEOC, which is an emergency management communication software, that would allow cooling center managers to communicate with one another and gather relevant information about the HRN. An MCDPH epidemiology data services manager said, "*WebEOC is actually paid for and supported out of MAG and through the Maricopa Emergency Management, and it has its limitations but there's a lot of features that are already built in that might be worthwhile for collaborative communications. It has document sharing repositories, it has communication logs similar to instant messaging, it has mapping features. And you can silo your communications so you could create a cooling center group that's for like the managers.*" This means that a separate software tool could be useful in helping improve communications among cooling center managers and HRN coordinators beyond the model itself.

High and low technology advertisement of cooling centers. An MCDPH epidemiologist was interested to learn about whether the model could be converted to an application that could be used on a smartphone, again looking to get crucial information into the hands of the consumer. She said, "*Can we put this on our phones? ... Would there be an app?*" Another participant in the focus group interview, a NASA employee, also suggested that it might be useful to make an application of the model for smartphones so people could find the nearest cooling center that is open. He said, "*Have you ever like thought about app development you know to kind of give the public a better idea where cooling center are? ... There's a huge homeless population so they might not have access you know to apps, but I would use it if there was an app out there.*" This type

of application would not be of use to someone without a smartphone, but for those who do have one this could be a helpful resource to avoid extreme heat.

One of the things that came up in discussion was how to get the information in the model into the hands of people that are destitute and did not have resources like a smartphone and therefore wouldn't have access to an online application of the model. A MAG representative said, "*On a non-electronic, non-application basis, how could we use this [model] to go to a, like a grassroots, ground level perspective? You have the people who are needing it the most don't have any resources*." This shows that there needs to be some low technology way to market cooling center availability to the homeless and others with very limited resources. She also said, "*Those of us that have the data usage [on mobile phones] don't need the application to get to that point [of the cooling centers]. So then what other steps can we take? Do we need some sort of marketing tactics to say, okay do we need to get posters, or how do we communicate that message*?" This indicates that there may be alternate means to reach the population who needs heat relief the most independent of a high technology application approach, such as having them call in to 211 phone information, or finding the information at bus and light rail stops in poster format posted as an advertisement. In support of this idea, she also said, "*Ideally it would be nice to have some sort of marketing application process component at transit stops because at transit stops, even if they were sleeping on the bench, they would be exposed to that [cooling center advertising]. Finding a very clear message, 'this is where you are, this is what you need [water], and this is how you get to that point the easiest way.*'"

In addition to low technology communication solutions, the high technology approach of having an electronic kiosk to display the model for cooling center availability was discussed. The problem in part is that a dedicated kiosk for heat relief may prove to be too expensive for the perceived benefit. So, to make it more cost effective, the kiosk could support multiple public service inquiries in addition to where nearest cooling centers are located. A NASA employee said, "*If you like add it as an addition to something that is already there, it doesn't sound as expensive. But if you create a kiosk just for cooling stations it sounds expensive*." Based on these suggestions, it seems that low technology solutions like poster adds at bus stops and combining electronic kiosk services for cooling centers with other services would be the best way to market cooling center availability to consumers.

Interview research question 1) How do organizations articulate their role in mitigating heat health risk?

Members of different organizations articulate different roles in mitigating heat health risk based on the type of role they serve in their organization and related individual perspectives. Some individuals had a higher-level planning perspective trying to think of ways to get the model into the hands of other stakeholders and end-users, while other individuals focused on map details in the model based on their experience. Some of the respondents talked about using the model in HRN planning meetings as a means of informing stakeholders about evening gaps, while others focused on transportation and informal cooling centers related to the built environment. This represents a diverse set of responses to the prototype model in the participatory modeling sessions.

An epidemiologist with MCDPH had the perspective of a higher-level network coordinator when referring to the HRN. She articulated a role in mitigating heat health risk that was related to their primary function of studying the HRN from a heat related mortality perspective, and a desire to avoid as many heat related deaths as possible. Hence, she articulated many suggestions that related to how the model could be put into the hands of other coordinators in the HRN, cooling center managers, and consumers seeking heat relief so that they could make use of the information on cooling center open availability in space and time to both planners and consumers. This perspective was one of a higher-level network planning coordinator and was focused on how the model could be best leveraged to inform others to improve cooling center functioning and cover the evening gaps after 5pm.

An MCDPH GIS analyst articulated a role of mitigating heat health risk from the perspective of someone with a GIS analyst background, thinking in spatial terms when viewing the model and giving lots of model improvement suggestions from that point of view. He also had experience doing interviews with cooling center managers for the MCDPH program evaluation so much of his role was to articulate how he thought different elements of the interview data fit in with the prototype participatory agent based model. For example, he considered his role as a researcher trying to put pieces of information together the improve the HRN by making suggestions as to how interview data could be incorporated into the model or how the interview results informed him of how to consider the prototype participatory model.

In the focus group, there were different articulations of how to mitigate heat health risk by different members of the focus group driven largely by the type of

organization they came from. The MAG representative mentioned ways to mitigate heat

health risk that was related to its usual planning activities via the regional heat planning

meetings and how the model could be useful to inform stakeholders such as cooling

center managers about the gaps in coverage. The City of Phoenix representative on the

other hand talked about how their mobile outreach teams were able to cover gaps in the

cooling center coverage by responding directly to reports of someone in heat crisis and

delivering water and outreach to them on the street. On the other hand the NASA

employee focused on technological solutions such as having the model developed into a

smartphone application or having the model provide information on the nearest cooling

center via a kiosk at public transit stops. This represents a wide array of articulations on

different organization's role in mitigating heat health risk.

A university researcher articulated a role in mitigating heat health risk by studying

the built environment and transportation by determining the number and distribution of

informal cooling centers. That is, this researcher used Maricopa County assessor data to

categorize informal cooling centers by land use such as big box stores, grocers, and

restaurants to better understand how and where people could use informal cooling centers

to get relief from the heat. Hence his role in mitigating heat health risk was from an

academic researcher's perspective, and his articulations and focus reflected this

perspective of the built environment and transportation.

**Interview research question 2) How do organizations frame their
responsibilities?** Organizations framed their responsibilities related to heat relief and the

prototype model in different ways, usually related to the role they play within the

organization they come from. The lower position workers that were interviewed, the university researcher and MCDPH GIS analyst, had suggestions that were often limited to the framework of the model and the map display it had. Hence their responsibilities were framed in these articulations of fine details of the model. Other higher position HRN coordinators had more strategic suggestions such as how to use the model to improve stakeholder understanding and communication about the post 5pm gaps in coverage. The MAG representative spoke about strategic planning with HRN participants while the City of Phoenix mentioned their mobile water outreach. Each of these relates to their primary service role and so is not surprising that they articulated these differences.

A university researcher framed his organizational responsibility to the HRN as one of contributing knowledge and a greater understanding of heat relief based on the build environment of building space use and transportation modes that people would use to seek heat relief. His perspective on responsibility to helping the HRN was related to his work studying the transportation networks and building use data to determine access via transit to both formal and informal cooling centers. On the other hand, an MCDPH GIS analyst framed his organizational responsibility in terms of being a GIS expert at MCDPH and knowledgeable about cooling centers based on experience with interviewing cooling center managers as part of a program evaluation study. This meant that he was focused on making suggestions for model improvement in the participatory modeling interview that was based on GIS layers and what information from the cooling center manager interviews might help inform different additional GIS layers that could be

added to the model. Hence his responsibility was couched in terms of learning and discovery new aspects of the HRN that could be used to improve its functioning.

An epidemiologist with MCDPH came from a perspective of organizational responsibility that stemmed from monitoring heat health risk mortality events and being part of the HRN planning and program evaluation study. This organizational framing of responsibility for heat health risk reduction was expressed in the participatory modeling interview in terms of how the model could be used to change the perspective of other members of the HRN to see the cooling centers more as an interacting system rather than a collection of independent nodes. She suggested that the model be brought to HRN coordinators, cooling center managers, and consumers using the participatory modeling to improve their systems perspective and for them to give their creative solutions on how to improve the HRN.

The organizations represented in the focus group framed their responsibilities in different ways. The MAG representative spoke a good deal about responsibilities for communicating with the heat relief regional planning meeting about what was going on for the upcoming heat season. This indicates MAG has responsibility for organizing and coordinating the HRN on an annual basis. The City of Phoenix framing of responsibilities included a lot of water bottle delivery to different cooling centers and other programs such as their mobile outreach teams that reach out to those in crisis on the street. The MCDPH epidemiologist mentioned a responsibility for trying to get the information in the model into the hands of different levels of the HRN, from HRN coordinators, to cooling center managers and consumers seeking heat relief. While the MCDPH epidemiology data services manager framed responsibility in terms of

evaluating what the best way to cover the spatial and temporal gaps was, asking whether the spatial or temporal strategy was the best approach to reducing heat health risk.

          Interview research question 3) How do organizations articulate awareness (or lack of awareness) to the rest of the system? There were similarities across those interviewed in how they had an increase in awareness of the HRN system after viewing the model and seeing the evening gap after 5pm. Their responses to this increased awareness however varied by individual. The MCDPH GIS analyst and epidemiologist saw the system beyond individual cooling centers and how they formed clusters and gaps in coverage. The articulation of the university researcher on the other hand was to describe his awareness to the rest of the system in terms of informal cooling centers such as libraries and retail establishments and how those could help cover the formal cooling center gaps. The City of Phoenix representative noted how most the same organizations volunteer each year and so the strategic gaps in space and time persist from year to year, showing an understanding of the rest of the system.

        An epidemiologist from MCDPH articulated a reasonable familiarity with the HRN prior to viewing the model having seen the static MAG maps and schedules and so had a limited understanding of the rest of the HRN system from those resources. However, she articulated a much greater awareness to the dynamics of the way the HRN system functions in both time and space after having viewed the model dynamic runs that use a map and time sequence of cooling center availability hour by hour. Specifically, the gaps in coverage in the evenings after 5pm and spatial gaps where there are not

cooling centers located in a given area were raised as issues that showed an increased systems level awareness of the HRN after viewing the participatory model.

An MCDPH GIS analyst indicated an awareness to the rest of the system that changed over the course of the participatory modeling interview. He generally was aware of the HRN cooling centers from the static map and schedule issued from MAG each year. However, he indicated that he became aware of the larger interaction of individual cooling centers as a network rather than individually after seeing the dynamic model run of the prototype agent based model. He said, "*It does kind of show that, like, this is a larger, like, process. It's not like it's just my individual [cooling center] facility that's like a part of this, like, cooling center process. It also kind of shows that the area around like where like one of the only cooling center's within like a couple like square miles. And so there's not too much around [the remotely located cooling center]*." This shows the participant had both increased awareness of the larger process at work across all cooling centers, and the remote isolation of some areas with few cooling centers located across a wide area in some parts of the county.

One university researcher articulated an awareness of the larger formal HRN system, while showing an especially acute understanding of informal cooling centers. He indicated that libraries were informal cooling centers. For example, he said, "*One of the other ones you know, that does show up as some of the cooling centers, is libraries. You know, I think that is a huge informal cooling center.*" He also said that he considered in his research other informal cooling centers such as stores or restaurants that one could spend more than thirty minutes in. He said, "*I looked at basically any commercial place where the transaction time could be greater than 30 minutes.*"

In the focus group, the MAG representative responded to the suggestion for the model to be put on a smart phone application by saying that many of the end users such as the homeless do not have access to technology and so there would need to be a low technology solution to reach those most in need of heat relief. This indicates a good awareness of the other parts of the HRN system, end users in particular. The MCDPH epidemiologist mentioned that the model could be used by different layers of the HRN, such as coordinators, managers, and consumers. This indicates a good awareness to the rest of the system besides the coordinating level that MCDPH participates at. The City of Phoenix representative mentioned that each year the same organizations volunteer and there is not a strategic approach to fill gaps in space or time. This shows an awareness of the limitations of the way the cooling centers volunteer each year where their location and open hours are historically constrained.

Interview research question 4) How do organizations understand what capacity they have to adjust their role or behavior? The different organizational members showed variable understandings of their capacity to adjust their role or behavior in service of heat relief for the HRN. The MCDPH epidemiologist described an ability to adjust role to one of coordinating larger participatory modeling meetings with other HRN stakeholders to view the model to increase network wide understanding of the system. The MCDPH GIS analyst had suggestions to change his role to one of advisement on how to cover the evening gaps with different alternate solutions. The NASA representative on the other hand recommended changing role from coordination to one of making advertisements to end-users using smart phone applications or a kiosk for cooling center information.

An epidemiologist with MCDPH indicated an advisory role in making suggestions to improve the HRN as one of the coordinating agencies involved with organizing the HRN. She indicated that she understood the capacity her organization has to change its role or behavior in making recommendations based on viewing the participatory model to other layers of the HRN that are involved in planning, implementing, or using the cooling centers. That is, she indicated that her organization could change its role or behavior by helping facilitate a larger participatory modeling meeting with several other HRN coordinating organizations including MAG and the City of Phoenix, among other coordinating agencies. She also indicated that they would be willing to promote viewing of the HRN participatory model by the HRN regional planning meeting which includes coordinating agencies and cooling center managers, as well as by individuals who need heat relief to see what the consumer's perspective on the model was.

An MCDPH GIS analyst understood the capacity of his organization to change their role and behavior in terms of how to make recommendation to the rest of the HRN to improve its functioning. That is, he could see in the model that the institutional arrangements of the cooling center open hours led to a gap in coverage after 5pm. Hence his recommendations for how to adjust role or behavior was in terms of how his organization could make recommendations to the rest of the HRN to stagger their hours so that some were open after 5pm when it was still dangerously hot outside. He also saw how the model could be improved by adding different layers so that is another way he made adjustments to his role or behavior by giving recommendations on how to improve

the model by adding different GIS layer types that would indicated additional cooling center attributes.

The NASA representative suggested that one way to market the model, and hence available nearby cooling centers, to end user consumers would be to build a smartphone application or put kiosks at public transit stops. This indicates a creative willingness to change the role of the HRN coordinators from one of just providing the HRN, to one of marketing their location to end users. Also, the MAG representative said that the approach to low technology marketing of cooling center location and availability could be achieved by putting poster advertisements at different public transit stops. This desire for a change from a role of just providing the infrastructure for the HRN to one that also includes advertising cooling centers to consumers represents a significant suggestion for change in behavior.

Interview research question 5) How do organizations interact with adjacent lower-level HRN managers? Interaction with adjacent lower level HRN cooling center managers was fairly low, with a few of the MCDPH representatives having had some contact with cooling center managers during a program evaluation interview of a few cooling center managers. On the other hand the MAG representative had regular annual contact with some of the cooling center managers at the annual pre-summer heat relief regional planning meeting. This is the only real contact MAG has with these adjacent lower-level cooling center managers, with other contact being passive email sign up for participation as a cooling center each year. Hence overall, there is little regular interaction between HRN coordinators and cooling center managers except at the annual heat planning meeting with MAG.

Of all the members of the focus group, the MAG representative had the most interaction with lower-level HRN managers at the regional heat relief organizing meeting. This is a meeting where HRN coordinators and cooling center managers meet to plan for the upcoming heat season before it has started. Besides that interaction at the regional planning meeting, the MAG representative did not interact directly with cooling center managers during the heat season, only getting email sign-ups to participate in the HRN online as far as most of those interactions go. The other focus group participants did not have direct interactions with lower level HRN managers.

An epidemiologist for MCDPH indicated that there was very little interaction with lower-level HRN managers. This interaction was limited to the cooling center program evaluation that MCDPH participated in during the summer 2014 when she did a few interviews with cooling center managers to learn more about their operations. Besides this limited interview interaction for the program evaluation study, she did not engage with any lower-level HRN cooling center managers.

Similarly, an MCDPH GIS analyst had interactions with lower-level HRN managers by participating in a 2014 program evaluation study where he interviewed different facility managers. These were limited one time interactions with each HRN cooling center facility manager and not ongoing relationships. Due to the nature of the role of a university researcher, and not being part of the formal HRN meant that there was no indication of interaction with adjacent lower-level HRN managers, but did interact with HRN coordinators like MCDPH in his research.

Interview research question 6) Within this layer of the network, how similar are the articulations across those interviewed? The focus group participants had

similar articulations across the different individuals present, focusing more on planning, gap coverage, and communication of cooling center location and availability to consumers and cooling center managers. This was different from the university researcher and MCDPH GIS analyst interviewed in that these individuals focused much more on the science of the model, making model improvement suggestions, and talking about areas related to their specialties respectively in the built environment and GIS. In contrast, the focus group participants represent high level HRN management rather than people that focus on ground level science and so their comments reflected strategic thinking on gap coverage and communication for example.

The articulations of the university researcher came from a built environment and transportation engineering perspective and was focused on model aspects related to that topic. This was different than the articulations of members from HRN coordinating agencies who had a much more managerial and organizational perspective. He did not give advice about how to cover the gaps in the evening after 5pm like the MCDPH GIS analyst, nor did he make suggestions about how to bring the model to other HRN coordinator and cooling center managers like a epidemiologist for MCDPH did.

An epidemiologist for MCDPH had unique articulations about the participatory model that were based on how to get the model into the hands of other members of the HRN, both coordinating agencies and cooling center managers. She saw the model as a great communication tool about the dynamics of the HRN system that would be beneficial for other members of the HRN to see in order to better understand the system dynamics of the cooling centers in space and time. Her articulations also included concern about how to cover the gap in spatial and temporal coverage (i.e. after 5pm) of

the cooling centers shown in the model. This concern about how to cover these gaps was similar to the articulation by the MCDPH GIS analyst who also observed and made comment on spatial and temporal gaps in coverage after viewing the model, but was different from that of the university researcher who focused on transit modes and the built environment.

An MCDPH GIS analyst had comments and perspectives that were related to his background in GIS programs, and so engaged with the model GIS format with great insight. For this reason, he had articulations for many different model improvements that related to the spatial aspects of the model. This differed from the perspective of the university researcher who focused on transportation and built environment aspects of his knowledge base rather than focusing on the GIS structure of the model like the MCDPH GIS analyst did.

Interview research question 7) How did participatory modeling give suggestions to improve the model? There was a variety of suggestions to improve the model, all of which fell into one of two categories — adding new layers to the model or improving the model display. These suggestions include using other variables besides transit distance to represent the circle around cooling centers such as how many water bottles they give out per day on average to get an idea of intensity of use. There was also a suggestion to develop a scale for the access radius circle around a cooling center that was proportional to how far someone could reasonably travel by bus, bike or walking. Other suggestions include updating the model to the current year of the interview from 2013 to 2015, and modeling the cooling centers as their separate components of heat refuge and hydration only stations. Display improvements were also suggested include

putting real time digital output on the map of the time, percent cooling center coverage, and heat index so that people don't have to look away from the map while the model is running to get this information.

A MCDPH GIS analyst gave a suggestion to improve the model by replacing the circles around each cooling center, that represents transit access radius, with a different variable so that circle size would vary about the different cooling centers based on a given selected variable. This could be in terms of their radius of access as not being the only metric defining the cooling centers, and using another metric besides transit radius to indicate a different type of status of the cooling center. Such status densities that could be added include using circles that indicate how much capacity or average usage each cooling center has available to look at usage availability or intensity rather than transit distance radius defining the circles around the cooling centers. He said, "*They are all just like the same dot size, the same, just showing the point where they are located and stuff so it makes it seem like they are all weighted equally. ... There might be one [cooling center] that's like way over used than the other ones, so based on this you can't really tell like if one is obsolete or maybe they are both used equally.*" He indicated that using water bottles given out per day might be a good relative use intensity variable that could be assigned a new layer on the model base map to show which cooling centers were used more intensely than others. He said, "*Maybe the number of water bottles they hand out, maybe another layer for that.*" He also suggested that it might be useful to add either population density, median income, or a weighted combination of both underneath the base map as an indication of the level of need for heat relief that could potentially differentiate the currently equally weighted map space. This would help show where the

179

greatest need by income and population lie, knowing that lower income correlates with greater need for heat relief.

Another suggestion by the MCDPH GIS analyst was to develop a scale on the user adjustable slider for the travel access circle radius that was proportional to average reasonable travel using public transit, bicycling, or walking. This would allow selection of known radius for travel that were proportional to each type of transit so one could consider how much coverage there was for cooling centers based on scale specific transit modes. He said, "*Maybe come to a certain radius that that would actually cover theoretically for a given transportation mode*." He also suggested the idea of adding a differentiation between different cooling center types, for example senior center versus a poor and homeless services organization, since the populations that utilize each are likely different. He said, "*A lot of times the population that's going to use the primary service [of the cooling center] is probably going to be one of the main users for the secondary cooling service. That could explain the demographics of that population [using the cooling center] potentially*." Finally, he said that it was hard to tell when looking at the main model map display when the temperature was above the 105° (F) heat index since the temperature display is off to the side of the model display. He suggested putting some type of text on the main map display saying when that dangerous heat threshold has been exceeded so that one can see at the same time that heat is dangerous just as almost all the cooling centers close at the same time. He said, "*Even add a little indicator like on the bottom part [of the model] that says 'extreme heat' like, an indicator that hits the mark of its considered extreme heat, why are you closing*?" This articulation suggests that this additional icon would be helpful in orienting viewers of the model to when

dangerous heat thresholds have been reached at the same time as when all the cooling centers close at once at 5pm.

An epidemiologist with MCDPH suggested several model improvements, including updating the model representation to the current year of 2015 rather than 2013, as well as additional display items such as adding a clock and alternate graphics to represent the percent cooling centers that are open and heat index. Her comments indicated that since the cooling center participation list varies year to year, the current model year of 2015 at the time of the interview should be what the model is based on, that way it had the up to date cooling center list for the year the interview was given. She said, "*As more reliable information would be ... it would be better to have the updated [information] because clearly this is changing every year. ... It would be good to have the updated list, the most updated list of cooling centers.*" She also indicated that it was hard to watch the progress of the model on the map while also trying to view the updated graph charts on the left of the model. So, she asked if it would be possible to update the model by adding both a digital clock indicating the current time on the map, along with a display of the current temperature. She said, "*Is there something that this could be a little bit more intuitive, that I can see for example 'oh, this is temperature at this time'?*" She suggested that this would help better orient the viewer of the model during a simulation and allow them to see the time of day and temperature intuitively while still looking at the main model display without having to look at charts on the side of the model.

Similarly, the MCDPH epidemiologist indicated that it would be also helpful to put a visualization on the main model map that would show the summary condition of the variable for both percent cooling center coverage and heat index in graphic form, in

addition to having time and temperature printed out on the main model map and updated for each time-step. She suggested that an intensity bar, going from relative maximum to zero for each variable would be helpful and that it could be in bar format, like a sound intensity bar from sound output that fills up and depletes based on the value of cooling center percent coverage or heat index. This would be displayed on the main map so one could view all information at once. She said, "*Is there is something that we could visually show under these where this is the number that is open and this is temperature ... This is how many are open right now. ... If we can show a thermometer or something visual just to translate these [side graphs], you know*." This suggests that the model can be improved by adding additional visual indicators for time of day, percent cooling center coverage, and heat index. That way people not used to line graph data format, as is the case with the side charts in the model, can more easily see the data output for key variables while they watch the model map output and don't have to look away to see the side figures.

There were several focus group suggestions to improve the model that were made during participatory modeling sessions. The MAG representative made a suggestion that the cooling centers, which are an aggregate of heat refuge and hydration only stations, be split into their component heat refuge and hydration only station parts in the model to better look at the different resources available. She said, "*I feel as though the application could also include hydration and refuge stations because I feel that every year we have more hydration stations, and to have the availability of just water itself*." This suggestion to split the cooling centers into its component parts of heat refuge and hydration only stations would allow one to see gaps in coverage for heat refuge versus hydration

stations. The MCDPH epidemiologist agreed with the idea that the cooling centers should be split into heat refuge and hydration only stations. She said, "*Maybe adding also hydration and refuge, because hydration alone it is a type of relief you know they get the water so maybe also seeing how that changes things*."

Another suggestion in the focus group to improve the model made by the MDCPH epidemiology data services manager was to consider the distance people would need to travel based on transportation mode to get to different cooling centers and include that in the model. This is because the mode of transit to cooling centers was a question asked on the visitor surveys from the cooling center program evaluation. The idea was to incorporate a different radial access distance for different cooling centers depending on the dominant mode of transit used by people visiting the different cooling centers. She said, "*Maybe centers where a high proportion of the visitors came on public transportation or something like that, versus the ones that didn't. I just don't know how that would look. And maybe one of your comments is transit, and maybe the issue is of those, who were using public transit, biking or walking versus a car. ... Maybe you could do different circles based on the amount of car transit versus the other modes, because you would assume that the ones that are far out are car transit*." This suggests adding custom access distance circle radius length in the model depending on the dominant mode of transportation for a given cooling center based on survey data. A final suggestion was from the City of Phoenix representative who indicated that it could be helpful to improve the model by adding a GIS sublayer to the model of actual observed heat related deaths as a density in space, this way one could see the spatial risk of heat mortality while viewing the model. She said, "*So I'm thinking that instead of something*

like income, based on some of your data where we know there were deaths. ... That way we can see too where that location is and where there are hydration or cooling centers in proximity from those areas."

Interview research question 8) What insights does this case bring to bear on climate adaptation and institutional resilience? Institutional resilience can take many forms, as suggested by the array of different examples the interviewees gave. Suggestions from interviewees that increased institutional resilience include shifting open hours to stay open until 7pm to cover the evening gap. Exterior signage on cooling centers when they are closed showing where nearby formal and informal cooling centers are located is one way to increase institutional resilience by giving ways to cool off after a cooling center is closed. In addition, offering informal cooling centers such as libraries and retail establishments is another way to increase institutional resilience by letting people seek heat relief in these latent resources. Another means of institutional resilience is getting the model into the hands of HRN facility managers and end users to increase their knowledge of the gaps in the system so they can plan around and come up with solutions to cover such gaps — for example a kiosk of the model at transit stations. Another form of resilience could be advertisement in the form of smart phone applications and low tech use of poster advertisements at transit stops to better inform end users where they can seek heat relief.

An MCDPH GIS analyst had suggestions related to the open hours of the cooling centers. He indicated that in terms of heat relief, it would serve that goal better for the cooling centers to be open from 10am to 7pm rather than from 8am to 5pm to better cover the evening hours with open cooling centers when it's still hot outside. This would

add institutional resilience to the system, though arguably most cooling centers have other primary functions and so changing open hours for the secondary heat relief function may be a challenge. Another suggestion he gave to increase institutional resilience is to have signs on the outside of the cooling centers when closed that gives information on where someone can go nearby to seek heat relief, whether from a formal cooling center or an informal cooling center like a fast food restaurant. A university researcher mentioned a great deal about informal retail cooling centers where people can go to seek heat relief that is not necessarily part of the formal HRN. There are thousands of retail establishments where people can go to escape from the heat in Maricopa County. This perspective speaks to the large amount of institutional resilience that exists in this metropolitan area to protect people from extreme heat by providing extensive indoor space that is cool distributed across the region.

An epidemiologist with MCDPH had a great deal of focus on how to get the model into the hands of other HRN coordinators, as well as cooling center managers and consumers seeking use of the cooling centers as a means of increasing institutional resilience. She thought that for HRN coordinators and cooling center managers, the model would help them see the gaps in time and space of cooling center coverage and help them better leverage their resources to cover some of these gaps through strategic thinking at the systems level. In a slightly different way, she articulated the desire to get the model into the hands of consumers in a kiosk or other format at public transit stops so that people could see from the model at the current or future time so as to learn where an open cooling center was located nearby. This use of the model in these ways points to opportunities to improve systems resilience by increasing systems awareness and gap

coverage by HRN planners and cooling center managers, and access to cooling centers on the consumer side.

The focus group case had participants that discussed elements of increased communication with other HRN stakeholders and advertising to consumers on how to get to the nearest open cooling center. The communication was suggested to be with cooling center managers to help them see the gaps in space and time, and help cover them if possible. Advertising to end user consumers on how to get to the nearest cooling center was suggested through smart phone applications, public transit kiosks, and poster adds at transit stops. These measures taken together represent an improvement in institutional resilience by making those at risk from heat better able to reach cooling centers.

Interview research question 9) How do HRN members show first or second loop learning type thinking in their responses? There was a variety of responses during the interviews with most of them being based on first loop learning type thinking, while there was some evidence of second loop type learning. A university researcher exhibited second loop type learning thinking in discussion of informal cooling centers, while the MCDPH GIS analyst showed second loop thinking by suggesting extending the open hours of cooling centers to 7pm to cover the evening gap. This latter example is second loop because it challenges existing norms of keeping regular business hours and serving those in need of heat relief with a higher priority by adjusting open hours to 7pm. The rest of the conversation with all participants was about first loop type learning that focused on daily operations and not adjusting normative values.

The university researcher showed indications of second loop learning type thinking by challenging usual norms of just thinking about and relying on formal cooling

centers. His articulations focused on changing the way people approach looking at the built environment in terms of how those in need of heat relief could seek relief at informal cooling centers such as retail stores or libraries. His role as a researcher studying the HRN has led him to have unique insights coming from an engineering background focusing on the built environment and transportation. He also spoke about things in terms of single loop learning, or daily operations, when thinking about different ways people use transit, such as biking, walking or public transit, to get to formal or informal cooling centers.

An MCDPH GIS analyst showed mostly first loop learning type thinking when talking about the different GIS layers that could be added to the model which related to daily operations of cooling centers and what attributes would be best to show their strategic use in the model. For example, he indicated that he noticed gaps in evening coverage and spatial gaps where there were not any cooling centers located. However, he did exhibit some second loop learning type thinking when he suggested that the norms of when cooling centers are open should be shifted to evening hours to cover the gaps left after 5pm when most cooling centers close. He also suggested a change in norms when he advocated that signs be left on the outside of the cooling centers to direct people seeking heat relief to the next closest open cooling center, whether formal or informal like a fast food restaurant. This suggests a willingness to think beyond the usual daily operations and normative assumptions that limit thinking to the formal cooling centers and their schedules.

An epidemiologist for MCDPH generally had comments that were indicative of first loop learning type thinking, with great insights on the level of day to day operations

and communications within the HRN. She suggested that the prototype model would be a very good communication tool to show the gaps in services to different layers of the HRN. That is, she said the model would be useful to present to HRN coordinators, cooling center managers, and as a navigation tool for end user consumers seeking heat relief. She believed that showing the model to other HRN members would help come up with creative solutions to cover some of the spatial and temporal gaps in the HRN cooling center coverage. This was first loop learning type thinking because it did not show a challenge to existing norms but rather operation within the existing normative framework.

The focus group had a general focus on first loop learning type thinking with most of the discussion occurring around how to improve the HRN in terms of daily operations, normative assumptions were generally not challenged. For example, the City of Phoenix representative noted that most of the cooling centers volunteer each year creating a consistent pattern of gaps or redundancies, and that the HRN hasn't been approached from a strategic gap perspective until now with the prototype model. The MAG representative suggested that the model should be shown to the regional heat planning meeting to help them identify gaps in coverage and propose possible solutions. Still, she said that most cooling centers do not have a lot of extra resources so they may not be able to cover the gaps even if identified. This represents first loop learning type thinking and does not indicated second loop normative re-evaluation type thinking.

Revised agent based model based on interview results. Some of the model improvement suggestions were taken into account and incorporated into a new version of the prototype agent based model, referred to here as the revised model. The

improvements undertaken include improving the model output display on the map, updating the model to the year the interviews were given (2015), and splitting the cooling centers into their component parts of heat refuge and hydration only stations. The revised model is shown in Figure 8, where there are heads-up digital displays of heat index, percent refuge station coverage, and percent hydration station coverage placed on the model map output display seen in the lower left hand corner of the map. The time of day and day of week display has also been added to the top left of the map output so users can orient themselves to the diurnal time sequence of the model at any point. There is also a separate user selectable radius of coverage for each heat refuge and hydration only stations, to give each their own transit access radius coverage. The revised model allows the user to select heat refuges, hydration only stations, or both when initializing the model run for the years 2013, 2014, or 2015. This gives a more realistic up to date version of the model relative to the year participatory modeling interviews were given in 2015.

Discussion

  General discussion. The overarching research question asked in this chapter is how can participatory agent based modeling intervention act as a catalyst for co-learning and ideation for problem solving in a complexity governance context? The answer is that the model acts as a central focus for people to view the system as it behaves based on individual cooling center decision making to hold their own open hours. This allowed participants to view the system more realistically and add their expertise to suggestions to

improve the system. The model helped participants generated creative ideas for

improving the HRN. They thought about ways in which the model could be used to help
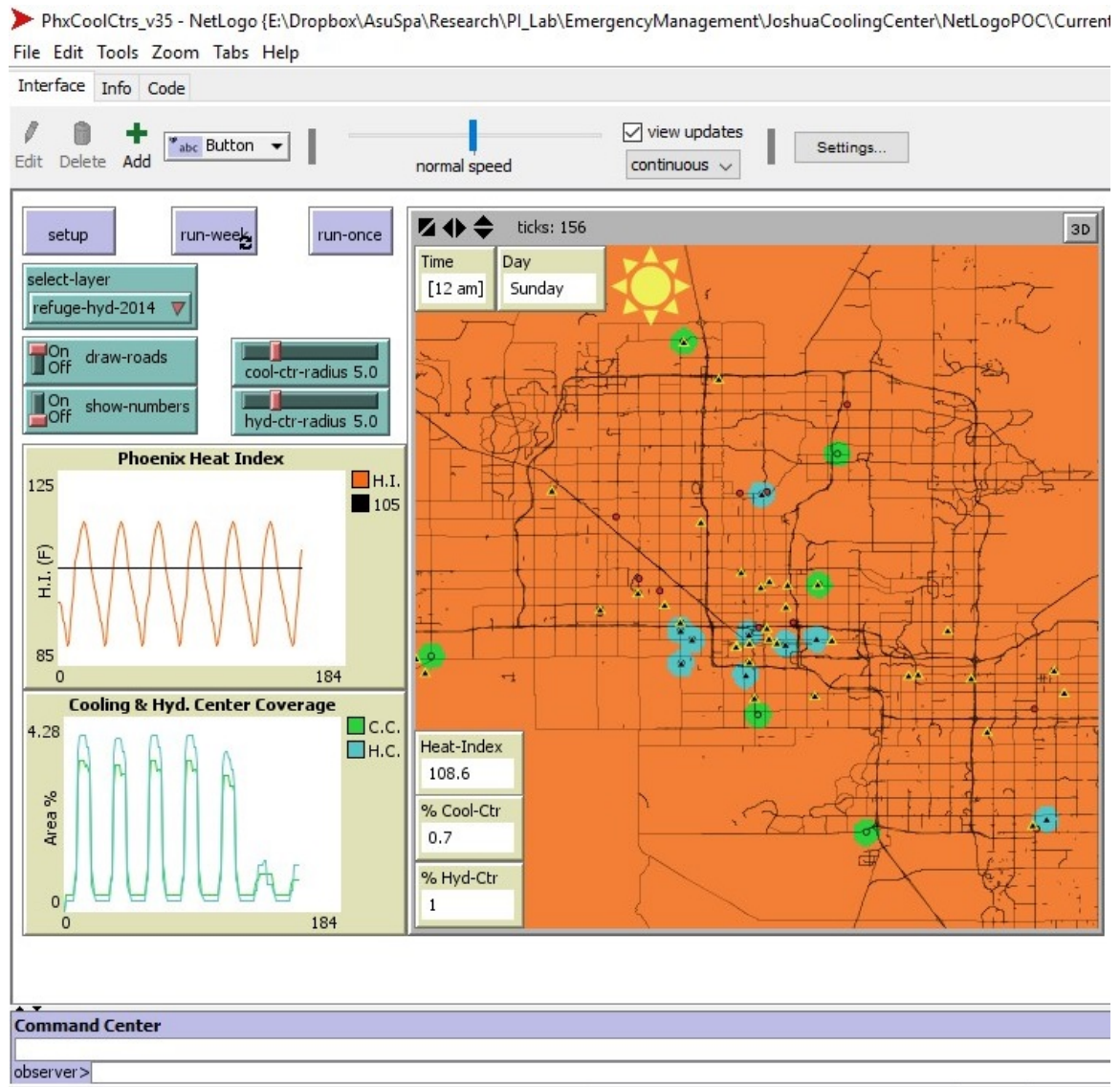

Figure 8. Revised agent based model based on interview input.

inform other members of the HRN about the systematic gaps and redundancies in cooling

center coverage in space and time. With the model as a centerpiece, co-learning about

the system was improved since participants could see how the HRN functions in space and time in reality, rather than imagining it without assistance of the model. The participatory modeling process **1)** brought out individual expertise for comparison to the model, **2)** allowed the system to be seen as interdependent and dynamic, **3)** allowed the viewer to step into the role of someone seeking heat relief, **4)** encouraged co-learning across modeler and participants, and **5)** fits within a complexity governance context meeting definition criteria. These concepts are explored further below.

Individual expertise within a given system is usually separated by organization and job type, and so often people only are aware of their own expertise in a given situation. In a participatory modeling exercise, there is the benefit of having a modeler bring expertise to the table to be integrated with the local expertise of stakeholders. In this study, interviewed participants brought their expertise to bear on the subject matter by engaging in generating creative solutions to the problem at hand, namely how to improve the HRN. The MAG representative for example had the most firsthand interaction with HRN cooling center managers at the annual heat relief planning meeting and so had a good deal to offer based on this experience. The university researcher and the MCDPH GIS analyst had specific knowledge about planning and GIS architecture, and so they brought that knowledge to bear in their suggestions. One aspect that is missing from the discussion is the perspective of cooling center managers and so it is important to bring them into the discussion and hold future participatory modeling exercises with them.

The HRN system functions as a collective and the emergent results of when cooling centers are open and available can arguably be best seen as a dynamic simulation.

As mentioned earlier, it is difficult to see from the static maps of the HRN where the gaps and redundancies lie in the system. As a result, the participatory agent based model provides a unique entre to seeing the system as it would be experienced by someone seeking heat relief. One interesting aspect of the HRN is that it is an ad-hoc self-organizing network with some hierarchical aspects through the HRN coordinators. Despite some of these independent attributes of self-selection of open hours, there is an interdependent aspect of the HRN in that the system elements yield an emergent result that is the due to most cooling centers choosing normal business hours as their operating hours. This is a normative aspect of when to open and close that is independently selected and yet is convergent on normal business operating hours. Hence what seems to be a collection of independent actors turns out to be a highly-coordinated set of convergent decisions on when to open and close.

An aspect of participatory modeling that is useful is that it allows the viewer to imagine themselves as an end user trying to seek heat relief. This is a dynamic approach that lets the participant ask how they would behave in such an environment if they were seeking heat refuge. One of the benefits of seeing oneself in the position of others seeking heat relief is that it can help generate empathy through a real concern for others in how challenging it is to find an open cooling center spatially and after 5pm when most of them close. This empathy is useful because it helps people understand through simulation what others might experience when trying to navigate through Maricopa County seeking heat relief. Such empathy is also useful in putting a more realistic motivation behind the problem-solving thinking of someone viewing the model.

Co-learning in the participatory modeling process is one of the main benefits of engaging in such an activity. In fact, co-learning and relationship building among the modeler and participants can be even more important than specific modeling results. In this research, most co-learning occurred in the focus group since there was a relatively high number of participants than in the single interview setting. Still, there was co-learning between the modeler and single participants since both parties learned from one another. In the focus group for example, the group learned about the WebEOC software that could be used as a communication platform among HRN coordinators and cooling center managers. In addition, there were many ideas about how to advertise the availability of cooling centers that were discussed including smartphone applications, as well as kiosks and poster adds at transit stops. These are different example of things that came up during the co-learning process.

The participatory modeling in this chapter fits squarely within the bounds of complexity governance. This is because the HRN is an emergent process of a self-organizing structure that is captured in the prototype agent based model. Participants in the modeling process are a wide array of stakeholders of governance entities. This allows viewing of the dynamic simulation of the agent based model that shows a large-scale problem that extends beyond municipal political boundaries. This is a collective effort to solve complex social problems in an innovative way that advances the common good. These efforts are leveraged by the use of information technology in the form of a prototype model.

Three affordances that were mentioned in chapter three that complexity governance offers is: contextual awareness within the system, a platform for

communication of best practices, and jurisdictional flexibility to address social challenges. The participatory modeling process lends itself to increased contextual awareness of the system as supported by the participants not knowing about the evening gap before seeing the model, but seeing it clearly after seeing the model. This is one aspect of increased contextual awareness. The co-learning process and communication during the participatory modeling allows transfer of information on best practices within the system with the prototype model acting as a catalyst. Also, there is an organic jurisdiction county wide in the model that is independent of the municipal boundaries that divide up the HRN that allows a flexible way to address challenges within the system.

A weakness of this study is that the initial prototype model did not separate out the cooling centers as component elements of heat refuge and hydration only stations. This was an oversight and would be done with separate heat refuge and hydration only stations if it were done over again. This improvement was one of the suggestions in the participatory modeling and so was noticed by participants as a potential area of improvement. This change was made to the revised model built based on interviewee suggestions.

Discussion of salient results. It was noticed that during the participatory modeling interviews there was a gap in cooling center coverage in the evenings after 5pm when nearly all the cooling centers close, but it's still dangerously hot outside. The model showed participants the larger process of the HRN cooling center availability in time and space. There were suggestions that cooling centers could consider staying open until 7pm to help cover the heat health risk in the evening hours. Another interesting idea was to have the cooling centers shift their open hours from 8am–5pm to 10am–7pm, to

194

better cover times of day when heat health risk is greatest. However, this may be a challenge since many cooling centers have a primary purpose other than giving heat relief, with being a cooling center as their ancillary function. Hence voluntary organizations that act as cooling centers may be unwilling or unable to shift their open hours later in the day since they have other clientele's needs to consider, or may have resource constraints that limit their open times to regular business hours. Another idea to help cover the gap in cooling center coverage at the end of the day when they close was to leave signage on the outside of cooling centers that could tell people where to go locally to seek heat relief, even if from an informal cooling center like a fast food restaurant. The idea was that there are additional resources for water access and cool space in many areas that may not be formal cooling centers that people could be directed to seek heat relief from if a cooling center was closed.

Most of the participants had an increase in awareness of the rest of the HRN system after having viewed the model. This is because the model itself seems to increase awareness of how the individual elements of the HRN system interact and shows the emergent features of gaps and redundancies in temporal and spatial coverage. An epidemiologist from MCDPH specifically increased awareness of the dynamics of the system and the gaps in coverage after 5pm after having viewed the model. This shows the model is helpful in showing the complexity of emergent features of the system. Similarly, the MCDPH GIS analyst also became acutely aware of the gaps after 5pm and in spatial coverage, showing an increased awareness to the rest of the system. He was generally aware of the static maps of the HRN and its schedule, but was not aware of the systematic gaps in coverage until viewing the prototype model. The university researcher

showed a good awareness to the rest of the system by having extensive knowledge of

informal cooling centers and the public transit system. He thought libraries were great

informal cooling centers, but really any place you could stay inside for 30 minutes or

longer he considered to be a good informal cooling center. Knowledge of the end user

part of the system was recognized by MAG who said that smart phone applications may

not be usable by homeless populations and we would need to use a different type of low

technology advertisement and outreach to inform them about where and when cooling

centers are available. The MCDPH epidemiologist was aware of different layers of the

HRN system, as indicated by her suggestion that the model should be brought to HRN

coordinators, cooling center managers, and end user consumers. These are different ways

these stakeholders were aware of the larger system as a result of their general work or as

a consequence of viewing the prototype model.

The suggestions for improving the model varied, but did generally fall in to two

categories — model GIS base layer additions or additional display features. There were

assertions that different base layer use attributes could be assigned to the display of the

circles around the cooling centers on the model map besides distance traveled. This

could include intensity of use variables that would help give insight on the relative weight

each cooling center has in contributing to heat relief such as using capacity, usage, or

number of water bottles given out. Another recommendation was to use demographics

from local areas in a base layer to integrate within a radius access circle what

demographics of people were coming to use a particular cooling center. It was also

indicated that the model should be updated to include a layer of cooling centers for the

current year, 2015 at the time of the interview. This way people viewing the model could

see the most current relevant information in the model. It was also suggested that the aggregate cooling centers be split into their component parts of heat refuge and hydration only stations. This way one could see in the model the relative availability of each type of resource separately. Finally, an improvement was suggested to add a base layer to the map that showed observed heat related mortality density in space so one could see the experienced heat health risk rather than using a proxy like median income. Together, these suggestions for additional model features gives more flexibility to present different types of information, and a more realistic representation. This is most true for updating the model to the current year and splitting the grouped cooling centers into separate heat refuge and hydration only stations.

The model display improvement suggestions ranged from transit access circle radius adjustment, to adding additional heads-up display outputs on the map itself so people could view the map while seeing relevant output information. It was recommended that the user adjustable circle cooling center access radius slider be bench marked to different transit distances. This way the user could easily pick a radius for walking, biking, or taking public transit. Other suggestions include other parts of the model display, namely the real-time output of results to the model map display so people don't have to look away from the model while it runs to see output information. For example, it was articulated that it would be helpful to have the time of day, heat index, and percent cooling centers open displayed in an intuitive way on the model display map to watch updated information and model map output at the same time. This could be done simply by putting digital outputs on the map face updating each of these three variables for each model time-step, or by designing more complex graphical ways of

presenting this information as output on the model map. For example, there could be a relative "sound-bar" intensity icon, pie chart, or thermometer that fills up and goes down with each respective variable as a visual way to interpret the data. These represent ways to adjust the visual presentation of the model to make its use and interpretation respectively easier and clearer.

There were several ways that increased institutional resilience was articulated by the interviewees. These included shifting the open hours of cooling centers from 8am to 5pm, to 10am to 7pm to cover the evening gap between 5 and 7pm when it's still very hot outside. Another form of institutional resilience suggested was to leave signs outside the cooling center showing where to go in order to get to the next nearest cooling center when the present one is closed. This could for example be a sign directing someone to the nearest open formal cooling center, or informal cooling center such as a fast food restaurant. This is important because there are many informal cooling centers that people can go to such as retail establishments to get out of the heat and often get water. This can add resilience by leading people to get to informal cooling centers even when formal cooling centers have closed for the day. Such informal cooling centers could be big box stores, grocers, and restaurants. This increases institutional resilience by giving people more resources to seek refuge from the heat. Communication of where nearest open cooling centers are located is also another form of institutional resilience that the HRN can offer through advertisement. This could be done through smartphone applications, or kiosks and poster adds at transit stops showing consumers where to go to get to the nearest open cooling center. In sum, there are many ways that the participants suggested increased institutional resilience to extreme heat. Importantly, many of these suggestions

for resilience surround how to get individuals to cooling centers that are open, and how to help them navigate the evening gap between 5pm and 7pm when most cooling centers are closed and yet it is still very hot outside.

The interviewees gave responses that were generally in line with first loop type thinking that seeks to reinforce existing norms and daily operations. Interestingly, the two lower level researchers that were interviewed, the university researcher and MCDPH GIS analyst, were the only individuals to show second loop learning type thinking. The more senior HRN coordinators focused more on daily functions and did not challenge underlying values. For example, the university researcher suggested that there are a myriad of informal cooling centers that could be a resource for people seeking relief from the heat, this challenges existing assumptions of relying only on formal cooling centers within the HRN. Likewise, the MCDPH GIS analyst suggested that cooling centers shift their open hours to the evenings to cover that evening gap after 5pm. He also suggested putting signage outside of closed cooling centers that showed people how to get to the nearest cool space, even if it was a fast food restaurant. This represents out of the box thinking and challenges existing norms. The other HRN members interviewed focused on more traditional topics of discussion such as communication across the HRN using the prototype model to show people where the gaps and redundancies lie, indicating that senior HRN managers were focused more on first loop learning type thinking. This result may be due to the higher level HRN managers are responsible for more of the planning and mundane aspects of the HRN than the lower level researchers who had more imaginative solutions.

Conclusion

The experiment done in this chapter was in large part a success because it was able to generate co-learning and ideation in a complexity governance context using participatory agent based modeling. All of the participants were enthusiastic and engaged through the interview process and brought their expertise to bear on challenges facing the HRN. The HRN, as any system, has strengths and weaknesses that were revealed to participants. One strength is that the HRN leverages latent resources that act together to provide heat relief, increasing public awareness of cooling centers more than if they were acting on their own without being part of the HRN. A weakness is that the cooling centers are often located in a clustered pattern, creating redundancies in space and leaving gaps without coverage. There is also a temporal weakness in that there is little cooling center availability after 5pm or on weekends.

The perspective of those viewing the model changed, regardless of the individual, from before to after seeing the dynamic simulation of cooling center coverage over the course of a week hour by hour. This is because none of them had systematic understanding of the evening gap after 5pm before the modeling, but did afterwards. Perspectives were different depending on the type of organization that the participant came from, but also was contingent on the level of the system that they focused on. For example, the MCDPH GIS analyst focused on GIS details of base layers and less on planning and communication of the model results than the MCDPH epidemiologist did. This suggests that each individual focused on the types of issues they were familiar with.

Everyone who viewed the model noted the large gap in cooling center coverage at the end of the day when it was still hot outside from 5pm to 7pm. What was different

was the types of solutions to covering that gap that people brought forward. This is indicative of them coming to understand their position within the system, and responding from that position with suggestions on how to improve the HRN or the modeling efforts. These different suggestions included informal cooling centers such as libraries and retail establishments. Importantly, suggestions to cover the gaps could include spatial or temporal coverage in the evenings after 5pm. The question is, given limited resources, what is more protective — recruiting additional cooling centers in spatial gaps or encouraging existing cooling centers to stay open later. How do we encourage existing cooling centers to stay open later or shift their hour to the evening given the limited resources of cooling centers who volunteer their space? Perhaps a mix of strategies would be useful in recruiting new cooling centers in the spatial gaps while finding strategic cooling centers that can shift their open hours to stay open later.

The participatory modeling exercise itself provided a learning environment for those viewing the model, and led participants to make suggestions to improve the model for future use (Pahl-Wostl, 2002a). Those who viewed the model were helpful in suggesting ways to improve the model, falling in two main classes of improvement suggestions: adding new layers as features to the mode, or improving the display output. The additional layers suggested to be added to the model would provide ways to look at the system differently, such as having the model use updated layers of the current interview year of 2015, and split the cooling centers into their component parts of heat refuge and hydration only stations. Other suggestions to improve the model related to the display output was to have the day and time output on the map, in addition to the heat index value, and percent refuge or hydration only station so that people could see these

values while viewing the map of the model without having to look away to side charts. These suggestions for model improvement were incorporated into the revised model, giving an updated choice of years to model, 2013-2015, and with the cooling centers split into heat refuge and hydration only stations. Similarly, the aforementioned updates were added to the revised model. This revised model should be useful in future modeling efforts to help improve the HRN by presenting it to additional stakeholders in the system for further improvement and ideas for HRN spatial and temporal gap coverage.

The research in this chapter has demonstrated how participatory agent based modeling can be used in a complexity governance context. The modeling process brought out individual expertise that was applied to improving the model. This is important because there is a wide range of expertise available from stakeholders and garners a diverse perspective. The modeling experience showed participants how the HRN operates collectively and is a complex dynamic system. This is important for viewers to understand so that they can take the mindset of someone seeking heat relief and ask themselves how they would negotiate the HRN cooling center availability. The process itself is useful as a co-learning exercise and builds relationships among stakeholders and so has value besides specific modeling results. Ultimately this type of approach helps demystify complex systems into understandable components that makes solutions to challenges in systems like the HRN more tractable.

CHAPTER 5

INTEGRATING PERSPECTIVES ACROSS THE

HEAT RELIEF NETWORK FROM DIFFERENT SYSTEM LEVELS

Introduction

The overall dissertation looks at a public health issue, extreme heat health risk, through the lens of complexity governance. There were four chapters that evaluate different aspects of the Maricopa County Heat Relief Network (HRN). Chapter one introduced ideas and theories relating to organizational learning, and aspects of climate adaptation, hazard preparedness and resilience in Maricopa County. The second chapter evaluated interviews conducted with cooling center facility managers to learn about their perspective and experience. Chapter three focused on the concept of complexity governance and introduced a prototype agent based model used in the participatory modeling. While the fourth chapter engaged HRN coordinating agency members and researchers in participatory modeling with the prototype model in an open-ended interview process. This chapter sums together important lessons learned from each chapter and what questions came about for future research. In addition, observations are made across the two scales studied in chapter two and chapter four, namely the cooling center managers, and the HRN coordinators and researchers respectively.

Chapter Summaries

     Chapter one. The first chapter is introductory and reviews some of the major theory behind the dissertation subsequent chapters. This includes organizational theory, climate adaptation, hazard preparedness, and resilience in Maricopa County. These are important topics because they set up the context for subsequent chapters. This is described further below.

     Organizational theory holds that how organizations perceive, change, and learn over time is influenced by organizational culture (Fiol & Lyles, 1985) and climate (Schneider et al., 1996) and is an important consideration when framing organizations. The organizations considered in this dissertation, the HRN, are embedded within organizational layers that often learn, persist, and change through time. Within organizational learning, there are always trade-offs to be made when deciding to take one action versus another. Public service is being delivered increasingly as the result of public and private partnerships (Brinkerhoff & Brinkerhoff, 2011) because there are increasing needs of urban populations (Koppenjan & Enserink, 2009). Such partnerships often exist as coupled infrastructure systems where there is hard infrastructure (physical structures) and soft infrastructure (policies and rules in use). The concept of increasing resilience in the face of complexity, such as the environment the HRN exists in, often requires choices between different types of resilience — there are always trade-offs and there is no set of choices that maximizes all type of resilience at once (Anderies, 2015). Hence there may be trade-offs that HRN cooling centers could make, for example increasing service for heat relief that may come as a cost to serving their primary service clientele. The idea is to find the most appropriate economic trade-offs between efficiency

of organizational output and adaptive measures that increase infrastructure resilience. This research contributes to understanding the perspective and practices of the different cooling centers and HRN coordinators as public and private partnerships of coupled infrastructure. There are trade-offs in the HRN where hours could be kept at normal business hours for primary service clientele, or extend hours later in the day could be kept at 10am–7pm to cover the evening gap but not serving the primary clientele as efficiently. The motivation behind which trade-offs are chosen is contingent on the culture and climate of the organization, and overarching organizational objectives.

Organizations learn in different ways than individuals, with distributed cognition representing how such organizations process information and understand the environment around them. When it comes to organizational learning, the cognition system must understand the relationship between organizational action and outcome relative to the external environment. Unless this connection between action and outcome is understood, organizational learning cannot take place (Fiol & Lyles, 1985). Cognition and memories in an organization occur across the organization through distributed cognition, thus organizational learning takes place at the level of this cognition (Lazlo, 1972). Information processing across an organization can experience distortion, filtering, and insufficient band-width, where relevant information for a given decision may not reach the appropriate level of the organization; this is a situation where the larger organization may not have as much information as the most informed subgroup (Argyris & Schön, 1978). To deal with large volumes of data coming into the organization, there are different approaches that include communication strategy, organization structure, and technology (Daft & Huber, 1987). Information overload in a digital age can be dealt with

by building a system of communication structures to sort information and an interpretive perspective to allow message summarizing. Depending on how variable the environment is, organizations may invest more or less resource in to learning — more stable environments have a lower return on learning investments than learning in a changing environment. The HRN at the facility manager level has been suggested in chapter two to benefit from increased communication to help sort and interpret information available in the network that is not being accessed presently. This could be achieved through implementation of a communication platform to make communication among facility managers efficient and practical. At the same time, the environment from the perspective of cooling center managers is relatively unchanging with chronic extreme heat in Maricopa County for the duration of the summer, hence investment in learning about the organizational environment may not yield improvements to service — they are already providing maximum service to those in need.

General systems theory gives a description of organizational learning as a single control loop comprised of a norm, a unit of measure, comparison, and unit for correction that constitutes a stimulus-response or cybernetic control loop (Boulding, 1956). This single control loop represents evaluation of function against a static norm, where a thermostat would be a physical analog to this type of control loop. This is similar to organizational learning using a single control loop, or first loop learning from organizational theory (Argyris, 1976). There is another type of learning in organizations that is values, norms and world views are changed (Hedberg, 1981) which constitutes second loop learning, or changing the norms for which the first loop learning cycle is set (Argyris & Schön, 1996) which would be analogous to changing the set temperature on a

thermostat. Single loop learning functioning as a positive assessment of action and outcome, whereas second loop learning is a normative re-evaluation and assessment. Research across case studies of organizational learning indicates that first loop learning is the most common, and second loop learning is rare. This is because second loop learning requires a properly functioning first loop learning cycle in order to operate. Beyond this second loop learning pre-requisite, there are two other main sources that prevent second loop learning, absence in dialogue or experimentation (Schimmel & Muntslag, 2009). The research in this dissertation, specifically chapters two and four, is consistent with the literature in that first loop learning type thinking was the dominant way both cooling center managers and HRN coordinators approached issues. Second loop learning type thinking was rare and was encouraged by dialogue in the interview process and encouragement to think experimentally for creative solutions to reduce heat health risk that indicated a change in norms or world view.

The HRN exists in an environment where there are increasing heat health risks driven in part by increasing temperatures due to climate change urbanization in Maricopa County. Global scale climate change, driven over the past 150 years mainly by carbon dioxide emissions, is expected to cause more intense and frequent heat waves through the southwest U.S. (Garfin et al., 2014). There is little debate that anthropogenic greenhouse gas emissions are contributing to increased global average temperatures (IPCC, 2013). At the same time increased urbanization is a large contributor to increased urban heat island effects which combines synergistically with climate change to add additional increased heat health risk over time (Li & Bou-Zeid, 2013). It has been observed is that there has been less heat death due to heat exposure driven by climate change and

urbanization in the past than would have been expected based on these changes. Much of

the lack in expected past heat related death is due to human adaptation to these changes

that are physiologic, infrastructural, technical or behavioral (Hondula et al., 2015). The

level of resilience in society is in part a function of the structure and nature of institutions

and the built environment that provide refuge from heat — the HRN for example. For

this reason it is important to understand the ability of technology and behavior in human

society to employ such solutions to intervene between human health risk and extreme

weather like extreme heat. Risk is not evenly spread among residents in the built

environment where socioeconomic status is a contributor to increased risk, where those

who are most at risk are "… urban residents who are physiologically susceptible,

socioeconomically disadvantaged, and live in the most degraded environments." (Harlan

& Ruddell, 2011, p. 131) Such degraded environments lack green space that can help

reduce the urban heat island effect hence there is a regressive socio-economic impact of

being poor on living in environments that are likely hotter than more wealthy

communities (Harlan et al., 2008). The lack of green space brings up social equity issues

where lower socio-economic status can lead to increased heat health risk based on the

amount of greenspace contained in such communities among other factors. Interventions

such as extreme heat response plans have been shown to reduce heat health risks in Italy

among the elderly for example (Schifano et al., 2012). As a result, it is clear that

adaptation interventions like heat warnings and the HRN can aid in adding resilience to

communities disproportionately affected by extreme heat, where access to cool space has

a positive effect in reducing heat health risk (Deschenes, 2014). The present research

shows that cooling centers are already offering the maximum amount of service for heat

relief currently. This means that additional learning and mapping of the environment may not yield much benefit to cooling centers since they are already doing as much as they can do given their limited resources. Despite this lack of benefit from learning against a slowly changing environment, cooling centers do offer increased social resilience to the lower socio-economic status communities that have a lack of green space for example because they are located in the poorest communities in the county. The cooling centers help reduce the overall impact of climate change and urbanization for these poor communities through an intervention with access to cool space and water.

Resilience to natural hazards is a critical aspect of preparing for threats from climate change and urbanization driven increased extreme heat health risk. Resilience is described as a, "measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973, p. 14). In terms of natural hazard preparedness, vulnerability is a measure of pre-event conditions of a social system for possible harm as a risk exposure function (Adger, 2006). There are four main common elements found across different types of vulnerability assessment: 1) using socio-ecological perspective, 2) place based studies, 3) vulnerability as human rights issue (i.e. equity), and 4) pre-impact hazard mitigation planning based on assessment of vulnerability (Borden & Cutter, 2008). An example of such a model that uses these elements in hazard planning is the Disaster Resilience of Place model that has similar learning cycle feedbacks as was seen in the first and second loop learning models for organizational learning (Cutter et al., 2008). Such an approach is useful in that it takes into account the built environment along with governance and ecosystems, with the ability to be applied to acute or chronic

natural disasters. It is important to keep in mind that, "[p]rocess-related resilience is defined in terms of continual learning …", which underscores the importance and relationship to overall organizational learning when preparing for natural hazards (Cutter et al., 2008, p. 600).

There is currently a lack of evidence on climate resilience intervention effectiveness for natural hazards, consequently there needs to be more studies that focus on evaluation, design, and reporting of such hazard interventions (Hess et al., 2014) as is the case with this present study. The current research shows that process related resilience through learning occurs mainly through first loop learning, and it is possible that second loop learning to challenge established norms could be beneficial. Consider for example challenging the norms of holding regular business hours and extending the hours to cover the evening gap. This is one way learning in a resilience process could improve heat relief delivery to those in need. The cooling centers do offer increased resilience to Maricopa County through heat relief, but such resilience could be increased by extending hours to cover the evening gap although with trade-offs that could potentially reduce the service hours offered to a cooling center's primary clientele.

Maricopa County has both assets and liabilities when it comes to dealing with the challenge presented by extreme heat health risk. One of positive attribute of the HRN is that it offers cool space and heat relief to those who need it. At the same time there are social structural attributes such as lack of social cohesion that is the result of historically segregated communities based on red-lining from the 1950's among other sources (Virginia G. Piper Charitable Trust, 2016). A recent report on Maricopa County showed that the biggest barrier to environmental, socio-economic, and individual resilience was

the lack of social cohesion in the county. "The single largest challenge we noted [for Maricopa County] — and one that is critical to the success of building resilience in all three domains [environment, socio-economic, and individual] — is the lack of social cohesion within Maricopa County" (Virginia G. Piper Charitable Trust, 2016, p. 7). This lack of social cohesion is not helped by the fact that only 38% of Arizonans were born in the state, leading to increased sense of disconnectedness to others (Aisch & Gebeloff, 2014b). Such disconnectedness likely contributes to a reduction in the amount of empathy residents have for those unlike themselves such as the poor and homeless who might need heat relief. This disconnectedness and historically concentrated poverty separates what could be a single community across the county in to several communities with different access to opportunity, education, and resources. This is a partial contributor to areas of concentrated areas in poverty that have a greater heat health risk than more wealthy communities that represents an environmental equity issue (Harlan et al., 2013). The current study showed a map of the cooling centers that are located in areas with the lowest median income across the county, hence the cooling center intervention is one way to start to address liabilities from concentrated areas of poverty in the county related to heat health risk. At the same time, the cooling centers address a symptom of the lack of social cohesion and concentrated areas of poverty rather than the root causes of it. To reduce heat health risk source, efforts should be made to increase the economic equity across these disparate communities so that the poor and homeless can provide cool space for themselves rather than rely on cooling centers. One of the challenges of this approach is resistance to social change and lack of empathy as indicated by lack of social cohesion, and so there are many challenges to reducing the source rather than symptom of heat

health risk. However, the most important aspect of theory from this first chapter is first

and second loop type learning that is explored in chapters two and four.

Chapter two. This second chapter uses interviews with sixteen cooling center

managers in a semi-structured interview format as a way to better understand their

perspective for delivering heat relief. The interviews were originally designed for a

program evaluation of the cooling centers conducted in the summer of 2014. In that

chapter, there were eight network attributes that were looked at to help answer four main

research questions. The main results from this inquiry are outlined below.

The first important result from chapter two is that cooling center managers have a

relatively low level of awareness overall to the rest of the system. They were generally

aware of the fact that there were other cooling centers and a coordinating HRN higher in

the network level, but did not have specific awareness of where other cooling centers

were located or what their hours of operation were. This perspective of organizations

perceive position and role relative to one another is at the interorganizational level of

network interaction (Yih-Tong Sun & Scott, 2005). The level of interaction with other

parts of the network followed this pattern with almost no horizontal connection among

cooling centers, with only one cooling center manager referring his clients to other

cooling centers because he knew them from his local network and not from working

within the HRN. As a result, most of the sparse interactions in the HRN were vertical

between cooling centers and the HRN coordinators when they signed up to be part of the

HRN at the beginning of the summer and maybe received an initial donation of water

bottles. Besides this vertical interaction with the HRN, cooling centers operate

independently of one another. Many of the cooling centers operate with limited budget

and staff time. Therefore, they may not have opportunity or motivation to reach out to other cooling centers to make connections if they are not aware of the other cooling centers and spend most of their time focusing on daily operations serving their primary clientele. The result of this is that the HRN ad-hoc network had few horizontal connections and mostly vertical connections in the network resulting in a hierarchical structure of communication.

Another important outcome informs about the motivation behind being a cooling center by the organization. The motivation for being a cooling center indicates a good deal about how an organization sees its position within the system and how it acts from that position. Most of the motivations for being cooling centers articulated were related to helping the core needs of populations cooling centers serve, whether those in need be the poor or homeless. The cooling center managers often indicated that they would be doing the same type of heat relief and hydration work whether they were part of the HRN or not, so they might as well be part of it and get more public awareness through participation. This type of motivation in an organization is an example of how organizational culture can manifest to motivate patterns of behavior (Martin, 1992; Schein, 1983). This intent to provide heat relief regardless of the HRN presence means that there is a large amount of internal motivation among these organizations to meet the needs of the poor and homeless. The participation in the HRN by cooling centers increases the awareness, through the MAG maps for example, to the public that they offer heat relief and so collectively the HRN makes a greater impact than the separate actions of these organizations if they were not part of the HRN.

A third result from the second chapter relates to first and second loop learning. We might expect, without knowing anything else, that most learning in an organization is first loop learning relating to stabilizing operations against a consistent normative comparator (Argyris & Schön, 1996). The results from these interviews were consistent with this, finding the vast majority of discussions were first loop type learning thinking with only three examples of second loop learning. First loop thinking would be for example holding water bottle drives to provide heat relief — an example of focus on daily operations. The initial second loop learning example came from a recovery facility manager who was once homeless who said there should be mobile water outreach given to the homeless at the encampment locations they inhabit. This is a different type of action and strategy than a recovery facility would normally undertake and so challenges accepted norms in this way. The second example of double loop learning type thinking was from a Christian ministry thrift store who took it upon themselves to go out to the streets surrounding the store and do outreach to the homeless and poor offering them relief from the heat inside. This is a different strategy than would be undertaken by a normal thrift store and so represents a shift in normative values as compared to the motivations of an average retail operation. The final example of second loop learning type thinking came from a senior center manager who expressed a desire to serve the homeless population showers and hygiene kits, which is not a service they provide or a population they serve. This too represents a shift in norms from that of serving seniors as a primary clientele to also serving the homeless. There may not be a great deal of opportunity to engage in second loop learning given the limited staff time and budgets available to the organizations that participate as cooling centers. Hence focus on daily

214

operations is likely to continue to be much more common than second loop learning. In addition, just because a member of an organization engages in thinking akin to second loop learning, does not necessarily mean they have the opportunity to make those changes in practice.

A fourth result is that cooling centers are an example of increased climate adaptation and institutional resilience simply because they offer heat health risk reduction opportunities to individuals needing heat relief. However, there are additional ways in which cooling centers contribute to increased resilience in the community. In this case, urban resilience allows maintenance of a desired function while experiencing disturbance, to adapt to environmental changes, and allow systems transformation to improve adaptive capacity (Meerow & Newell, 2016). One way cooling centers increase urban resilience of the HRN is through consistent participation year after year. This is because awareness among the homeless of where cooling centers are located is passed by word of mouth based on interview data in chapter from chapter two. The homeless community becomes familiar with and uses historically active cooling centers that they knew from previous experiences and information passed on by other homeless individuals. If a new cooling center is present for only a single summer for example, that new information would only be available in the digital online MAG maps of the HRN. As a result, it would take some time for the knowledge to penetrate the homeless community and be used by the homeless. Conversely a cooling center that participates every year becomes well known to the homeless and increases the system resilience as a result because more homeless know about the cooling center and use it for heat relief than in the opposing case. Another way that cooling centers increase institutional

resilience is the ability to open up existing unused space to cool hundred more people in the event of a large-scale emergency such as a local power outage. In such a case, where there was one example from the interviews, the cooling center could provide heat relief to many more their normal capacity if they opened up all their extra space in the case of a power outage and lots of people needed heat relief. This increases resilience to Maricopa County at large because it provides a way to keep large numbers of people cool in the event of such an emergency.

A final important lesson learned in chapter two interviews is that ultimately addressing the needs of those who are homeless, or keeping the poor from becoming homeless, is a way to address the root causes of heat health risk and eliminate their need to reach a cooling center. Consider that many poor individuals live on the edge of becoming homeless with little extra savings or ability to absorb cost increases. Poor and homeless services organizations offer social services such as support for food, utility, or rent/mortgage assistance that can help keep people from becoming homeless and keep their air conditioning running when it is hot outside. This is especially important at certain times of the year, for example as the summer approaches August. This is because many poor families with children have them on school lunch programs during the year, and so when the summer starts they have extra costs feeding their children. Then in addition, air conditioning driven electric utilities increase over the course of the summer approaching August. This puts pressure on household budgets from these two sources of increased cost that can lead a household toward becoming homeless, having to choose between paying rent or one bill versus another. The social services offered by poor and homeless service organizations can provide access to public assistance that can keep them

from losing their homes, keep them from homelessness, and avoid future heat health risk. As a result, the social support services to the poor and homeless is a key aspect of addressing the root causes of heat health risk, rather than just treating the symptoms by implementing the HRN.

An important question for future research that comes out of chapter two is: how can an investment be made in a communication platform that would improve horizontal and vertical communication within the HRN? One of the potential benefits of having the cooling centers listed together as a collective rather than operating individually is the potential leveraging of collective resources to reduce heat health risk. Each facility has different supply drive profiles, with some having collection drives for water bottles, sunscreen, hats, and lip balm for example. Being in regular communication with other cooling centers could help redistribute unevenly held resources to improve the level of heat relief offered to those in need across the HRN. In addition, being in touch with other cooling centers could help foster awareness of other facilities and allow cooling center managers to refer their clients to other cooling centers as they travel about the city. This is as opposed to the current case where cooling center managers generally are not aware of other cooling center locations or open hours. Increased communication could be achieved using an online virtual commons, among other possibilities such as simple list serve email communication, where cooling center managers could interact with horizontal connections of other cooling centers or vertically to interact with the HRN to get resupplied with bottled water for example.

The results of chapter two are informed by the results found in chapter four. In chapter two there was a diversity of perspectives among the facility managers but at the

same time many expressed a desire to be part of a larger heat relief effort if given the opportunity to interact with the HRN coordinators more, and other cooling center managers at all. Hence if HRN coordinators from chapter two knew about the level of interest expressed in communication by the HRN coordinators in chapter four, they might promote better communication (i.e. WebEOC software) across the HRN. This could improve delivery of service and optimize donated resource allocation across the network. Likewise, if the cooling center managers from chapter two could see the results of the model presented in chapter four, they would have greater systems awareness that there is a gap in the evenings after 5pm for cooling center coverage. This could encourage discussion for strategic scheduling of cooling centers to cover the evening gap as well. If facility managers from chapter two had access to the model in chapter four, they could also see the location of surrounding cooling centers to themselves encouraging inter-manager interactions. Bringing cooling center managers together in a modeling exercise could also promote second loop learning since it promotes dialogue and thought experiments, two key ingredients for second loop learning (Schimmel & Muntslag, 2009). Also, these aspects of interaction of facility managers in a participatory modeling exercise could allow them to become better complexity managers based on the chapter three complexity governance approach.

Chapter three. The third chapter is takes a complexity governance approach to the HRN case and develops this approach using participatory agent based modeling. There are many conceptions of governance such as hierarchical (Cleveland, 1985), neoliberal (Harvey, 2005), new public management (Lynn Jr., 2001), and network (Meuleman, 2009). The goal of chapter three is to open up governance to a new

approach that is not a rigid hierarchy of command and control but rather an ad-hoc

partially self-organizing system (Fung, 2006b). The approach of complexity governance

is proposed as a way to bridge multiple jurisdictions to create a co-learning process with

stakeholders, potentially using modeling. The research question being asked in this

chapter is: *can the HRN be viewed from a complexity governance perspective?*

Complexity governance as stated in chapter three is defined as "… an emergent, self-

organizing process and structure in which a wide range of actors including the public,

government agencies, nonprofit organizations, for-profit organizations, and/or

international organizations voluntarily and dynamically interact with one another on a

relatively large scale to resolve complex social problems in an innovative and collective

way and ultimately advance the common good by using information and communication

technologies." (Park & Johnston, n.d.) Participatory modeling (Cinderby & Forrester,

2005; Yearley et al., 2003), as a tool to facilitate complexity governance, is a useful way

to translate evidence into practice, give system awareness to participants, and improve

collaboration.

   In the participatory modeling introduced in chapter three, the stakeholder is the

expert with local knowledge, and the modeler seeks to incorporate that local knowledge

instead of dictating to local experts. Rather than taking a completed model to

stakeholders and tell them what the answers to their problems are, the idea is to bring

them into the model development process and have their input in model development

through co-learning (Pahl-wostl et al., 2007). Participatory modeling is a process of

incorporating stakeholders as well as decision makers into an analytic modeling process

(Voinov & Bousquet, 2010). Here meaningful participation is increased through

stakeholders being involved in the modeling and increase local innovation due to local stakeholder knowledge (Cinderby & Forrester, 2005; King et al., 1998). In addition, participatory modeling creates systemic awareness and conditions for increased self-organization. The HRN itself is self-organizing to a certain extent in that cooling centers choose their own open hours, hence participatory modeling is an appropriate tool for studying this system.

Participatory agent based modeling of a complexity governance approach has three affordances: contextual awareness in the system, communication and transmission of best practices, and jurisdictional flexibility. This approach allows participants see their position in the system as they see the larger context of the HRN built in an agent based model of the cooling centers. Using an agent based model allows a complex adaptive systems lens to be applied to the problem at hand by building the system from individual agent decisions that yields emergent results that could not be predicted based on the sum of the components (Miller & Page, 2009). This allows modeling of the type of multi-attribute governance approaches seen more in recent years, as traditional pure hierarchical command and control forms of governance are used less over time, and as we search for democratic accountability under these new forms of governance (Sørensen & Torfing, 2005).

The main results in chapter three was that the HRN is an example of complexity governance, especially when approached from a participatory modeling perspective where local stakeholders help build a model in participatory engagement with the modeler. This is supported by the finding that the HRN meets the definition of complexity governance articulated above. Modeling is a useful approach to the systemic

nature of a complexity governance approach. It articulates the diverse agents in a system, their interactions with each other, their interactions with their environment, and the behaviors that might or might not emerge depending on information interventions. The HRN itself has a range of actors ranging from non-profit to public organizations that form an emergent self-organizing structure and process. There is a dynamic interaction between institutions and actors that yield an emergent outcome that could not easily be predicted in advance of looking at the HRN system as whole. This participatory modeling is done on a large scale where the agent based model fits the size of the problem with an organic multijurisdictional cover of relevant areas in the agent based model. In addition, the approach uses information technology in the participatory modeling process to resolve complex social problems.

A future research question from chapter three for this agent based model is can we develop a model that adds mobile agents to the prototype model that has people move about the county seeking heat relief and gain insight on individual heat health risk as a result of their experience in the system? The idea is that people have personal heat exposure as they move through the environment. We could build a simulation of agents that experience outdoor or indoor cooling center temperatures as they go about their day choosing to either stay outside or go into a cooling center as they move around. There are a number of simulations that could be run. Some of these simulations could focus on the experienced temperatures of individuals, in addition to changing the temperature input to a more variable real world diurnal temperature feed rather than the peak hourly heat index used in the prototype model. This is important to understand because it allows

a look at the experience of those trying to seek heat relief rather than only information about the cooling center agents in the model.

Chapter four. The agent based model constructed in chapter three was used in chapter four to conduct participatory modeling with three individual interviews and one focus group. The research method used was open ended research question, asking 1) what are the important questions to answer to improve the HRN? and 2) how can these questions be answered in the modeling framework? Nine different research questions were used to interrogate the interview data, with some of the highlighted results from these described further below.

The first research question asked in chapter four sought to understand how organizations articulate their role in mitigating heat health risk. The result was that there were different articulations based not just on which organization they came from, but also the type of position an individual had within the organization. This is because three of the eight total interviewees were from the same organization — the Maricopa Department of Public Health (MCDPH). There was a distinct perspective taken during participatory modeling from each individual. Within the MCDPH perspectives, the GIS analyst focused most on GIS layers in the model and making suggestions in those terms. The MCDPH epidemiologist thought in terms of how to best use the model as a communication tool with other stakeholders in the HRN to communicate the gaps and redundancies in the system. On the other hand, the MCDPH data services and program manager focused on whether it would be better to invest in more (spatial gap coverage) or better (open after 5pm) cooling centers if one had the choice with limited resources. This diversity in perspectives shows that even within a single organization, there can be a

diversity of perspectives — often driven by what type of work that person does and where their thinking usually lies. There was however a greater disparity in articulations between MCDPH and MAG representatives since MAG has a much different role than MCDPH as the primary coordinating agency organizing the HRN.

The second highlighted research question from chapter four is: how do organizations articulate an awareness to the rest of the system? Prior to engaging the model with interview participants, they already had an understanding of the HRN from the static maps that MAG publishes every year and so had a basic understanding of the spatial arrangement of cooling centers from the map. However, participants in the interviews did not have a strategic understanding of the spatial and temporal gaps and redundancies in the HRN system before viewing the model. After viewing the model they had an increased awareness on how all the elements of the HRN come together to function as a whole. This increased awareness was indicated by them becoming aware of gaps after 5pm where the model showed it was still dangerously hot outside, yet nearly all the cooling centers closed at that time. The MCDPH and MAG representatives were keen on finding ways to communicate the gaps in coverage to the rest of the HRN once aware to try and come up with solutions to cover those gaps. While the university researcher showed a keen awareness of informal cooling centers that could be used such as retail establishments where people could go in and cool off. This shows a wide variety of ways of looking at the system based on the organization they are a part of and the position in the HRN they occupy.

In chapter four, the third highlighted research question asked: what participatory modeling suggestions were given by interviewees to improve the model? There were two

main categories of model improvement suggested, one having to do with adding different base layers to the model map to look at different variables, and the other was to make output display improvements that eased the ability of viewers to takin in real time information from the model while it ran. One of the important layer addition suggestions was to update the model from 2013 to the 2015 which was the year the interviews were given. This would give an up to date version of the system. It was also recommended to split the aggregate cooling centers into their component parts of heat refuge, and hydration only stations. This would allow a look at the spread of these different resources through the county. Another important suggestion was to include a base layer in the model map of density of observed heat related mortality to compare the need for heat relief to the location of the cooling centers. The model display changes suggested included putting the time, heat index and percent cooling center coverage on the model map display so people could read those values without looking away from the map. This could be done by simply putting digital outputs on the map in real time. This is a way to change the model visual presentation to make the interpretation easier for the viewer.

The fourth highlighted research question from the fourth chapter asked: what insights does this case bring to climate adaptation and institutional resilience? One important suggestion about increasing resilience was made to cover the evening gaps between 5pm and 7pm when cooling centers closed and it was still extremely hot outside. The idea offered was to ask some of the cooling centers to shift their open hours from 8am–5pm to 10am–7pm to better serve those in need of heat relief. This may be difficult since most cooling centers operate their heat relief as a secondary set of services in addition to their primary service mission. Hence they may not be able move their open

hours for reasons of meeting their primary clientele's needs. Another form of institutional resilience suggested by interviewees was to put on the outside of closed cooling centers a list of what other cooling centers were open, and where nearby informal cooling centers were located such as fast food restaurants or other retail establishments. This can add to resilience at the individual level by leading people to get to the informal cooling centers when formal cooling centers are closed for the day. Using different types of advertisement to the public for awareness such as signs at bus stops and smartphone applications was also suggested as ways to increase the use of the cooling centers by those in need and as a result adding to a higher level of institutional resilience through better communication to the public. However, it was noted that many of those who need heat relief do not have smart phone or internet access to get a smartphone application for heat relief and so low technology communication and advertisement was suggested to reach the homeless for example as poster adds at transit stops.

The fifth highlighted research question from chapter four is: do HRN members show first or second loop learning thinking in their responses? It is difficult to determine whether first or second loop learning is going on in a given organization, but one can ask questions of the interview responses to see if there was an indication of first or second loop learning type thinking. The differences in thinking for these two categories keys off whether articulations are about focusing on normal operations, or ideas that suggest a shift in the usual norms and values an organization engages in. Nearly all discussion, as one would expect from the literature (Schimmel & Muntslag, 2009), is based on first loop learning type thinking with discussion of daily operations or extension of existing approaches. It was interesting that the two lower level researchers interviewed for the

participatory modeling had suggestions for improving the HRN that were akin to second loop learning of shifting norms and values. This included suggestions to use informal cooling centers as well as shifting formal cooling center hours to later in the day to cover the evening temporal gap between 5pm and 7pm. This represents shifting norms from considering any retail establishment as a possible cooling center, not just formal cooling centers. The shift in evening open hours represents a shift in normative thinking because it puts the heat relief as a priority in value equal to or ahead of the value in providing services earlier in the day for a cooling center's primary clientele. The higher-level participants in terms of their organizational position had mostly a discussion of ideas that were indicative of first loop learning. It may be that these higher-level employees spend so much time focusing on the structure and logistics of the HRN, that they think mostly in terms of first loop learning and daily operations with stable norms.

If the participants in chapter four HRN coordinator interviews were aware of the results from chapter two, they would recognize the lack of communication in the network both vertically and horizontally. This could help them devise a communication strategy that could help improve the dearth of vertical communication and non-existent horizontal communication in the HRN. At the same time, facility managers in chapter two were at the limits of their resources for service provision, so any additional communication and tasks added to being a cooling center from the perspective of facility managers would have to be effective and efficient. The participatory modeling in chapter four garnered a diverse set of responses and suggestions to improve the network. One of these suggestions was to improve the advertisement of cooling centers to the public through various means such as an electronic application or low technology solution like a bus stop

poster add. This informs the perspective of the facility managers interviewed in chapter two because they mentioned a lack of signage and public awareness that they were a cooling center. Hence implementing the advertisement suggestion from chapter four could help with the need of advertisement expressed in the chapter two manager interviews. Also, if the facility managers from chapter two knew about the idea of informal cooling centers from chapter four, they might be able to advertise to the public about places to go to cool off that were not a formal cooling center. This could be done for example by leaving a sign on the outside of a cooling center showing where the nearest available informal cooling center is located such as a fast food restaurant. This is one way that the HRN coordinators could be better complexity managers, by passing their perspective and lessons learned on to the cooling center managers in a group participatory modeling exercise for example.

A future research question generated by the results in chapter four is: how can the revised agent based model be used in participatory modeling interviews with the HRN cooling center managers to improve their systems awareness and find ways to cover the spatial and temporal gaps? One of the results from chapter four was a revised agent based model with a new base layer that separated cooling centers into their component heat refuge and hydration only stations. Another improvement to the model was real time digital output displays on the map of the time, day, heat index, percent heat refuge coverage, and percent hydration station coverage. This new revised model is a more accurate and useful representation than the prototype, and could be used in future participatory modeling exercises with other members of the HRN, for example cooling center managers. This would follow suggestions made during the chapter four

participatory modeling interviews that the model is a useful communication tool to show other members of the HRN how they fit into the system and find out from their expertise how one might cover the spatial and temporal gaps in coverage. For example, it could spark self-organization for some cooling centers to choose to shift their open hours to the evenings to cover the gap at that time. Such a modeling endeavor would need to be sustained over a the course of a few years to properly reach appropriate stakeholders and iteratively improve the model based on stakeholder input. This would require engagement with cooling center facility managers two to three times per year to iterate model improvements and incorporate their suggestions for improving the HRN.

Differences and Similarities Across Two Network Scales

There are different perspectives, based on their different network positions, in the Heat Relief Network (HRN) whether one comes from the cooling center facility manager level, or from the HRN coordination and research level. For example, the facility managers in some instances have a primary function other than heat relief, and being a cooling center is a secondary function for which they volunteer their resources — senior centers for example. Hence their point of view may consider heat relief as not part of their primary mission. However in other examples, as seen from the interviews in chapter two, heat relief is often a primary service that their regular clientele needs and so heat relief is a primary function of the facility, as in poor and homeless service organizations. At the same time, an organization like MAG that leads the coordination and organization effort for the HRN each year likely does not focus on heat relief interactions with individuals who frequent cooling centers, but rather focus more on

individual cooling centers since that is the population they coordinate. This is because

MAG is at a higher network position than the cooling centers who work with individuals

seeking heat relief. This shows two examples of different perspectives that can be based

on the type of organization and where it is positioned within the HRN. The following are

further examples of similarities and differences across the two network layers

investigated in this dissertation, namely the HRN coordinator and cooling center facility

manager level.

The HRN coordinators and cooling center managers see their positions differently

as might be expected based on the different positions they occupy and functions they

carry out. The HRN coordinators looked at the HRN from more of a systems perspective

considering how the individual cooling centers work together in aggregate. They came

from a diverse set of perspectives and yet saw the system as a whole even before viewing

the prototype model of the HRN since they were all familiar with the annual MAG maps

of the HRN. This is because these planning organizations do not generally interact with

individual cooling centers, but rather study and plan the HRN as a whole — especially

MAG. Their participation with the prototype model further focused their view of their

role as planners and researchers for the HRN, trying to come up with creative solutions

for the model to be used to help improve the functioning of the cooling centers. Cooling

center managers on the other hand thought mostly in terms of how to serve their primary

service clientele, with heat relief being a secondary consideration. There however was

often a convergence between their focus on primary clientele and heat relief when they

were a poor and homeless services organization since heat relief and serving that

population's needs are one in the same. The types of suggestions for improving cooling

center service by the HRN coordinators after viewing the model were of how to use the model as a communication tool to bring cooling center managers together to solve problems of gaps in spatial or temporal coverage among others. Cooling center facility managers on the other hand had suggestions for improving the functioning of the cooling centers that related to expanding or extending their traditional services for heat relief to help more people in need. Hence there were quite different perspectives on relative position in the network and how individuals articulated different suggestions based on that position.

Another similarity across these two different layers of the network is that they were not aware of the spatial or temporal gaps and redundancies that the cooling center coverage provided. For the HRN coordinators, it was not until they saw the agent based model that they solidified their understanding on how all the cooling centers acted together to yield an emergent result of aggregate behavior. The cooling center managers focused primarily on their daily operations and did not view the prototype model and hence did not have a chance to see the system as a whole. It is striking that they both had similar knowledge gaps about to the gaps and redundancies before the model was viewed. But this could be expected of anyone who had not seen the model before. One of the important results from this is that viewing the agent based model can change systems level awareness and thinking as was seen in the case of the HRN coordinators. This suggests a useful future research question of: how does cooling center facility manager's perspective change based on viewing the agent based model? This suggests that future participatory modeling work with the cooling center managers, as suggested by the HRN

coordinators, would be a useful way to increase their awareness of their position within the system and help elicit novel suggestions on how they might act from that position.

One of the differences between the two layers of the network studied in this dissertation has to do with focus on communication. The cooling center facility managers did not describe any direct communication with adjacent cooling center managers through horizontal network connections. Similarly, there was almost no direct communication between cooling center managers and the HRN through vertical connections except for the initial sign-up and through intermediary meta-coordinators and one exceptional example of direct communication with the HRN to get donated water bottles delivered. This represents a much lower amount of communication than might have been expected from an ad-hoc voluntary network. However, because these cooling centers are under such tight resource constraints for money and staff time, it does make sense that they focus on communication within their own local network they usually work within during the entire year, rather than reaching out to other cooling centers to coordinate distribution of donated supplies for example. The HRN coordinating organization members on the other hand said that communication could be improved in the network by showing other stakeholders, such as cooling center managers, the model to communicate to them the gaps and redundancies in the system. They suggested that increased communication could help generate novel solutions to cover the gaps, and that it could bring together the cooling center managers and HRN coordinators to enhance future coordination. Further, it was suggested by the HRN coordinators that a software application could be used to enable communication among the coordinators and cooling center managers such as WebEOC which is an emergency management communication

software. The suggestion made by the HRN coordinators was to create a virtual commons and communication platform that HRN coordinators and cooling center managers could contact each other to ask for resupply of needed items such as water bottles, and increase coordination to help cover gaps left after 5pm when most cooling centers close but it is still very hot outside. Such a communication platform could help facilitate both horizontal and vertical communication in the network and help optimize service hours and resource allocation. In order to implement such communication software as WebEOC, there would need to be public resources for software and staff time made available to the HRN to provide the licensed software and staff support to develop and maintain its operation. This would likely involve the Maricopa County agency that has licensing and expertise access to the WebEOC software. It would also be important for MAG to engage with cooling center managers at their heat planning meetings to encourage them to use the software.

There were similar patterns in relation to first loop versus second loop learning type thinking displayed by the members of the two different layers in the network studied. Among both the HRN coordinators and the cooling center managers first loop learning type thinking was dominant which makes sense as organizations usually spend most of their time focusing on daily operations and the task at hand. In both examples, however there were instances where there were articulations of second loop learning type thinking where an individual expressed an intention to engage in an activity or strategy that challenged the usual norms of the organization. In the case of the HRN coordinators, one example of second loop learning had to do with thinking beyond formal cooling centers to include informal cooling centers as a means of heat relief. In the case of the

cooling center managers, the second loop learning type thinking had to do with the idea of bringing mobile water to homeless encampments, and developing a shower and hygiene station at a senior center for the homeless. The interviews in this study provided dialogue and encouraged creative thinking and mental experimentation with ideas that could improve the HRN. These are just the two requisites for second loop learning besides a properly functioning first loop, namely dialogue and experimentation. What is similar between these two layers in the network is that in both cases first loop learning type thinking was dominant, while second loop learning type thinking was rare but detectable in a small minority of cases. It may be the case that first loop learning type thinking is warranted since the environment is relatively unchanging from year to year with chronic extreme heat every year — despite the slow march forward of climate change and urbanization adding to heat health risk. Hence a stabilizing focus on optimizing daily operations may be the most rewarded learning strategy. This is especially true considering the limited resources available for most cooling centers hence they do not have a lot of resources available to question their norms and change their current strategies through dialogue and experimentation — necessary elements of second loop learning besides a proper first loop learning cycle.

Conclusion

Ultimately there are four take away lessons learned in this dissertation relating to communication, increased systems awareness, first and second loop learning, and the root causes of poverty and homelessness. The first important lesson from this research is that cooling center facility managers have limited time and resources, so although

233

communication would be ideal, it may not easily fit within the work schedule of cooling center managers. There would also have to be a benefit perceived by cooling center managers from putting time and effort into communication relative to the results they get for such participation at a higher level. It may be the case that horizontal communication is not as beneficial as vertical communication with the HRN to get additional water bottle donations for example. The challenge is to find the right balance between simplicity and effectiveness for any communication approach or computer software employed to improve communication across the HRN.

Systems awareness was revealed through participatory modeling with the HRN coordinators to identify gaps in coverage and come up with novel solutions to improve the cooling centers functioning. This increase in systems awareness after participatory modeling means that cooling center managers could learn more systems awareness by also engaging in the participatory agent based modeling conducted with the HRN coordinators. An even better option would be to have the HRN coordinators and facility managers engage in participatory modeling together so that they could experience co-learning with members of other parts of the HRN. This would facilitate ideation for solutions to problems perceived in the system including but not limited to the evening gap after 5pm. This joint participatory modeling exercise could be done at meetings a few times a year over two to three years where a communication platform is also introduced to the HRN coordinators and facility managers. It would be best to hold such a meeting early in the year before it becomes hot out when most of these organizations are less stressed for available time and resources — once the summer heat season arrives

everyone in the HRN becomes busy delivering heat relief services with less time available for planning.

The finding in this research that first loop learning type thinking is the dominant type of learning articulated is consistent with the literature, with only minority of cases expressing any type of double loop learning type thinking. Bringing together HRN coordinators and facility managers in a joint participatory modeling process could help stimulate dialogue and experimentation that encourages second loop learning type thinking. However, it makes sense that in a relatively static environment from the point of view of cooling center managers they would focus mostly on first loop learning since they are resource limited and face a chronically hot environment each summer year after year. With such a static perception of a consistently hot environment, there may not be a lot of motivation for facility managers to engage in second loop learning, although this could be encouraged by the process participatory agent based modeling.

Participatory modeling was a way in which to test for the possibility of second loop learning type thinking among participants. This is important because generally second loop learning is rare in organizations and difficult to test for. What is important to note is that the participatory modeling sets up required conditions for second loop learning that have been identified in the literature — experimentation and dialogue. This presents the opportunity to examine whether examples of double loop thinking changes due to participatory modeling given the conditions during such exercises. The conditions of participatory modeling dialogue and experimentation are necessary to begin second loop learning type thinking, but a properly functioning first loop learning cycle and opportunities for second loop learning must be present for there to be a shift from second

loop type thinking to action across an organization. That is to say, true double loop

learning would mean a change not only in a single individual's thinking but across the

organization in terms of thinking and behavior. The shift in cognition of individuals in

the participatory modeling demonstrated the potential for organizational learning within

the HRN. The next steps to try to encourage second loop learning type thinking through

participatory modeling as a catalyst is to bring the cooling center managers in for such

modeling exercises to stimulate second loop learning thinking across that group as well.

Such cooling center manager participation in future participatory modeling would be a

way to have a broader dialogue with possibilities for implementation of strategies and

behavior change. The objective would be to encourage second loop learning with

participatory modeling as a catalyst across HRN coordinators and cooling center

managers.

The considerations of networks in hazard management is not new, and often is

employed using mathematical network theory. The idea is that if organizations are part

of a network, they should have some connections among them. However, what is

important to understand from chapter two and four is that how local operators work in

practice is of great import. The network connections across the HRN are very weak, and

assuming they have strong ties could skew an understanding of how the cooling centers

function. In the instance of an organization joining the HRN, organizations had an

interaction that was to become part of a larger group of cooling centers but this does not

mean they were connected to other cooling centers. Rather the network was weakly

connected to the HRN vertically when they signed up initially and requested additional

donated bottled water, for example. There were no horizontal connections to speak of,

and this has a great impact on the type of connection structure when mapping the network connections, being more hierarchical than one might expect for an ad-hoc self-organizing network. These lessons learned for how managers operate on the ground with weak horizontal connections can help inform other community hazard management practices. That is, other hazard management studies could benefit from the transferability of the methods used in this chapter to interview participants to learn about how the network functions in practice without having to rely on assumptions about the network structure. Such an approach employed in other studies would reveal the true behavior associated with different types of network ties, giving a qualitative analysis approach to mapping the network structure that helps inform any mathematical mapping of the same network.

This research has shown that the cooling centers address the symptoms rather than the causes of heat health risk among the poor and homeless. The evidence for this was revealed through interview quotes from chapter two. That evidence showed that many more people rely on the social services provided by community and poor services organizations as the summer progresses. The reasons given for this is that poor households on fixed low income cannot deal well with increased utility costs and food expenses for feeding children during the summer. Many of the social services for public assistance for the poor offered by poor and homeless service centers are a means to try and help address financial constraints on households that lead to heat health risk. This could be assistance with food, utilities, rent or mortgage, and other social services that can keep the poor from not being able to afford to run their air conditioning or from becoming homeless. The financial limitations of the poor appear to build up over the course of the summer as high utility bills constrain household resources. These attributes

taken together provides a myriad of ways to intervene to reduce heat health risk by employing attributes of complexity governance.

One of the useful lessons learned in this dissertation is that second loop learning type thinking can be encouraged through dialogue and an opportunity to experiment with ideas (Schimmel & Muntslag, 2009). The opportunity for dialogue and experimental ideas was provided for in the chapter two interviews with some examples of second loop learning examples. Likewise, the participatory modeling environment was conducive to creating an environment for dialogue and thought experiments about what kinds of solutions could be brought to improve the HRN. From an organizational theory perspective, this shows how important the dialogue and experimental aspect of an interaction can be in generating different kinds of learning. This type of participatory modeling is a useful avenue for generating novel solutions by encouraging second loop learning type thinking and should be tested in other applications to determine if these results are more generalizable. Similarly, the participatory model itself can act as a centerpiece to a larger discussion among diverse stakeholders and encourage increased communication across the network. However, using a communication technology intervention in the future may be helpful in increasing both horizontal and vertical communication in the HRN. The question is can such a communication software approach be simple and effective for use by busy cooling center managers, and is this result generalizable to other ad-hoc governance networks?

REFERENCES

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268–281. http://doi.org/10.1016/j.gloenvcha.2006.02.006

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., … Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic Change*, *93*(3), 335–354.

Aisch, G., & Gebeloff, R. (2014a). Mapping Migration in the United States. *The New York Times*, 2015–2016. Retrieved from http://www.nytimes.com/2014/08/16/upshot/mapping-migration-in-the-united-states-since-1900.html%5Cnhttp://www.nytimes.com/2014/08/16/upshot/mapping-migration-in-the-united-states-since-1900.html?WT.mc_id=2015-Q1-KWP-AUD_DEV-0101-0331&WT.mc_ev=click&bicmp=

Aisch, G., & Gebeloff, R. (2014b, August). Mapping Migration in the United State. *New York Times*. New York.

Alexander, D. E. (2013). Resilience and disaster risk reduction: An etymological journey. *Natural Hazards and Earth System Sciences*, *13*(11), 2707–2716. http://doi.org/10.5194/nhess-13-2707-2013

Almeida, J. E., Kokkinogenis, Z., & Rossetti, R. J. F. (2012). NetLogo Implementation of an Evacuation Scenario. In *7th Iberian Conference on Information Systems and Technologies (CISTI)* (pp. 1–4). Retrieved from http://arxiv.org/ftp/arxiv/papers/1303/1303.4695.pdf

Anderies, J. M. (2015). Understanding the Dynamics of Sustainable Social-Ecological Systems: Human Behavior, Institutions, and Regulatory Feedback Networks. *Bulletin of Mathematical Biology*, *77*(2), 259–280. http://doi.org/10.1007/s11538-014-0030-z

Anderies, J. M., & Janssen, M. A. (2013). Robustness of social-ecological systems: Implications for public policy. *Policy Studies Journal*, *41*(3), 513–536. http://doi.org/10.1111/psj.12027

Anderies, J. M., Janssen, M. A., & Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society*, *9*(1), 18. http://doi.org/18

Argüeso, D., Evans, J. P., Fita, L., & Bormann, K. J. (2013). Temperature response to future urbanization and climate change. *Climate Dynamics*, *42*(7–8), 2183–2199. http://doi.org/10.1007/s00382-013-1789-6

Argyris, C. (1976). Leadership, learning, and changing the status quo. *Organizational Dynamics*, *4*(3), 29–43. http://doi.org/10.1016/0090-2616(76)90034-6

Argyris, C. (1992). *On Organizational Learning*. Massachusetts: Blackwell.

Argyris, C., & Schön. (1996). *Organizational learning II: Theory, method, and practice.* Reading, MA: Addison-Wesley.

Argyris, C., & Schön, D. A. (1978). Organizational Learning, 2 vol. Reading,(Mass.), Addison-Wesley Pub C o, Coll."Addisson-Wesley series on organization development.

Arthur, W. B. (1999). Complexity and the Economy. *Science*, *284*(5411), 107–109. http://doi.org/10.1126/science.284.5411.107

Bäckstrand, K. (2004). Civic Science for Sustainability: Reframing the Role of Experts, Policy-Makers and Citizens in Environmental Governance, (November 2003), 24–41.

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016). Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. *Journal of Political Economy*, *124*(1), 105–159.

Bateson, G. (1972). *Steps to an ecology of mind: Collected essays in anthropology, psychiatry, evolution, and epistemology*. University of Chicago Press.

Berisha, V., Hondula, D. M., Roach, M., White, J. R., McKinney, B., Bentz, D., … Goodin, K. (2017). Assessing Adaptation Strategies for Extreme Heat: A Public Health Evaluation of Cooling Centers in Maricopa County, Arizona. *Weather, Climate, and Society*, *9*, 71–80.

Berko, J., Ingram, D. D., Saha, S., & Parker, J. (2014). Deaths Attributed to Heat, Cold, and Other Weather Events in the United States, 2006 – 2010. *National Health Statistics Reports*, (76), 1–15.

Bernard, H. R. (2011). *Research methods in anthropology: Qualitative and quantitative approaches*. Rowman Altamira.

Bernauer, J. A. (2015). Opening the ears that science closed: Transforming qualitative data using oral coding. *The Qualitative Report*, *20*(4), 406.

Bobb, J. F., Peng, R. D., Bell, M. L., & Dominici, F. (2014). Heat-related mortality and adaptation to heat in the United States. *Environmental Health Perspectives (Online)*, *122*(8), 811.

Booher, D. E., & Innes, J. E. (2010). Governance for Resilience: CALFED as a complex adaptive network for resource management. *Ecology and Society*, *15*(3), 1–23.

Borden, K. A., & Cutter, S. L. (2008). Spatial patterns of natural hazards mortality in the United States. *International Journal of Health Geographics*, *7*(1), 64. http://doi.org/10.1186/1476-072X-7-64

Borgatti, S. P., & Foster, P. C. (2003). The network paradigm in organizational research: A review and typology. *Journal of Management*. http://doi.org/10.1016/S0149-

2063(03)00087-4

Boulding, K. E. (1956). General Systems Theory--The Skeleton of Science. *Management Science*, *2*(3), 197–208. http://doi.org/10.1287/mnsc.2.3.197

Brinkerhoff, D. W., & Brinkerhoff, J. M. (2011). Public-private partnerships: Perspectives on purposes, publicness, and good governance. *Public Administration and Development*, *31*(1), 2–14. http://doi.org/10.1002/pad.584

Burkart, K., Breitner, S., Schneider, A., Khan, M. M. H., Krämer, A., & Endlicher, W. (2014). An analysis of heat effects in different subpopulations of Bangladesh. *International Journal of Biometeorology*, *58*(2), 227–237.

Camerer, C., Loewenstein, G., & Rabin, M. (2004). Behavioral Economics: Past, Present, Future. *Advances in Behavioral Economics*.

Camerer, C., & Malmendier, U. (2004). Behavioral Organizational Economics. *Yrjö Jahnsson Foundation Conference*, 0–67.

Carlson, J. M., & Doyle, J. (2002). Complexity and robustness. *Proceedings of the National Academy of Sciences*, *99*(suppl 1), 2538–2545.

Casciaro, T. (1998). Seeing things clearly: Social structure, personality, and accuracy in social network perception. *Social Networks*, *20*(4), 331–351.

Cash, D., & Moser, S. C. (2000). Linking global and local scales: designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120. http://doi.org/10.1016/S0959-3780(00)00017-0

Castells, M. (2000). Materials for an exploratory theory of the network society. *The British Journal of Sociology*, *51*, 5–24. http://doi.org/10.1111/j.1468-4446.2000.00005.x

Chow, W. T. L., Chuang, W.-C., & Gober, P. (2012). Vulnerability to Extreme Heat in Metropolitan Phoenix: Spatial, Temporal, and Demographic Dimensions. *The Professional Geographer*, *64*(2), 286–302. http://doi.org/10.1080/00330124.2011.600225

Chuang, W.-C., Gober, P., Chow, W. T. L., & Golden, J. (2013). Sensitivity to heat: A comparative study of Phoenix, Arizona and Chicago, Illinois (2003–2006). *Urban Climate*, *5*, 1–18. http://doi.org/10.1016/j.uclim.2013.07.003

Cinderby, S., & Forrester, J. (2005). Facilitating the local governance of air pollution using GIS for participation. *Applied Geography*, *25*(2), 143–158. http://doi.org/10.1016/j.apgeog.2005.03.003

Cleveland, H. (1985). The Twilight of Hierarchy: Speculations on the Global Information Society. *Public Administration Review*, *45*(1), 185–195.

Cole, T. (2012). Heat Relief Network. Retrieved from http://www.sonoraninstitute.org/images/stories/pdfs/Webinars/uhi-presentation_cop-

2012.pdf

Colyvas, J. A., & Maroulis, S. (2014). Moving from an Exception to a Rule: Analyzing Mechanisms in Emergence-Based Institutionalization. *SSRN Electronic Journal*. http://doi.org/10.2139/ssrn.2426347

Cook, F. L., Tyler, T. R., Goetz, E. G., Gordon, M. T., Protess, D., Leff, D. R., & Molotch, H. L. (1983). Media and agenda setting: effects on the public, interest group leaders, policy makers, and policy. *Public Opinion Quarterly*, *47*(1), 16–35. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10261275

Cook, S. D. N., & Yanow, D. (2011). Culture and Organizational Learning. *Journal of Management Inquiry*, *20*(4), 362–379. http://doi.org/10.1177/1056492611432809

Coumou, D., Robinson, A., & Rahmstorf, S. (2013). Global increase in record-breaking monthly-mean temperatures. *Climatic Change*, *118*(3–4), 771–782. http://doi.org/10.1007/s10584-012-0668-1

Creswell, J. W. (2008). Controversies in mixed methods research. In Denzel & Lincoln (Eds.), *Handbook of Qualitative Research*.

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (3rd ed.). SAGE Publications. Retrieved from http://books.google.com/books?hl=en&lr=&id=4uB76IC_pOQC&pgis=1

Cummings, T. G., & Worley, C. G. (2008). *Organization Development and Change. Annual Review of Psychology* (Vol. 38). http://doi.org/10.1146/annurev.ps.38.020187.002011

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, *18*(4), 598–606. http://doi.org/10.1016/j.gloenvcha.2008.07.013

Cyert, R. M., & March, J. G. (1963). *A behavioral theory of the firm* (2nd ed.). Englewood Cliffs, NJ.

Daft, R. L., & Huber, G. P. (1987). How Organizations Learn: A communication Framework. *Research in the Sociology of Organizations*, *5*, 1–36.

Declet-Barreto, J., Brazel, A. J., Martin, C. a., Chow, W. T. L., & Harlan, S. L. (2012). Creating the park cool island in an inner-city neighborhood: heat mitigation strategy for Phoenix, AZ. *Urban Ecosystems*, *16*(3), 617–635. http://doi.org/10.1007/s11252-012-0278-8

Delworth, T. L., Mahlman, J. D., & Knutson, T. R. (1999). Changes in heat index associated with CO2-induced global warming. *Climatic Change*, *43*(2), 369–386.

Derman, B. B. (2014). Climate governance, justice, and transnational civil society. *Climate Policy*, *14*(1), 23–41. http://doi.org/10.1080/14693062.2014.849492

Deschenes, O. (2014). Temperature, human health, and adaptation: A review of the empirical literature. *Energy Economics*, *46*, 606–619.

Diamond, M. A. (2008). Telling Them What They Know: Organizational Change, Defensive Resistance, and the Unthought Known. *The Journal of Applied Behavioral Science*, *44*(3), 348–364. http://doi.org/10.1177/0021886308317403

Dietz, T. (2013). Bringing values and deliberation to science communication. *Proceedings of the National Academy of Sciences of the United States of America*, *s110*, 14081–14087. http://doi.org/10.1073/pnas.1212740110

Djalante, R., Holley, C., Thomalla, F., & Carnegie, M. (2013). Pathways for adaptive and integrated disaster resilience. *Natural Hazards*, *69*(3), 2105–2135. http://doi.org/10.1007/s11069-013-0797-5

Dow, K., Haywood, B. K., Kettle, N. P., & Lackstrom, K. (2013). The role of ad hoc networks in supporting climate change adaptation: a case study from the Southeastern United States. *Regional Environmental Change*, *13*(6), 1235–1244. http://doi.org/10.1007/s10113-013-0440-8

Downing, T. E., Moss, S., & Pahl-Wostl, C. (2000). Understanding climate policy using participatory agent-based social simulation. In *Multi-Agent-Based Simulation* (pp. 198–213). Springer.

Duit, A., & Galaz, V. (2008). Governance and Complexity — Emerging Issues for Governance Theory. *Governance: An International Journal of Policy, Administration, and Institutions*, *21*(3), 311–335.

Fiol, M., & Lyles, M. (1985). Organizational learning. *The Academy of Management Review*, *10*(4), 803–813. http://doi.org/10.2307/258048

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). ADAPTIVE GOVERNANCE OF SOCIAL-ECOLOGICAL SYSTEMS. *Annual Review of Environment and Resources*, *30*(1), 441–473. http://doi.org/10.1146/annurev.energy.30.050504.144511

Fraser, A. M., Chester, M. V, Eisenman, D., Hondula, D. M., Pincetl, S. S., English, P., & Bondank, E. (2016). Household accessibility to heat refuges: Residential air conditioning, public cooled space, and walkability. *Environment and Planning B: Planning and Design*, 265813516657342.

Friese, S. (2014). *Qualitative data analysis with ATLAS. ti*. Sage.

Fung, A. (2006a). Varieties of Participation in Complex Governance. *Public Administration Review*, *66*(s1), 66–75. http://doi.org/10.1111/j.1540-6210.2006.00667.x

Fung, A. (2006b). Varieties of Participation in Complex Governance. *Public Administration Review*, *66*(s1), 66–75. http://doi.org/10.1111/j.1540-6210.2006.00667.x

Furnas, G. W. (2000). Future Design Mindful of the MoRAS. *Human-Computer Interaction*, *15*, 207–263.

Garfin, G., Franco, G., Blanco, H., Comrie, A., Gonzalez, P., Piechota, T., … Waskom, R. (2014). *Southwest*. (J. M. Melillo, T. C. Richmond, & G. W. Yohe, Eds.)*Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program. http://doi.org/10.7930/J08G8HMN

Garnett, J. L., Marlowe, J., & Pandey, S. K. (2008). Penetrating the performance predicament: communication as a mediator or moderator of organizational culture's impact on public organizational performance. *Public Administration Review*, *68*(2), 266–281.

Georgescu, M., Morefield, P. E., Bierwagen, B. G., & Weaver, C. P. (2014). Urban adaptation can roll back warming of emerging megapolitan regions. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(8), 2909–14. http://doi.org/10.1073/pnas.1322280111

Georgescu, M., Moustaoui, M., Mahalov, A., & Dudhia, J. (2011). An alternative explanation of the semiarid urban area "oasis effect." *Journal of Geophysical Research: Atmospheres*, *116*(D24), D24113-. http://doi.org/10.1029/2011JD016720

Glimell, H. R. (1975). Designing interactive systems for organizational change.

Goodin, K., Castle, M., Martinez, J., Speck, L., & Trembath, F. (2015). *Community Assessment for Public Health Emergency Response (CASPER) Heat Vulnerability and Emergency Preparedness Needs Assessment Maricopa County, Arizona*.

Grol, R., & Wensing, M. (2004). What drives change? Barriers to and incentives for achieving evidence-based practice. *Medical Journal of Australia*, *180*(6 SUPPL.), S57–S60. http://doi.org/gro10753_fm [pii]

Haffeld, J. (2012). Facilitative governance: transforming global health through complexity theory. *Global Public Health*, *7*(5), 452–64. http://doi.org/10.1080/17441692.2011.649486

Hare, M., & Deadman, P. (2004). Further towards a taxonomy of agent-based simulation models in environmental management. *Mathematics and Computers in Simulation*, *64*(1), 25–40. http://doi.org/10.1016/S0378-4754(03)00118-6

Hare, M., Letcher, R. A., & Jakeman, A. J. (2003). Participatory modelling in natural resource management: a comparison of four case studies. *Integrated Assessment*, *4*(2), 62–72.

Harlan, S. L., Brazel, A. J., Jenerette, G. D., Jones, N. S., Larsen, L., Prashad, L., & Stefanov, W. L. (2008). In The Shade of Affluence: The Inequitable Distribution Of The Urban Heat Island. *Equity and the Environment*, *15*, 173–202.

Harlan, S. L., Brazel, A. J., Prashad, L., Stefanov, W. L., & Larsen, L. (2006). Neighborhood microclimates and vulnerability to heat stress. *Social Science &*

Medicine (1982), *63*(11), 2847–63. http://doi.org/10.1016/j.socscimed.2006.07.030

Harlan, S. L., Chowell, G., Yang, S., Petitti, D. B., Morales Butler, E. J., Ruddell, B. L., & Ruddell, D. M. (2014a). Heat-related deaths in hot cities: estimates of human tolerance to high temperature thresholds. *International Journal of Environmental Research and Public Health*, *11*(3), 3304–26. http://doi.org/10.3390/ijerph110303304

Harlan, S. L., Chowell, G., Yang, S., Petitti, D. B., Morales Butler, E. J., Ruddell, B. L., & Ruddell, D. M. (2014b). Heat-related deaths in hot cities: estimates of human tolerance to high temperature thresholds. *International Journal of Environmental Research and Public Health*, *11*(3), 3304–26. http://doi.org/10.3390/ijerph110303304

Harlan, S. L., Declet-Barreto, J. H., Stefanov, W. L., & Petitti, D. B. (2013). Neighborhood effects on heat deaths: social and environmental predictors of vulnerability in Maricopa County, Arizona. *Environmental Health Perspectives*, *121*(2), 197–204. http://doi.org/10.1289/ehp.1104625

Harlan, S. L., & Ruddell, D. M. (2011). Climate change and health in cities: impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. *Current Opinion in Environmental Sustainability*, *3*(3), 126–134. http://doi.org/10.1016/j.cosust.2011.01.001

Harvey, D. (2005). *A Brief History of Neoliberalism*. Oxford University Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=F5DZvEVt890C&pgis=1

Hedberg, B. (1981). How organizations learn and unlearn. In P. C. Nystrom & W. H. Starbuck (Eds.), *Handbook of Organizaional Design* (pp. 1–27). New York: Oxford University Press.

Hess, J. J., Eidson, M., Tlumak, J. E., Raab, K. K., & Luber, G. (2014). An evidence-based public health approach to climate change adaptation. *Environmental Health Perspectives (Online)*, *122*(11), 1177.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 1–23.

Hondula, D. M., Balling, R. C., Vanos, J. K., & Georgescu, M. (2015). Rising Temperatures, Human Health, and the Role of Adaptation. *Current Climate Change Reports*, 1–11. http://doi.org/10.1007/s40641-015-0016-4

Hondula, D. M., & Davis, R. E. (2014). The predictability of high-risk zones for heat-related mortality in seven US cities. *Natural Hazards*, *74*(2), 771–788. http://doi.org/10.1007/s11069-014-1213-5

Hondula, D. M., Georgescu, M., & Balling, R. C. (2014). Challenges associated with projecting urbanization-induced heat-related mortality. *The Science of the Total Environment*, *490C*, 538–544. http://doi.org/10.1016/j.scitotenv.2014.04.130

Huang, C., Barnett, A. G., Wang, X., Vaneckova, P., FitzGerald, G., & Tong, S. (2011). Projecting future heat-related mortality under climate change scenarios: a systematic review. *Environmental Health Perspectives*, *119*(12), 1681–90. http://doi.org/10.1289/ehp.1103456

Huang, C., Barnett, A. G., Xu, Z., Chu, C., Wang, X., Turner, L. R., & Tong, S. (2013). Managing the Health Effects of Temperature in Response to Climate Change : *Environmental Health Perspectives*, *121*(4), 415–420.

Innes, J. E., & Booher, D. E. (2004). Reframing public participation: strategies for the 21st century. *Planning Theory & Practice*, *5*(4), 419–436. http://doi.org/10.1080/1464935042000293170

IPCC. (2013). *The physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change*. USA: Cambridge University Press.

Janis, I. L., & Mann, L. (1977). *Decision making: A psychological analysis of conflict, choice, and commitment.* Free Press.

Jenerette, G. D., Harlan, S. L., Stefanov, W. L., & Martin, C. A. (2014). Ecosystem services and urban heat riskscape moderation : water , green spaces , and social inequality in Phoenix , USA Author (s): G . Darrel Jenerette , Sharon L . Harlan , William L . Stefanov and Chris A . Martin Stable URL : http://www.jstor.org/sta. *Ecological Applications*, *21*(7), 2637–2651.

Johnston, E. W. (2010). Governance Infrastructures in 2020. *Public Administration Review*, *70*, s122–s128. http://doi.org/10.1111/j.1540-6210.2010.02254.x

Johnston, E. W., Hicks, D., Nan, N., & Auer, J. C. (2010). Managing the Inclusion Process in Collaborative Governance. *Journal of Public Administration Research and Theory*, *21*(4), 699–721. http://doi.org/10.1093/jopart/muq045

Johnston, E. W., Kim, Y., & Ayyangar, M. (2007). Intending the unintended: the act of building agent-based models as a regular source of knowledge generation. *Interdisciplinary Description of Complex Systems*, *5*(2), 81–91.

Kim, Y., Johnston, E. W., & Kang, H. S. (2011). A Computational Approach to Managing Performance Dynamics in Networked Governance Systems. *Public Performance & Management Review*, *34*(4), 580–597. http://doi.org/10.2753/PMR1530-9576340407

King, C. S., Feltey, K. M., & Susel, B. O. (1998). The Question of Participation: Toward Authentic Public Participation in Public Administration. *Public Administration Review*, *58*(4), 317–326.

Knight-Lenihan, S. (2015). Benefit cost analysis, resilience and climate change. *Climate Policy*, 1–15. http://doi.org/10.1080/14693062.2015.1052957

Koffijberg, J., De Bruijn, H., & Priemus, H. (2012). Combining Hierarchical and

Network Strategies: Successful Changes in Dutch Social Housing. *Public Administration*, *90*(1), 262–275. http://doi.org/10.1111/j.1467-9299.2011.01974.x

Koliba, C., Zia, A., & Lee, B. H. (2011). Governance Informatics: Managing the Performance of Inter-Organizational Governance Networks. *The Innovation Journal*, *16*(October 2015).

Kooiman, J., & Jentoft, S. (2009). Meta-governance: Values, norms and principles, and the making of hard choices. *Public Administration*, *87*, 818–836. http://doi.org/10.1111/j.1467-9299.2009.01780.x

Koppell, J. G. (2010). Administration without Borders Part I 2020: The Good, the Bad, and the Ugly. *Public Administration Review*, (December), s546–s555.

Koppenjan, J. F. M., & Enserink, B. (2009). Public--private partnerships in urban infrastructures: reconciling private sector participation and sustainability. *Public Administration Review*, *69*(2), 284–296.

Kuras, E. R., Hondula, D. M., & Brown-Saracino, J. (2015). Heterogeneity in individually experienced temperatures (IETs) within an urban neighborhood: insights from a new approach to measuring heat exposure. *International Journal of Biometeorology*. http://doi.org/10.1007/s00484-014-0946-x

Lazlo, E. (1972). *Introduction to systems philosophy: Toward a new paradigm of contemporary thought*. *Gordon and Breach, New York and London*.

Learmonth, G. P., Smith, D. E., Sherman, W. H., White, M. A., & Plank, J. (2011). A practical approach to the complex problem of environmental sustainability: The UVa Bay Game. *The Innovation Journal: The Public Sector Innovation Journal*, *16*(1), 1–8.

Leong, K. M., Decker, D. J., Lauber, T. B., Raik, D. B., & Siemer, W. F. (2009). *Overcoming jurisdictional boundaries through stakeholder engagement and collaborative governance: Lessons learned from white-tailed deer management in the U.S. : Beyond the Rural-Urban Divide: Cross-Continental Perspectives on the Differentiated*. (K. Andersson, M. Lehtola, E. Eklund, & P. Salmi, Eds.) (1st ed.). Bingley, England: Emerald Group Publishing Limited. Retrieved from http://www.emeraldinsight.com/doi/abs/10.1108/S1057-1922%282009%290000014012

Leong, K. M., Emmerson, D. P., & Byron, R. (Rudi). (2011). The New Governance Era: Implications for Collaborative Conservation and Adaptive Management in Department of the Interior Agencies. *Human Dimensions of Wildlife*, *16*, 236–243. http://doi.org/10.1080/10871209.2011.585436

Lewin, K., Lippitt, R., & White, R. K. (1939). Patterns of aggressive behavior in experimentally created "social climates." *The Journal of Social Psychology*, *10*(2), 269–299.

Li, D., & Bou-Zeid, E. (2013). Synergistic interactions between urban heat islands and

heat waves: the impact in cities is larger than the sum of its parts. *Journal of Applied Meteorology and Climatology*, *52*(9), 2051–2064.

Liesbet, H., & Gary, M. (2003). Unraveling the Central State, but How? Types of Multi-level Governance. *American Political Science Review*, *97*(2), 233–243. http://doi.org/10.1017/S0003055403000649

Lissner, T. K., Holsten, A., Walther, C., & Kropp, J. P. (2012). Towards sectoral and standardised vulnerability assessments: the example of heatwave impacts on human health. *Climatic Change*, *112*(3–4), 687–708.

Lynn Jr., L. E. (2001). The Myth of the Bureaucratic Paradigm: What Traditional Public Administration Really Stood For. *Public Administration Review*, *61*(2), 144–160. http://doi.org/10.1111/0033-3352.00016

Marakas, G. M. (1999). Decision Support Systems in the Twenty-first Century. Prentice-Hall, Englewood Cliffs, NJ.

March, J. G., & Olsen, J. P. (1976). *Ambiguity and Choice in Organizations*. Bergen: Universitetsforlaget.

Maricopa Association of Governments. (2015). Heat Relief Regional Network. Retrieved July 3, 2015, from http://www.azmag.gov/heatrelief

Marinucci, G. D., Luber, G., Uejio, C. K., Saha, S., & Hess, J. J. (2014). Building resilience against climate effects—a novel framework to facilitate climate readiness in public health agencies. *International Journal of Environmental Research and Public Health*, *11*(6), 6433–6458.

Marks, P. K., & Gerrits, L. M. (2013). Approaching Public Administration from a Complexity Perspective, (December).

Martin, J. (1992). *Cultures in organizations: Three perspectives*. Oxford University Press.

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological review1*, *50*(4), 370–396.

McDaniel, R. R., & Anderson, R. A. (2009). Implications of complex adaptive research on health care organizations, (June), 191–199.

MCDPH. (2014). *Maricopa County Department of Public Health: Heat-Associated Deaths in Maricopa County, AZ Final Report* for 2013*.

MCDPH. (2015a). *Heat-Associated Deaths in Maricopa County, AZ - Multiyear Report for 2006-2013*. Retrieved from http://www.maricopa.gov/publichealth/Services/EPI/pdf/heat/2006-2013MortalityReport.pdf

MCDPH. (2015b). Heat-Associated Deaths in Maricopa County , AZ Final Report for 2014, 28 pp. Retrieved from

http://www.maricopa.gov/publichealth/services/epi/pdf/heat/2014annualreport.pdf

McGregor, D. (1957). *The Human Side of Enterprise. Management Review*.

Meerow, S., & Newell, J. P. (2016). Urban resilience for whom, what, when, where, and why? *Urban Geography*, 1–21.

Meuleman, L. (2008a). *Public management and the metagovernance of hierarchies, networks and markets: the feasibility of designing and managing governance style combinations*. Springer Science & Business Media.

Meuleman, L. (2008b). Reflections on Meta Governance and Community Policing: The Utrecht Case in the Netherlands and Questions about the Cultural Transferability of Governance Approaches and Meta Governance. *Governance and Institutional Re-Engineering*, *34*, 150–183. http://doi.org/http://dx.doi.org/10.5848/CSP.0855.00008

Meuleman, L. (2009). The Cultural Dimension of Metagovernance: Why Governance Doctrines May Fail. *Public Organization Review*, *10*(1), 49–70. http://doi.org/10.1007/s11115-009-0088-5

Meuleman, L. (2011). Metagoverning governance styles - broadening the public manager's action perspective. In J. Torfing & P. Triantafillou (Eds.), *Interactive Policy Making, Metagovernance and Democracy* (pp. 95–110). ECPR Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=pUZLAQAAQBAJ&pgis=1

Miller, J. H., & Page, S. E. (2009a). *Complex adaptive systems: An introduction to computational models of social life*. Princeton university press.

Miller, J. H., & Page, S. E. (2009b). *Complex Adaptive Systems: An Introduction to Computational Models of Social Life: An Introduction to Computational Models of Social Life (Google eBook)* (Vol. 2009). Princeton University Press. Retrieved from http://books.google.com/books?hl=en&lr=&id=XQUHZC8wcdMC&pgis=1

Mintzberg, H. (1973). The nature of managerial work.

Morgan, J., & Waskow, D. (2013). A new look at climate equity in the UNFCCC. *Climate Policy*, *14*(1), 17–22.

Moser, S. C. (2010). Communicating climate change : history , challenges , process and future directions. *Climate Change*, *1*, 31–53. http://doi.org/10.1002/wcc.011

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(51), 22026–22031. http://doi.org/10.1073/pnas.1007887107/-/DCSupplemental.www.pnas.org/cgi/doi/10.1073/pnas.1007887107

Murphy, D. W. A. (2014). Theorizing climate change, (im)mobility and socio-ecological systems resilience in low-elevation coastal zones. *Climate and Development*, *7*(4), 380–397. http://doi.org/10.1080/17565529.2014.953904

Ngwadla, X. (2013). An operational framework for equity in the 2015 Agreement. *Climate Policy*, *14*(1), 8–16. http://doi.org/10.1080/14693062.2014.857199

O'Neill, M. S., Jackman, D. K., Wyman, M., Manarolla, X., Gronlund, C. J., Brown, D. G., … Diez-Roux, A. V. (2010). US local action on heat and health: are we prepared for climate change? *International Journal of Public Health*, *55*(2), 105–12. http://doi.org/10.1007/s00038-009-0071-5

Oberg, A., & Walgenbach, P. (2008). Hierarchical structures of communication in a network organization. *Scandinavian Journal of Management*, *24*(3), 183–198. http://doi.org/10.1016/j.scaman.2008.03.011

Ojha, A. K. (2014). Public Private Partnerships: Analysing the Network form of Organization. In G. Ramesh, V. Nagadevara, G. Naik, & A. Suraj (Eds.), *Public–Private Partnerships* (pp. 1–19). Routledge. Retrieved from https://books.google.com/books?hl=en&lr=&id=1zNEAwAAQBAJ&pgis=1

Pachauri, R. K., Meyer, L., Plattner, G.-K., & Stocker, T. (2015). *IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC.

Pahl-Wostl, C. (2002a). Participative and Stakeholder-Based Policy Design, Evaluation and Modeling Processes. *Integrated Assessment*, *3*(1), 3–14. http://doi.org/10.1076/iaij.3.1.3.7409

Pahl-Wostl, C. (2002b). Towards sustainability in the water sector--The importance of human actors and processes of social learning. *Aquatic Sciences-Research Across Boundaries*, *64*(4), 394–411.

Pahl-wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007). Social Learning and Water Resources Management, *12*(2).

Park, C. H., & Johnston, E. W. (n.d.). An Event-Driven Lens for Bridging Formal Organizations and Informal Online Participation: How Policy Informatics Enables Just-In-Time Responses to Crises. In *Policy Analytics, Modelling, and Informatics: Innovative Tools for Solving Complex Social Problems*.

Patton, M. Q. (2002). Qualitative interviewing. *Qualitative Research and Evaluation Methods*, *3*, 344–347.

Petitti, D. B., Harlan, S. L., Chowell-Puente, G., & Ruddell, D. (2013). Occupation and environmental heat-associated deaths in Maricopa county, Arizona: a case-control study. *PloS One*, *8*(5), e62596. http://doi.org/10.1371/journal.pone.0062596

Petitti, D. B., Hondula, D. M., Yang, S., Harlan, S. L., & Chowell, G. (2015). Multiple trigger points for quantifying heat-health impacts: new evidence from a hot climate. *Environmental Health Perspectives*, 124(2), 176. http://doi.org/10.1289/ehp.1409119

Plsek, P. E., & Greenhalgh, T. (2001). Complexity science: The challenge of complexity

in health care. *BMJ (Clinical Research Ed.)*, *323*, 625–628. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1121189&tool=pmcentr ez&rendertype=abstract

Plsek, P. E., & Wilson, T. (2001). Complexity science Complexity , leadership , and management in healthcare organisations, *323*, 746–749.

Podolny, J. M., & Page, K. L. (1998a). Network Forms of Organization. *Annual Review of Sociology*, *24*(1), 57–76. http://doi.org/10.1146/annurev.soc.24.1.57

Podolny, J. M., & Page, K. L. (1998b). Network Forms of Organization. *Annual Review of Sociology*, *24*, 57–76. http://doi.org/10.1146/annurev.soc.24.1.57

Rossman, G. B., & Wilson, B. L. (1985). Numbers and words combining quantitative and qualitative methods in a single large-scale evaluation study. *Evaluation Review*, *9*(5), 627–643.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.

Schein, E. H. (1983). The role of the founder in creating organizational culture. *Organizational Dynamics*, *12*(1), 13–28.

Schein, E. H. (1993). Defining Organizational Culture. In *Organizational Culture and Leadership* (2nd ed., pp. 3–15). John Wiley & Sons Inc.

Schifano, P., Leone, M., De Sario, M., de'Donato, F., Bargagli, A. M., D'Ippoliti, D., … Michelozzi, P. (2012). Changes in the effects of heat on mortality among the elderly from 1998--2010: results from a multicenter time series study in Italy. *Environmental Health*, *11*(1), 58.

Schimmel, R., & Muntslag, D. R. (2009). Learning barriers: a framework for the examination of structural impediments to organizational change. *Human Resource Management*, *48*(3), 399–416. http://doi.org/10.1002/hrm.20287

Schneider, B., Brief, A. P., & Guzzo, R. A. (1996). Creating a climate and culture for sustainable organizational change. *Organizational Dynamics*, *24*(4), 7–19. http://doi.org/10.1016/S0090-2616(96)90010-8

Sheppard, S. R. J., Shaw, A., Flanders, D., Burch, S., Wiek, A., Carmichael, J., … Cohen, S. (2011). Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. *Futures*, *43*(4), 400–412. http://doi.org/10.1016/j.futures.2011.01.009

Shirvastava, P. (1983). A Typology of Organizational Learning Systems. *Journal of Management Studies*, *20*(1), 7–28.

Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review*, *63*(2), 129–38. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/13310708

Skogstad, G. (2003). Who Governs? Who Should Govern?: Political Authority and

Legitimacy in Canada in the Twenty-First Century. *Canadian Journal of Political Science/Revue Canadienne de Science Politique*, *36*, 955–973. http://doi.org/10.1017/S0008423903778925

Sole, R., & Goodwin, B. (2002). Signs Of Life How Complexity Pervades Biology (pp. 277–303).

Sorensen, E. (2006). Processes of Democratic Governance. *American Review of Public Administration*, *36*(1), 98–114.

Sørensen, E., & Torfing, J. (2005). The Democratic Anchorage of Governance Networks. *Scandinavian Political Studies*, *28*(3), 195–218.

Stake, R. E. (1995). *The art of case study research*. Sage.

Sussman, F., Krishnan, N., Maher, K., Miller, R., Mack, C., Stewart, P., … Perkins, B. (2014). Climate change adaptation cost in the US: what do we know? *Climate Policy*, *14*(2), 242–282. http://doi.org/10.1080/14693062.2013.777604

Thompson, J. D. (1967). *Organizations in action: Social science bases of administrative theory*. Transaction publishers.

Thompson, K. M. (2015). Making a Difference. In E. Johnston (Ed.), *Governance in the Information Era: Theory and Practice of Policy Informatics* (pp. 174–186). Routledge.

Tisue, S., & Wilensky, U. (2004). Netlogo: A simple environment for modeling complexity. *… Conference on Complex Systems*, 1–10. http://doi.org/10.1109/ICVD.2004.1261037

Turner, B. L., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., … Tyler, N. (2003). Illustrating the coupled human-environment system for vulnerability analysis: three case studies. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(14), 8080–8085. http://doi.org/10.1073/pnas.1231334100

United Nations Department of Economic and Social Affairs Population Division. (2013). *World Population Ageing 2013. ST/ESA/SER.A/348*.

Virginia G. Piper Charitable Trust. (2016). *Building Community Resilience in Maricopa County*.

Voinov, A., & Bousquet, F. (2010). Modelling with stakeholders. *Environmental Modelling & Software*, *25*(11), 1268–1281. http://doi.org/10.1016/j.envsoft.2010.03.007

Walz, A., Lardelli, C., Behrendt, H., Regamey, A., Lundstr, C., Kytzia, S., & Bebi, P. (2007). Participatory scenario analysis for integrated regional modelling. *Landscape and Urban Planning*, *81*(1–2), 114–131. http://doi.org/10.1016/j.landurbplan.2006.11.001

Wolcott, H. F. (1994). *Transforming qualitative data: Description, analysis, and interpretation*. Sage.

Wyborn, C., & Bixler, R. P. (2013). Collaboration and nested environmental governance: Scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *Journal of Environmental Management*, *123*, 58–67. http://doi.org/10.1016/j.jenvman.2013.03.014

Yearley, S., Cinderby, S., Forrester, J., Bailey, P., & Rosen, P. (2003). Participatory Modelling and the Local Governance of the Politics of UK Air Pollution: A Three-City Case Study. *Environmental Values*, *12*, 247–262. Retrieved from http://www.jstor.org/discover/10.2307/30301943?uid=2&uid=4&sid=21104874571663

Yih-Tong Sun, P., & Scott, J. L. (2005). An investigation of barriers to knowledge transfer. *Journal of Knowledge Management*, *9*(2), 75–90. http://doi.org/10.1108/13673270510590236

Yin, R. K. (1994). Case study research: design and methods. Applied social research methods series, 5. *Biography, Sage Publications, London*.

APPENDIX A

LIST OF HEAT RELIEF NETWORK

FACILITY MANAGER OPEN ENDED QUESTIONS

1) What motivated your facility to become a cooling center?

2) How does your facility alert the public that services are available?

3) Does your staff have an established protocol in the case of medical and other emergencies?

4) Additional services or supplies provided to visitors?

5) If you've ever run out of available water, are there any actions that you typically take to remedy the situation?

6) What other supplies and services are available at your facility?

7) What are the costs to your facility associated with serving as a cooling center?

8) Does the facility receive an assistance in incurring these costs from outside agencies? If so, from whom? How much?

9) What constrains does the facility face when providing services, in regards to times and days that it can be open? Are any of these constraints significant enough to the point that your participation would be difficult or unlikley next season?

10) How many people, in addition to your regular staff, do you typically need to operate this cooling center?

11) What services and supplies would you like to provide if your facility had unlimited resources?

12) Is there any more information about services and supplies that you would like to share?

13) How does your cooling center accommodate individuals with physical disabilities?

14) How does your cooling center accommodate homeless individuals seeking relief?

15) How does your cooling center accommodate individuals who do not speak English?

16) Are there ever times where you have to turn individuals away from services? If yes, what are the reasons?

17) How is your communication with the HRN?

18) Is there anything else you would like to add?

APPENDIX B

CHAPTER TWO FACILITY

MANAGER INTERVIEW CODEBOOK

211Phone_use of community services info. line

AdditionalServices_activities, classes, exercise, arts/crafts, case work

AdditionalServices_bible study, pot luck monthly

AdditionalServices_classes, support groups, light lunch

AdditionalServices_Extensive homeless services

AdditionalServices_food bank

AdditionalServices_Hats, sunscreen, chapstick

AdditionalServices_homeless and social services

AdditionalServices_just water and cool space for heat relief

AdditionalServices_lots of community services

AdditionalServices_Offer food

AdditionalServices_park info. and education

AdditionalServices_sun protection, hygene kits, util. assist., bread

AdditionalServices_utility & HVAC assistance

AvoidPeakHeat_budget restricted senior AC use

AvoidPeakHeat_Stay at cooling center all day

BodyfTemperatureRegulation_Elderly lack of ability to regulate their temperature

BodyTemperatureRegulation_Run AC at home a lot, high bills

CabAsSocialService

CapacityToAdjustRole

CapacityToAdjustRole_constraint

ClientelOfCenter_homeless, public transit users

CommunicationWithHRN

CommunicationWithHRN_low, good

CommunicationWithHRN_low, only deliver water palettes

CommunicationWithHRN_low, only initial email sign up

CommunicationWithHRN_none, central coordinator

CommunicationWithHRN_none, need HRN to call & check

CommunicationWithHRN_Through central node

CommunicationWithHRN_very good, networking to get water

ConserveFinancially_Do not run AC at home while visiting center

CostAdditionality_AC electricity, water bottles, staff/volunteer time

CostAdditionality_AC, water bottles, mailing adverts

CostAdditionality_none, already part of what they do

CostAdditionality_park staff time giving out water

ElectricBills_cumulatively high by August

EmergencyMedicalSituations_Call 911, service + avoid liability

EmergencyMedicalSituations_Call 911, staff CPR & 1st aid cert.

EmergencySituation_ExtendHoursIfNeeded

EmergencySituation_large capacity for extreme heat disaster

EmergencySituation_open additional space

Homeless_old teach the new

HomelessBussedIn_from out of state

HomelessExperience_told personal homeless story

HomelessReticence_anonymous and sit by door

HomelessTreatment_clear out, find alt. shelter

HomelessTreatment_given shelter list, food, hygene kits, and water

HomelessTreatment_primary service population

HomelessTreatment_welcome but must adhere to code of conduct

HomelessTreatment_welcome to cool space & water

HomelessTreatment_welcome, given hydration

HumanKindnessMotive_giving water bottles

Hydration_mobile water distribution to homeless

Hydration_Vigilance by community members

InformalCooling_libraries, light rail

InformalCooling_park trees, ramadas

InviteOffStreet_welcome offered to those on street looking for water

LargeCapacitySituation

LengthOfStay_short 10 minutes, cool off get water

LocalVisitors_from neighborhood seek heat relief

M Power_electric bill system helps, pay as you go

MotivationForParticipation

MotivationForParticipation_All Salvation Army are cooling centers

MotivationForParticipation_care about people,meet their needs

MotivationForParticipation_christian ministry

MotivationForParticipation_delegated by City of Phoenix

MotivationForParticipation_homeless at risk

MotivationForParticipation_make sure they are well

MotivationForParticipation_to serve their vulnerable populations better

NoiseOrdinance_restricts morning work

NonEnglishSpeakers_body language

NonEnglishSpeakers_body language + google translation

NonEnglishSpeakers_Dont' get them

NonEnglishSpeakers_HRN pamplets in english & spanish

NonEnglishSpeakers_Spanish onsite

NonEnglishSpeakers_Spanish onsite + translation service

NonEnglishSpeakers_translation number

NoOffGridBackupPower

OffBeatenPath_little foot traffic, few heat relief visitors

OffBeatenPath_no heat relief visitors yet this year

Open_24Hours

Open_During excessive heat warning

PhysicalDisabledAccess_ADA compliant

PhysicalDisabledAccess_all welcome, electric door

PhysicalDisabledAccess_all welcome, not ADA compliant

PhysicalDisabledAccess_paved trails for wheelchair

PoliceStation_next door, may scare homeless away

PublicAwareness_cooling center word of mouth

PublicAwareness_Go out to parking lot and bus stop outside

PublicAwareness_newspaper, word of mouth

PublicAwareness_no signs outside, but want them

PublicAwareness_PIO bulletin, signage, outreach, bullitins, word of mouth

PublicAwareness_referred by other local partners

PublicAwareness_Rely on bieng part of HRN

PublicAwareness_signs outside

PublicAwareness_Suggest signage at bus stops

PublicAwareness_Use facebook for heat relief awareness

PublicAwareness_word of mouth

PublicAwareness_word of mouth, web, tv

Recognize unusual visitors who need heat relief

Recreation_welcome disk golfers and other recreators to cool off inside

Resilience_cooling center for years

Resilience_extended capacity

Resilience_hydration center for years

Resilience_senior center and parks/rec colocated

Resilience_watch for ind. w/ heat risk on warning days

RoleMitigatingHeatRisk_find homeless/hikers & give water

SignInRequirement_all are required to sign in

SignInRequirement_no sign in at all

SignInRequirement_No sign in for heat relief

SocialOrganizations_cut throat grant competition

StaffResponsibilities_staff help as needed despite position

SwampCoolers_don't work during monsoon

TemporaryLocation_for this year

TransitToFacility_ bus

TransitToFacility_light rail

TransitToFacility_trolley, bus, walking

TransitToFacility_walking + some cabs

TreeShade_fewer heat emergencies than other parks

UnlimitedReseources_would put signage outside and at busstop, homeless
showers

UnlimitedResources_After hours water, mister, showers, hats, sunscreen

UnlimitedResources_All types of things the poor needs

UnlimitedResources_community services, signage, public health

UnlimitedResources_cool room with tables and fridges

UnlimitedResources_education about heat & hydration

UnlimitedResources_Food, Shelter, AC assistance

UnlimitedResources_Hats, Suncreen, lipbalm, showers

UnlimitedResources_heat and safety kits, mobile water

UnlimitedResources_homeless case workers

UnlimitedResources_more shade

UnlimitedResources_open an extra day & housing for homeless

UnlimitedResources_would want to give out meals

Volunteers_large portion of labor

WaterBottleDonations_have run out, from HRN & local network

WaterBottleDonations_have run out, internal network donations

WaterBottleDonations_never ran out, internal network donations

WaterBottleDonations_palettes from MAG & Phoenix

WaterBottleDonations_supply from HRN plus other's donations

WaterCups_cold water + cups

APPENDIX C

CHAPTER FOUR HEAT RELIEF NETWORK

COORDINATOR INTERVIEW CODEBOOK

*AdHocNetwork_Not optimized for user, no coordination of open times

*CC close at 5pm, want some to stay open to at least 7pm

*Reluctance to go to cooling center not aligned with status

*Shift open hours from 8-5 to 10-7 to meet heat relief need

*Signs when CC is closed saying where to go for heat relief

Adds posted at transit stops to advertise CC

AssessorDataBaseLimitation_don't know time of day open

Bring model to heat planning meeting

Can't get to cooling center without awareness & transportation

CC managers limited in resources and open hours

CC marketing at transit stops through poster signs etc.

CcUseProxy_use water bottles given out as use intensity proxy for CC

CcUseShift_does cooling center use shift when one closes

Connect model to an alert system

Consumers at bus or light rail could use the model at kiosk

Convert model to an application for a smart phone

Could use communication tool for nearby CC capacity

Get model into the hands of consumer to find open CC

Helps CC managers see open times

How can model be brought down to a low tech level?

How to get info. in hands of consumer in app. or low tech way

Hydration stations are open later than refuges

ImproveModel_Add 105 degree extreme heat indicator icon to map

ImproveModel_add capacity or usage weights to circle radius

ImproveModel_Add clock and heat index on map to orient

ImproveModel_Add fine scale streets, agents move along them

ImproveModel_Add hydration stations to the model

ImproveModel_add intensity indicator for open % and temperature

ImproveModel_add survey data, have they run out of water?

ImproveModel_create zoom in feature to look at tight clusters

ImproveModel_Differentiate between refuge and hydration stations.

ImproveModel_include actual usage intensity for cooling centers

ImproveModel_include CC capacity and % capacity used

ImproveModel_include city jurisdictions, only Phx got water bottle distribution

ImproveModel_include population density and income

ImproveModel_Look at transit CC transit access radius: bus, car, walk, bike

ImproveModel_make CC point distinct color when closed

ImproveModel_make circle radius equal to transit mode access

ImproveModel_pie chart display for % coverage or something

ImproveModel_Update model with current year cooling center list

ImproveModel_Use GIS road network analysis for transit

ImproveModel_use sublayer of observed heat deaths in the model

ImproveModel_What type populations within radius of cooling center for service

IncludeOrgType_Primary service clients also secondary heat relief clients

InformalCoolingCenters_Libraries

InformalCoolingCenters_stay time > 30 minutes, i.e. shopping cart

IsolatedAreas_No planned transportation

IsolatedAreas_suburbs & few informal cooling centers

Kiosk only for CC too expensive, need other services too

map homeless encampments to know their location for outreach

Model as communication tool, bring people together

Model at kiosks at public transit stops for public to see CC open locations

Model good communication/coordination tool for managers

Model shows where there is a need for more CC in space

Model useful to regional managers and cooling center managers

Model Useful, no gap analysis tool at MAG for HRN

Model would be useful communication tool for CC managers

Most CC volunteer each year, no strategic gap recruiting

MotorizedTransportation=access to formal & informal cooling centers

Notices all cooling centers close at 5pm

NoTransportation_these people are most vulnerable, cannot reach CC

Phoenix offers water to outreach teams for heat crisis intervention

Present model to Regional Heat Network for their creative input

Public tranist to cooling center exposes people to heat

PublicTransportation_informal cooling centers

TransportationAccess_what are the modes?

Use model at several levels_coordinators, managers, consumers

Use model for 211 dispatch to give out info for open CC

WebEOC could be used to coordinate CC communciation