# Unraveling the complexities of disaster management: A framework for critical social infrastructure to promote population health and resilience

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## ARTICLE INFO

## ABSTRACT

Complexity is a useful frame of reference for disaster management and understanding population health. An important means to unraveling the complexities of disaster management is to recognize the interdependencies between health care and broader social systems and how they intersect to promote health and resilience before, during and after a crisis. While recent literature has expanded our understanding of the complexity of disasters at the macro level, few studies have examined empirically how dynamic elements of critical social infrastructure at the micro level influence community capacity. The purpose of this study was to explore empirically the complexity of disasters, to determine levers for action where interventions can be used to facilitate collaborative action and promote health among high risk populations. A second purpose was to build a framework for critical social infrastructure and develop a model to identify potential points of intervention to promote population health and resilience. A community-based participatory research design was used in nine focus group consultations ($n = 143$) held in five communities in Canada, between October 2010 and March 2011, using the Structured Interview Matrix facilitation technique. The findings underscore the importance of interconnectedness of hard and soft systems at the micro level, with culture providing the backdrop for the social fabric of each community. Open coding drawing upon the tenets of complexity theory was used to develop four core themes that provide structure for the framework that evolved; they relate to dynamic context, situational awareness and connectedness, flexible planning, and collaboration, which are needed to foster adaptive responses to disasters. Seven action recommendations are presented, to promote community resilience and population health.

## Introduction

Recent disasters, such as the oil spill in the Gulf, the tsunami and nuclear reactor leak in Japan, global pandemic, and the earthquake in Haiti have all demonstrated the complexity of responding to events which cross jurisdictional, organizational and other forms of boundaries. Complexity is a characteristic of large scale events, but also manifests in routine disasters such as floods, tornados, outbreaks and hazmat events that occur more frequently. All these events present high levels of uncertainty and require collaborative action between multiple sectors, which are part of complex adaptive systems (Ansell, Boin, & Keller, 2010; Okros, Verdun, & Chouinard, 2011; Wyche, Pfefferbaum, Pfefferbaum, & Norris, 2011).

Complexity theory and its basic tenets such as emergence, self organization, non-linearity, adaptiveness, and connectivity, are well suited for studying the dynamic and collaborative nature of disaster management. This theory has been useful in the analysis of complex adaptive systems, such as health care organizations, providing knowledge to assist with policy development, and design of information technology and work environments that support nonlinear processes that characterize the provision of patient care (Burns, 2001; Coiera, 2011). Systems characterized by change, particularly those crossing jurisdictional boundaries, cannot be analyzed without consideration of the dynamic context influencing operations (Ansell et al., 2010; Cilliers, 1998). The complexity frame of reference recognizes the interactions among system components, and between a given system and the larger environment (Coiera, 2011), and is now recognized as an essential lens for disaster management and resilience-oriented development (Kahan, Allen, George, & Thompson, 2009).

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Each phase of a disaster has distinct objectives and its own degree of complexity, including time demands, organizational involvement, and functional needs for collaboration (Kahan et al., 2009; Wyche et al., 2011). As observed during the 2009 influenza A pandemic, the response phase tends to be the most visible, yet depending on the event, the response can be quite short, whereas recovery efforts may extend for weeks, months and years (Norris, Stevens, Pfefferbaum, Wyche, & Pfefferbaum, 2008). The 2010 earthquake in Haiti exemplifies this. The acute response spanned several months, yet recovery will continue for years, and will continue to require extensive collaboration between Haitian and international agencies to develop the infrastructure to promote population health and resilience in the country. Likewise, following the relatively short response phase for the 2003 outbreak of Severe Acute Respiratory Syndrome (SARS), recovery and planning efforts to prepare for the next global outbreak have been ongoing for nearly a decade (Public Health Agency of Canada, 2009; Reissman, Watson, Klomp, Tanielian, & Prior, 2006; World Health Organization [WHO], 2009).

Disasters are typically managed locally, however they become increasingly complex when the impacts cross jurisdictional boundaries and outstrip community resources (McConnell & Drennan, 2006). Discussions of systems of critical infrastructure tend to focus on securing and protecting hard capital resources, such as facilities, supplies (e.g. vaccines), technology, and equipment. Recognition of soft capital (e.g. people and knowledge) has been slower, and there is a need for deeper understanding of the dynamics of critical social infrastructure and how it influences community capacity. Several authors have recognized this gap and suggest more empirical studies focused on social infrastructure such as communication networks, social capital, collaboration and community engagement, and methods for evaluating resilience-oriented intervention activities which focus on soft infrastructure are needed (Chandra et al., 2011; Sherrieb, Norris, & Galea, 2010; Wyche et al., 2011).

Complexity theory provides an appropriate lens for modeling social infrastructure in a disaster context for several reasons. First, disaster management, which is dynamic and adaptive, involves cross boundary integration and a diverse mix of people. Second, previous literature has expanded our understanding of the complexity of disasters, but few studies have examined empirically what the necessary ingredients for crisis management are at the grass roots, micro level, and how dynamic elements of critical social infrastructure influence community capacity. This gap in the literature is particularly apparent with respect to protecting and promoting the health of high risk populations, who are people at heightened risk for negative impacts from a crisis, due to the intersection of the social determinants of health (O'Sullivan & Bourgoin, 2010). These groups are reliant on community supports for activities of daily living, and when these supports are compromised, high risk populations, particularly people with complex medical needs, are at even greater risk for health and social problems, which create additional demands for health and social services.

Interventions to support disaster management have been published, such as checklists of essential tasks to be completed during disaster response and information systems to support aspects of complex collaboration, such as awareness and development of communities of practice (Carroll, Rosson, Farooq, & Xiao, 2009). However many interventions focus on macro outcomes, without relating to the complexity of inputs at the micro level, and there is a lack of emphasis on upstream initiatives to address the complexity. Mapping of hard and soft system infrastructure, and how they contribute to managing uncertainty in disaster management, is a gap that has not been adequately addressed in the

literature. We suggest the development of resilience-oriented interventions requires unpacking of the complexity at the micro level, and that interventions must emerge from the underlying complex structure including dynamic organizations, processes, technology and people; therefore an essential first step is to model the complexity inherent in the social infrastructure of a community.

The purpose of this study was to explore empirically the complexity of disasters at the micro level, emphasizing the voices of community stakeholders, to determine levers for action where intervention strategies can facilitate collaborative action and promote health among high risk populations. A second purpose was to build a framework for critical social infrastructure informed by the emergent themes from this study and existing literature on community resilience, and develop a model to identify potential points of intervention. This study was conducted as part of The EnRiCH Project, which is a community-based participatory research study focused on enhancing resilience and emergency preparedness among high risk populations.

## Method

### Design

This study employs a community-based participatory research design. Over the past two years, partnerships have been established with emergency management, health, and social service agencies in five communities in Canada to promote community resilience and emergency preparedness among high risk populations. The communities were selected to represent different geographic and linguistic groups, as well as the presence of complex hazards (e.g. trepid climate; being a hub for transportation; or being located on a flood plain). As part of the broader project objectives, asset/need assessments were conducted in each of the communities between October 2010 and March 2011. The theoretical framework used to guide data collection combined Norris et al.'s (2008) components of resilient communities and Kailes and Enders's (2007) functional needs framework. The tenets of complexity theory were used for data analysis to 1) unpack issues around resilience and functional capabilities assessment, and 2) identify potential points of intervention.

### Data sources

The asset/need assessments involved nine focus group consultations across five communities, using the Structured Interview Matrix (SIM) facilitation technique (O'Sullivan et al., 2009). We planned two focus groups per community (one evening and one daytime session), to ensure broad representation, however, in one community we canceled the evening session due to low recruitment. In another community, the second session was held on a Saturday, rather than an evening.

The number of participants per session ranged from ($n = 9$) to ($n = 26$), with lower participation in the evening sessions. Participants ($N = 143$) were recruited for the focus groups via distribution of email notices, using purposeful sampling to recruit professionals and volunteers from emergency management, health and social service organizations. Additional recruitment techniques involved snowball sampling as the community members became aware of the sessions and disseminated information through their networks. Broad inclusion criteria ensured representation from different sectors, and fostered inclusion of community groups representing high risk populations. In each community there was representation from municipal or regional emergency management, public health, tri-services (e.g. fire, police, paramedic), emergency service

organizations, food banks, and associations which advocate or provide direct care for people with disabilities. Multi-generational representatives from high risk groups participated in the focus groups, including stroke survivors and their family caregivers, several people who are hard-of-hearing or Deaf, people with low (or no) vision, and people who use assistive devices, such as a cane, wheelchair or service animal. The focus groups were conducted in English in three communities and French for the other two. Sign interpreters were provided for participants from the Deaf community and notetakers were provided for people with limited vision or fine motor control, to ensure they could participate. All participants signed a consent form approved by the university ethics review board prior to participating in the focus groups. Ethics approval for the study was obtained on July 23, 2010.

*Data collection and analysis*

The SIM format for the focus groups involves three phases of data generation and collection. The room is set up with four tables and each table is assigned a different question. The first phase is a series of one-on-one interviews where each participant spends 5 min with a participant from another table and asks them to respond to a specific question. The participant who is the interviewer writes down the response in the form of field notes, whereas the participant being interviewed voices his/her thoughts about the question without the pressure of speaking in front of the whole group. The process is repeated until each participant has interviewed one person from each of the other tables and also responded to the questions from each table. The facilitator guides the group so participants know how to proceed through the matrix. Following the interview matrix, the participants return to their assigned table for the small group deliberation phase, to review and summarize the data from the interviews. Data during this phase is in the form of conversations as the people at each table discuss the responses they received to their question during the interview phase. Each group identifies 3 main findings to present to the larger group during the next phase, which is a facilitated plenary discussion with all the participants.

The SIM design has been used in previous studies to address common pitfalls in traditional focus groups (O'Sullivan et al., 2009). It is designed for larger groups (10–40 people), yet enables voices of all participants to be heard, and provides a structure to reduce power differentials within the group. In this study, we repeated the phases twice, to generate data for eight questions which focused on strengths, weaknesses, opportunities and threats to disaster preparedness in each community, with emphasis on protection of high risk populations with functional needs related to communication, complex medical needs, supervision, independence and transportation. The questions were informed by the CMIST functional needs framework (Kailes & Enders, 2007). Sample questions included: "What are the strengths/assets/resources within your community that contribute to preparedness for, response to, and recovery from a disaster?" (the same question was asked in relation to weaknesses/vulnerabilities) and "In a disaster in your community, what supports and challenges would appear for people who have limited ability to communicate (due to disabilities affecting communication, being socially isolated, or communication technology being down)?"

The data generated from the focus groups was divided into three levels of analysis. The first was the field notes from the interview matrix, which were typically formatted as lists. They were transcribed and open coding was used to organize the data and create a coding grid. The second and third units of analysis were the audio recordings from the small group and plenary discussions. Following transcription and accuracy checks, the transcripts were coded by

the first author, using the grid developed from the interview matrix; and additional nodes were added as needed. Preliminary themes were identified and then discussed and revised by all the authors until consensus was reached. The emergent themes, which related to the complexity of disasters, were used to develop a framework to depict the interdependencies and dynamics of critical social infrastructure at the community level.

There were two primary objectives of our analysis. First was to identify core themes that unpack the complexity of community resilience and population health as it pertains to disaster and emergency management. Second, we identified a set of action recommendations as potential intervention strategies, to address the complexity from the core themes. This approach is consistent with recommendations from several authors (Chandra et al., 2011; Coiera, 2011) who suggest it is important to map systems and reduce complexity to identify 'levers' which can be used to overcome system inertia and resistance to change. Hence, through a complexity lens we identified the core themes and action recommendations and mapped them (with directional relationships) into a framework of critical social infrastructure.

## Results

The results of this study are presented in two parts. First we discuss the core themes and action recommendations that emerged from our analyses. They provide an understanding of the complexity of disaster management and highlight the hard and soft system aspects of that complexity, as well as potential intervention strategies. Second we show a formalized model which maps the complexity from the themes with existing literature, and highlights the relationships between the components of critical social infrastructure (Fig. 1). This model depicts a framework for critical social infrastructure which can be used to protect high risk populations in the context of disaster management, but has broader applications for identifying levers which can be targeted for interventions to promote community resilience and population health.

What became clear during our analyses was the interconnectedness of the various components of the hard and soft systems in a community, and how culture provides the backdrop for the social fabric for both. The four core themes (dynamic context, awareness and connectedness, adaptive response and collaboration) underscore this interconnectivity and represent the structure for the framework, as shown by the darker line around these components in the model (Fig. 1). From the action recommendations we identified micro level inputs that support core components in the model and represent levers for action to managing the dynamic complexity.

*Core themes*

*Manage complexity as a dynamic context*

Interconnectivity and emergence are basic tenets of complexity theory and emerged in the discussions of how community context continually changes. This theme is represented in Fig. 1 as 'dynamic context', which changes in response to restructuring, political pressure, emerging hazards, generation of information, changes in human needs and capabilities, and the influence of increased situational awareness.

The factors influencing the context of a community in all phases of a disaster are multi-directional, and they interact with the culture. Political priorities influence funding structures and priorities and trickle down to the municipal level, while at the same time grass roots initiatives exert upward pressure to influence political priorities. Disasters highlight gaps in community systems and stimulate change in protocols to prepare for the next disaster.
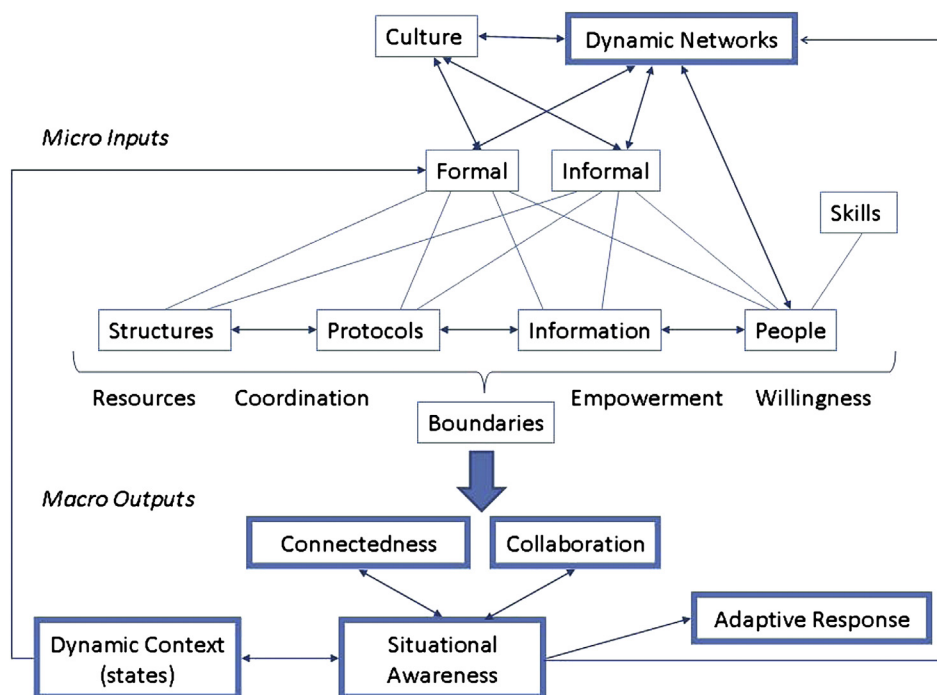
**Fig. 1.** Framework for critical social infrastructure to promote population health and resilience.

Expanding knowledge and skills, social networks, emergent opportunities for collaboration, evolving relationships, lessons from previous disasters, and changing attitudes with increased awareness, all contribute to the dynamic context of a community and the complexity of the inputs that lead to an adaptive response. The following quotation from a participant in Community A exemplifies how vulnerability is a dynamic context:

"*Vulnerability is an area that can change. We have a changing demographic … [that] makes a difference in the makeup of your population, but if a new facility is built into your community, then it tends to draw people there, you've perhaps within a very short time frame changed the level of vulnerability within your community….*"

*Build situational awareness and connect the dots*

A second core theme was the need for awareness and connectedness in each community. Awareness develops in a non-linear pattern, is influenced by a variety of processes, and loops back to exert influences on the inputs themselves, creating a catalyst for sustainable action. Along with connectedness, it exemplifies the tenets of emergence, self-organization, and connectivity in complexity theory. The participants listed numerous assets available in the communities, and there was a defined need to be more aware of various organizations, the services they offer, and the resources that could be drawn on to assist with a community response. Awareness and connectedness emerged as the foundation for a resilient community, to maximize the use of critical social infrastructure and enact a collaborative, adaptive response to a disaster.

All 5 communities emphasized the importance of relationships founded on trust, and learning from others who have expertise that could contribute to situational awareness, particularly around the needs of people with functional limitations. The following quotation from Community B exemplifies how this theme relates to resilience:

"*… there is agency to agency communication, but it seems to be in pockets… how do we make that widespread? … [it is important to] broaden our links and make better use of our human capacity, so we're talking about person to person, whether that's through email or other links, making use of those.*"

The stroke club is a group of people who are caregivers and stroke survivors who support people in the community who are recovering from stroke. This group was largely unknown to participants in the focus groups, yet it represents an important resource in the community with connections to a population at risk of being forgotten in disaster planning and response, due to changes in social connections, functional abilities, and participation in home, work and community life. During the focus groups the participants gained awareness about the important role the stroke club assumes in any community, and their connectedness to this high risk group. The population of people who have had a stroke in any community changes on a daily basis. Therefore, it is essential to leverage the knowledge organizations such as the stroke club have, because they monitor and actively seek connections with families coping with stroke.

One challenge in creating a more connected and aware community is the availability of time and opportunities to get to know people. In each community there was a need and willingness, but systemic barriers make it difficult for people to take time to develop connections and learn from each other. The following quotation depicts how participants in Community D felt leadership is needed to create opportunities for connectedness:

"*… it does take leadership though, to bring people together and then to keep them together even if there is a willingness to do so… I'm not sure if we really know where the leadership needs to come from. … Provincially they're trying to do it, but the province is just so big and so diverse that there are pockets of activity…. Often it takes somebody who is not involved in any of the organizations that has a passion for it to happen.*"

## Pliable planning and open mindset for adaptive response

The third core theme emphasizes how planning is important, but plans need to be pliable, so response activities and protocols can adapt to changing contextual demands. As plans become more complex, there is a risk that the response will become rigid and unrealistic, whereas optimal response relies on organizational adaptive capacity, to respond to the changing needs of a disaster. Plans provide a good structure to consider the 'what ifs', however, it is essential to have flexibility when the context changes quickly, and what was planned may not be easily implemented. This really underscores the importance of the collaborative process and the strengthening of relationships as the foundation of a good response.

Creative solutions emerge when people are open to new ways of thinking. It demands a shift in paradigm, which may require revisions to protocols or authoritative structure, and fluidity in sharing resources. Pliable planning and open mindsets align with resilience-oriented solutions that focus on assets and embrace complexity, as opposed to accounting for every imaginable risk and trying to control dynamic contexts. This core theme intersects with awareness, as the knowledge of resources and knowing where to find information provides empowerment among the population.

Participants in Community D expressed the need for "…*agencies to move beyond their mandates to support clients where there might be a gap in service*". This comment was specifically oriented toward assisting high risk populations with complex functional needs, where privacy policies, resource constraints, and rigid authoritative structures often restrict organizations from collaborating in client care. The group was concerned about the risk of people "*falling through the cracks*" during disaster response, when gaps in service are likely to occur.

## Dismantle silos and adopt a collaborative lens

When systems are overwhelmed and demands for resources increase, a collaborative lens is needed. This theme crosses several tenets of complexity such as emergence, self-organization, connectivity and adaptiveness. Understanding how assets in the community can be used to assist with the response, and engaging non-traditional stakeholders (e.g. companies that sell RVs or snowmobile clubs) may provide new solutions to help systems cope with overwhelming demands. Redundancy in assets and services provides a safety net when capacity diminishes, but also duplicates efforts that could be used elsewhere; this is part of the complexity of resource distribution.

As described by one participant in Community D who was referring to surge capacity in hospitals:

"*How do we move people around? The system is at capacity now, so how do we extend that in a disaster situation? We need to look at alternate supports … we need to get over the 'silo-ing' of our resources and be more flexible*"

Community B explained:

"*We need to know what's out there because there's lots we've all said and there's different supports for different target populations but we're not always sure where they are and then you know you can marry those together with the needs… But it's what do we have? Who needs it? How do we bring it together?*"

## Action recommendations

Seven action recommendations emerged in our analysis and are depicted as micro level inputs in the formal model (Fig. 1). Each recommendation has embedded complexity to guide preparatory, response and recovery actions in disaster management and contribute to building social infrastructure for adaptive response.

They are presented as levers or intervention strategies to promote population health and community resilience.

## Recognize the good news/bad news

The first action recommendation relates to the opportunity/crisis dichotomy of how community assets often present vulnerabilities or challenges as well. It depicts non-linearity in complex systems and how interdependencies emerge as assets, but also liabilities when the system becomes disrupted.

The good news in each community was the extensive lists of available assets, particularly the knowledge within response organizations and community associations. The bad news, or challenge, was how to manage the complexity of coordinating the assets. Connectedness is considered to be an asset and is good news for disaster management, as it expands possibilities for resource sharing, training and access to information. However, the inherent challenge with increased engagement of community organizations is that the enhanced awareness prompts more demands for preparedness activities, information and support.

New technologies present good news because they expand possibilities for interoperability between organizations, however technologies also present vulnerability because of the dependencies that are created. Many technologies, such as electronic health records, resource databases, transportation, surveillance systems, and social media, assist with disaster response, but are reliant on power, hardware, and the skills and willingness of people to use them. When systems are disrupted, processes such as communication protocols, surge capacity, access to information, risk management, and supply chains dependent on transportation systems, are all affected because they rely on interoperability between humans and technology. The following quotations are from discussions in Communities E and D, respectively:

"*We are at the technology era, with Blackberry and all the network gadgets. But one of the first things to fall apart during a catastrophe is electricity. We have our Blackberry but we still carry around our pager in case the system falls and we need to communicate with each other. I also always carry around my good old papers which inform me how to contact my people when something serious happens.*"

"*I think typically people rely on television for that source of communication. It could be through radio or now it's twitter, it's facebook, it's other forms of social media, and if those systems go down, it's how do you reach the population?*"

The action lever recommended here is for communities to recognize that pliable contingency planning is influenced by awareness of the good news and bad news associated with each asset. Collaborative asset mapping which acknowledges the opportunities and threats associated with different resources or aspects of the community context enables organizations and support personnel to be open-minded and adapt to changing circumstances and demands.

## Information please! … to navigate the matrix of uncertainty

Inherent in the complexity of planning and preparing for disasters is the matrix of uncertainty surrounding potential impacts of extreme events. There is often uncertainty about roles and responsibilities of various actors in the health care sector and extended community, the needs of the population, and potential solutions to minimize the damage and restore system functions as quickly as possible. Individuals need information about what to do in an emergency and how to prepare, while organizations need to know about resources and continuity planning, and how to align organizational plans with those at the macro level, The emergency management sector needs to become aware of the assets and needs

of high risk populations and how to incorporate them into contingency planning activities. As discussed in Community B:

> "As we were going around [during the focus groups] we found out that many organizations have incredible resources available already… that's where this whole knowledge, access, mobilization came in. Because we started talking about the different things, and everybody went 'wow I didn't know about that' and it's like none of us knew. And probably a lot of the rest of you didn't know, so we think that's really important"

Assumptions are part of the complexity in disaster management and the matrix of uncertainty. People are part of critical social infrastructure in a community, and they bring assumptions about how needs should be prioritized, what information is known or unknown about the situation, and what supports will be available. Situational awareness about available resources and potential solutions fosters adaptive responses to uncertain events, and these outputs are influenced by how people and organizations use information. As described by a participant in Community B: "We all have to look at the bigger picture and make sure that we have our back up plan and our back-up-back-up plan".

The availability of new communication technologies has streamlined many operations in disaster management, however there are complexities surrounding the sharing of information, both vertically and horizontally, formally and informally. Peoples' skills in using new technologies also contribute to interoperability of new information systems. Connectedness and having ample information are assets, however it is essential not to provide people with too much information that it becomes overwhelming and the messages confusing. The participants recommended having a central hub to manage communication. Sociotechnical considerations, such as training people how to use communication systems, making them convenient so people will use them, and ensuring they are interoperable between organizations are paramount to ensuring the flow of information is efficient and effective. These complexities around sharing and accessing information as a micro level input are represented in Fig. 1.

The action lever recommended here is to ensure the complexity of pushing and pulling information across individual, organizational and broader societal levels is recognized and simplified as much as possible, to ensure essential information is accessible, but not overwhelming. Community engagement can contribute to determining what type of information should be shared, in what format, and through which channels.

### Let the community teach the responders

The participants emphasized the need for target populations and agencies which advocate for high risk populations to be engaged in disaster management activities, particularly providing guidance on specific functional needs and how responders can identify and act when providing services. Community organizations can suggest strategies for talking to people with cognitive or emotional limitations during evacuation efforts, such as asking the individual how best to assist him/her. One person in Community D said: "If I'm injured or something happens, I'll say, hey look, I don't have my hearing aids, I need you to look at me … so sometimes the support can be from the actual person that has the chronic condition". During the large group discussion, a participant from Community C commented:

> "Community organisations' field expertise is one of the strengths we can rely on for better emergency preparedness, response and recovery. Their leadership and sense of innovation along with their close contact and good knowledge of the high risk populations are of great value before, during and after disaster interventions."

As shown in Fig. 1, people and their skills and networks are part of critical social infrastructure. Engagement of target populations is not always a simple task. Opportunities for connectivity, collaboration and sharing knowledge require investment of effort, time and money, which in turn requires higher authoritative support and structures. However, the lever for action recommended here is for communities to invest in efforts to identify expertise among the population, and to reach out to the population and invite them to be part of planning and training for the response community. Inclusiveness and reaching out is an important antecedent for people to be willing to share their expertise and contribute to their community.

### Training beyond the job requirements

Organizational resilience requires diversification of skills and strategic redundancies to ensure key functions are maintained. It demands a paradigm shift where staff are trained to do tasks required for their own job as well as other jobs, in case a co-worker becomes injured, ill, or has competing demands at home (such as caregiving responsibilities, damage to their own home, or they have been displaced as a result of the event). This crosses the tenets of emergence and non-linearity in complexity theory. One group in Community E emphasized the need for surge capacity and the dilemma of being understaffed:

> "Sometimes there's contradiction among contingency plans. In the case of pandemics, hospital recruitment plans would ask our staff, notably social workers and other stakeholders — already dealing with the crisis in our establishment — to give hospitals assistance. We would then become understaffed and have difficulty maintaining our services to the population"

The micro inputs identified in this theme are people, their knowledge and their skills. The action lever recommended is to build redundancies within the system and invest in human development, so people can step in and provide an adaptive response when context changes and the everyday protocols don't work, or the people typically responsible for a given task are unable to respond.

### Fine tune the guest list without ruffling feathers

A recurring question was 'who would I call for this?' This theme speaks to the emergence of networks in a community, which is one aspect of the complexity. The value of fostering an inclusive culture must compete with the backdrop of the inherent challenges of having an enormous guest list for planning activities. Participants from one city noted there are 5000 organizations in their community, therefore the dilemma became one of balancing the complexity of identifying which organizations need to be at the table, and ensuring collaboration and engagement could reasonably be facilitated. However, to align with the predominant themes which endorse efforts to foster connectedness and draw on the expertise in the community, inclusivity must be front and center when fine tuning the invitation list for collaborative planning activities, to ensure high risk populations are represented and their functional needs are acknowledged.

Several participants emphasized stigma and lack of awareness about 'how' to include high risk populations in planning activities. An invitation to participate is a first step, however it is important to ensure people who are invited are provided with the means to support their engagement (such as support for communication through sign interpreters, ensuring barrier-free meeting spaces, and providing a safe atmosphere to feel comfortable expressing their needs). The following quotation is from a discussion that occurred among participants in Community D:

"*I think most of us here are dealing with vulnerable populations…the very nature of our business has a certain stigma attached to [it] ….So that becomes one of those things that you have to get over in order to engage these other groups that could be a support*"

Culture and networks were added to the model as micro level inputs to represent this theme. The action lever recommended is for communities to foster a culture where inclusion of people with different functional capabilities is valued, desired and expected. However, the extension of an invitation to the planning table must be backed with a commitment to accommodate needs so everyone can truly participate.

*Invest time and effort in relationships … with haste*

Solid, trusted relationships were identified as the foundation on which collaboration, communication, mobilization of resources, and knowledge of population needs are based. The development of trust occurs as people recognize other peoples' competencies and intentions, and have the opportunity to work together. 'Knowing' that you can rely on someone for information or assistance contributes to trust and confidence in relationships as organizations and individuals let go of power, egos and rigid protocols to facilitate creative solutions and collaborative action.

An inherent complexity in collaboration is the need to invest time in developing and nurturing relationships, but few participants believed they had the time to do it, and some doubted whether their organizations would support it. Yet willingness to collaborate was expressed by this participant in Community E and was prominent throughout the discussions in each community:

"*Maybe we shouldn't wait until the next meeting convened by a university research to get back to each other. I think we have the willingness to collaborate, we all wish to get together to be able to help one another.*"

The micro level inputs from this theme are represented in the model as networks, people, and structures. They all feed into connectedness, willingness to collaborate, opportunities to share information and activities to foster awareness. The action lever recommended here is to invest time and resources in building relationships and establishing trust and common ground. This strategy supports the development of social capital and ultimately adaptive response to changing context.

*Identify who is at heightened risk, but respect their anonymity*

Identifying high risk populations is a complex process and many communities have considered developing databases to assist response organizations in knowing who requires additional support during a response. However, because of privacy laws and other issues related to having lists of 'vulnerable people', there are strong arguments against the development of central databases. An alternative strategy is to engage community organizations that already have established relationships with high risk groups and contact lists for people who need particular supports. The following quotation is an excerpt from the focus group in Community D where the group discussed the merits and challenges with having a central database for people with disabilities:

"*So the question is, should there be some sort of database available for all the people with disabilities that has a basic fact sheet? Their name, their family contact, their medication, their basic limitations, like not a big long 8 page summary, but their basic information…I don't know. I don't know what the answer is.*" … "*it's a bit of a dilemma … you want to know where people are and help them, but on the other side respect their privacy…*"

In our model, the micro level inputs relating to this theme are informal and formal protocols, structures, information and boundaries. These inputs require coordination, resources, and collaboration to foster awareness of who is most at risk during daily living, and in a disaster context. The action lever recommended here is to invest time, energy and human resources toward helping response organizations connect with community groups who are aware of and have established relationships with high risk groups. This fosters connectivity, which is one of the main tenets of complexity theory and an essential component of community social infrastructure.

*Emergent framework*

Fig. 1 depicts the *Framework for Critical Social Infrastructure to Promote Population Health and Resilience* which emerged as the summation of data analysis, informed by knowledge from previous studies on disasters, complexity, communication, awareness, collaboration, and community resilience. The model shows integrated complexity at the micro level where the inputs are continually in flux and interacting to influence the type and availability of resources, the coordination of hard and soft resources, and the willingness and empowerment of the population to collaborate, before, during and after a community crisis. All of these elements intersect to determine community capacity at a given time, and within a given context, and ultimately influence situational awareness and adaptive response.

The inputs in the model are potential levers for action, which can be targeted for interventions to enhance community capacity for adaptive response. For example, policies and structures respond to different political pressures, such as recognition of the need to provide more accessible spaces and services for people with disabilities. This has an impact on people, organizations, and demands for information. It also influences subsequent awareness, attitudes, willingness to collaborate, and the culture within a community. Because dynamic context requires continual adjustment, a 'new normal' is continually defined within a community and influences its resilience at any time. When a traumatic event exerts an impact on a community, the shift requires a tailored response and all the inputs represented in the model are drawn on to update situational awareness and adapt to the changes.

Each of the core themes were placed into the model with a label (e.g. dynamic context, awareness, connectedness, collaboration, and adaptive response). The themes align with different components of complexity theory, and show the interconnectivity of dependencies within a system. The action recommendations were also assigned a label and placed within the model to show how the micro inputs (e.g. people/information/structures/networks) feed into the core structures. The macro outputs exert critical influences on how a community responds to a disaster in an adaptive way. These outputs in turn loop back to influence micro level inputs such as formal and informal social networks, information, structures and protocols, and people's knowledge, attitudes, and skills. Many of these inputs change in response to previous experience or new context, such as hazard identification, new resources or political pressures within a community, vicarious experience from disasters in other regions, and people leaving or entering the community. They all influence community capacity and resilience, and should be considered when designing community and organizational interventions.

**Discussion**

Complexity occurs across different levels and between and within different systems, including agent complexity (e.g. individuals and families), organizational complexity (within formal and

informal community groups), and cross-boundary complexity (between organizations and across jurisdictions). Previous studies have emphasized the need to unpack complexity and identify levers for action to improve health system performance (Coiera, 2011) and community resilience (Chandra et al., 2011). In this empirical study we explored the complexity of community disasters at the micro level, to determine levers for action where intervention strategies can be used to facilitate collaborative action and promote health among high risk populations. The emergent themes were formalized into a model and combined with knowledge from existing literature to present a framework for critical social infrastructure, to simplify the complexity within health and social systems and identify potential points of intervention to promote population health and resilience.

The four core themes which emerged in this study showed complexity related to: a) managing dynamic contexts; b) situational awareness and interconnectivity; c) flexible planning to ensure adaptive response; and d) active engagement and the challenges of collaborative work. These themes created the structure for the emergent framework and are consistent with the suggestion by Okros et al. (2011) that complexity can be understood by analyzing adaptive systems which operate according to chaotic, spontaneous, unpredictable changes from "dynamic interactions amongst multiple entities" (p. 43). The key to unraveling complexity in disaster management is to understand how these issues intersect and develop interventions to enhance community capacity and promote collaborative activities, to increase situational awareness and facilitate adaptive responses to dynamic, complex events.

The inputs we identified are contained within and across all types of boundaries, such as those identified by Ansell et al. (2010) (e.g. political, geographic, functional, time). The outputs in our framework are consistent with previous literature (Carroll et al., 2009; Chandra et al., 2011; McConnell & Drennan, 2006; Pfefferbaum, Reissman, Pfefferbaum, Klomp, & Gurwitch, 2007), however an important finding from our study is that complexity is a constant at each input and output of the system, and is an integral part of interactions with other systems. Our results support the objectives of resilience (resistance, absorption and restoration) outlined by Kahan et al. (2009) and the guiding principles outlined in the FEMA National Response Framework (2008), which emphasize "engaged partnership; tiered response; scalable, flexible and adaptable operational capacity; unity of effort through unified command; and readiness to act" (p. 8). While the participants in our study acknowledged the need for leadership and centralized coordination, more prominent themes emphasized collaboration, awareness, and flexible planning, with the understanding that coordination of resources and protocols is a way of building relationships and situational awareness for better understanding of community assets and needs. These themes support suggestions by Kahan et al. (2009) that complexity is the backdrop for community resilience and must be integrated into any intervention strategies designed to support high risk populations who are dependent on the health and social system supports. Chandra et al. (2011) also emphasized the need for empirical studies to unpack complexities and provide specific mechanisms or levers for action which can be used to tailor intervention strategies, such as the action recommendations provided here.

The intersection between health and social services systems is a good example of how community crises naturally cross system boundaries. In Canada, and worldwide, the transboundary nature of the 2003 outbreak of Severe Acute Respiratory Syndrome (SARS) and the 2009 pandemic of influenza A highlighted the complexity of interdependencies among different systems and how emergency plans are implemented at the community level (O'Sullivan et al., 2009; O'Sullivan & Bourgoin, 2010; The Campbell Commission,

2006). These examples underscore the need to consider how the impact of massive demands on the acute health care system radiate into other parts of the health sector where service delivery is provided, including public health and home care, as well as occupational health and safety, employee assistance programs, and other sectors which ultimately influence population health. There is extensive literature on the need for coordination and collaboration for unified, comprehensive response to disasters, and national frameworks for disaster response acknowledge the need for multi-sector engagement and action. Population health and resilience requires collaboration between multi-disciplinary sectors, to ensure there is adequate surge capacity, as well as efficient and effective communication, particularly when infrastructure and operating systems are disrupted (Chandra et al., 2011; FEMA, 2008; Okros et al., 2011; WHO, 2009).

Contingency planning is an important community process, and the complexity of developing coordinated emergency plans amidst a matrix of uncertainty was a central point of discussion in each of the communities, consistent with extant literature promoting all-hazards planning (McConnell & Drennan, 2006) and a whole-of-society approach (Chandra et al., 2011; WHO, 2009). Coordinated plans provide structure to consider the possible scenarios and response strategies, however flexibility is essential because self-organization, a central tenet of complexity theory, is often what evolves during a disaster when the context changes quickly (Norris et al., 2008). Action recommendations from our study, supported by the literature, include interventions designed to facilitate open-minded, pliable contingency planning, to ensure organizational adaptive capacity (Cilliers & Preiser, 2010; Kahan et al., 2009). Wyche et al. (2011) emphasized the role of flexible protocols in the provision of support for people evacuated after Hurricane Katrina. The responders were empowered when they were able to appropriately bend protocols to meet the immediate needs of the survivors and adapt to the emergent issues that arose in the shelters. In the context of pandemic, the WHO (2009) recommends contingency planning include designating and training alternate people for critical positions in any organization, to ensure back-up is available to sustain operations. This represents an important action lever for interventions at the micro level to utilize redundancy as a key strategy for surge capacity.

The need for situational awareness was the most prominent theme in this study, and the complexity of increasing awareness amongst organizations and the public was something each community struggled with. In particular, communities were challenged to connect the dots by identifying organizations with resources that could be used in training, information-sharing, and service provision. This finding is consistent with previous studies (Chandra et al., 2011; Norris et al., 2008) emphasizing organizational and individual linkages as key components of community resilience. Our results underscore the need for possibility thinking, to allow organizations to dismantle silos, create functional and informational linkages, and cross boundaries more easily to manage the dynamic context during a disaster.

Collaboration emerged as an important output in our study, with an emphasis on inclusion of people with functional needs, and community organizations who are not traditionally involved in disaster planning. This is consistent with the findings from Chandra et al. (2011) suggesting engagement and partnerships are critical for community resilience, but that opportunities to engage in resilience-oriented activities are limited. Part of the complexity of fostering collaborative activities is the culture clash between different sectors and organizations, which McConnell and Drennan (2006) describe as institutional fragmentation. The expense and logistics of engaging a wide variety of organizations create additional barriers, yet interventions which foster collaborative activities can be useful for

sharing information, social learning, and building collaborative relationships (Carroll et al., 2009; Kuziemsky & Varpio, 2010).

Two important limitations of this study should be considered. First, the data from this study is limited to five communities in Canada, therefore cannot be generalized. Second, recruitment for this study was broad, including participants in full time paid positions with extensive expertise in emergency management, as well as volunteers and employees from community organizations with little to no experience with disaster planning. Our study provides an empirical model to map critical social infrastructure within a community and identify levers for action to promote community resilience. It represents an assets-based lens for identifying resources and opportunities to reduce vulnerabilities for high risk populations, but can also be applied to the broader community to promote well-being. Future studies could explore the directional relationships depicted in the model and effectiveness, feasibility and appropriateness of different intervention strategies targeting each of the inputs in the framework of critical social infrastructure presented in this paper. In particular it will be important to determine how to fully engage representatives of high risk populations and non-traditional organizations not typically involved in disaster planning activities.

## Conclusion

Promoting population health in a disaster context requires a shift from risk management to one of resilience, which by its very nature acknowledges changing complexities. The results from this study underscore the need to move from a command and control model to one of collaboration, which is at the core of the Framework for Critical Social Infrastructure to Promote Population Health and Resilience presented in this paper. By unraveling the complexities of the inputs and outputs influencing adaptive community response, it simplifies the identification of target points for intervention to enhance resilience. 'One size fits all' solutions are not adequate to promote community resilience. Instead, intervention design must emerge from the complexity of the situation and be tailored to the community context at any point in time.

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