Disaster Risk Management: Toward a Spatiotemporal Strategy

Karim Hardy,

Ph.D., CSP, CSHM, CMIOSH

Associate Professor, College of Aeronautics,

Worldwide Campus

Embry-Riddle Aeronautical University, USA

Abstract

Disaster as sociotechnical systems are complex and can be described as a source of instability for populations.

In such systems, decision-makers need to address a specific problem: how to manage both time (delays) and resources (i.e., stocks) to make meaningful decisions?

Traditional models of accidents that exist to manage complex systems are inadequate and insufficient to deal with resources and time pressure due to uncertainty and level of instability within a sociotechnical system. Current disaster response organizations are also unable to handle a dynamic evolution of resources and delays to bring a structure back to stability.

The objective of this article is twofold. At first, it aims to define what complexity is and to introduce the concepts of delays and stocks (i.e. resources). This approach is nowadays important to appreciate system's performance and to control instability due to a need for risk-informed actions.

Second, it aims to introduce a trend for understanding disasters that results from theories of systems, and complexity. This new approach states that instability can be viewed as a spatiotemporal phenomenon that result from inadequate management of both spaces of resources and time (delays).

1. Introduction

Implementing risk-based information into sociotechnical systems creates challenges in integrating resilient decision-making processes. Disaster risk reduction, which aims to analyze and reduce the causal factors and impacts of natural and human-made hazards that lead to disasters, is one such challenge (7, 48–50).

The utmost constant of contemporary eras is changed. Fast changes in technology, demography, and economic are altering our world, from the banal —the effect of information technology on the manner we use our smartphone— to the deep —the consequence of greenhouse gases on the worldwide climate.

Some of the changes are necessary; others despoil the planet, deprive the human spirit, and endanger our existence. All challenge traditional institutions, practices, and beliefs. Most importantly, most of the changes we currently try to comprehend as outcomes, planned and unplanned, of humankind itself.

Our mental models conduct frequent errors and biases in complex dynamic systems like disaster and climate. Where the effects of our activities spill out through space and time, our mental models have thin borders and emphasize on the short term. Where the dynamics of sociotechnical systems are inured by numerous feedbacks, delays, stocks and nonlinearities, we have trouble identifying and appreciating feedback processes, undervalue time delays, and do not recognize fundamental principles of accumulation or in what way nonlinearities can produce regime alterations.

These difficulties are the result of not only laity but also amongst highly educated leaders with substantial education and knowledge in science. They are the result of not only in complex and sociotechnical systems like nations, disasters but also in everyday contexts such as driving a car.

Consequently, they cannot be alleviated purely by granting more information about disasters and catastrophes, but need diverse methods of communication, including experiential learning contexts such as shared simulations.

2. Disaster view as Complex Systems

2.1 First-generation complexity

Complexity has permanently been hard to define.

Despite that, the concept of complexity is broadly applied, in default of a clear definition, in all disciplines of science fluctuating from biology to philosophy. One method of defining complexity is to observe that it is the contrary of simplicity.

Something is simple if it comprises limited elements and if the relations among the elements are painless to understand, while something is complex if it includes many elements and if the relations among the elements are not primary.

A more proper line of attack is to describe complexity as a measure of the number of conceivable states a system can take, or as the state of a system, population, or organization that is combined with some level of order, but with too many components and associations to be appreciated in straightforward analytic or logical approaches. Wiener (1948) suggested that the complexity of a specific system is the degree of convolutedness in forecasting the properties of the system if the properties of the system's elements are specified.

A shared trait of many definitions is that something is complex if it is hard or unfeasible to envisage what is going to occur—both regarding the dynamics of the context itself and more precisely regarding what the results of particular activities or interventions will be. This is also representative of the notion of 'coping with complexity.' (Rasmussen and Lind, 1981). Active coping cannot be achieved barely by responding to what occurs when it occurs, i.e., as feedback control, since that will sooner or later be flopped. Effective coping must be founded on predictions—of some kind—of what is going to occur, i.e., it must be founded on anticipation. If it is hard or unfeasible to make the predictions, we may state that the environment is complex. The significance of being able to define the aspects of a system and how it operates is seized by the distinction between epistemological and ontological complexity. This is the interrogation of whether the system is complex as of what it is, or whether it is only the explanation that is complex. Pringle (1951) claimed that:

It must be emphasized that this representation of complexity is fundamentally epistemological; the measure of complexity is of the statement about the system and is not the complexity of the system itself, an expression which has no scientifically discoverable meaning.

This difference is compatible with the other definitions cited above and with the concept of 'coping.' The central thing is whether the description of the system and the context makes their performance understandable. If so, predictions can be formed and coping can be positive. If not, predictions will be extremely indeterminate, and the aptitude to cope will be impeded.

2.2 Second-generation Complexity

Managing complexity was recognized as a vital topic in the early 1980s, but it was not the first complexity had been a subject about humans and the population.

We incline to low complexity with the application of ‘modern’ technologies.

Right the way through these technological developments, it had been implicitly supposed that accidents and disasters occurred because something was wrong or had gone wrong. The incapacity to encounter the needs from progressively powerful technologies had primarily been pushing the developments in human factors engineering and later did the same for automation. In the first decades of the 20th century, the outcomes had mostly been on the economic side—loss of efficiency or productivity. After the 1950s, a rising number of systems had become so big and so tightly coupled that disasters could have irrepressible adverse results.

As a consequence of this, the concern for disasters commenced expanding, in no small measure helped along by the fact that severe accidents turned out to be more ordinary and that the aftermaths of accidents became greater.

In 1984, Charles Perrow suggested that, as an outcome of this change, accidents should be viewed as normal (Perrow, 1984). The most significant repercussion of this view was that one should no longer look for one category of description for accidents and another kind of description for ‘normal’ performance. As an alternative, they were both understood as resulting from the same cause—or that is at least the psychological and philosophical effect of the view.

This denoted that accidents should not be viewed as the consequence of handling that failed, but rather as handling that was deficient because it was inexact.

Perrow attempted to state this incapacity to cope by remarking how the circumstances for coping—and the exigencies to coping— had changed. The world in which persons had to cope had progressively become more tightly coupled and nonlinear, in other words less straightforward to appreciate. Illogically, as our sociotechnical world had become more complex, coping had become more imperative.

The key to ‘coping with complexity’ was thus to persist what was previously done, specifically to offer more ‘intelligent’ support—such as intelligent decision systems, adaptive interface, and improved training. The formed approach has continuously been to attempt to handle the problems as they occur, wordlessly presuming that we recognize what the problems are, rather than struggling to comprehend what the problems are.

2.3 Third-generation Complexity

Several sociotechnical systems have become so complex that the associated conditions are persistently under-identified, therefore somewhat unstable.

In these human systems limited, if any, activities can profitably be carried out except tools, procedures and performance are tailored to the state. Performance variability (i.e., coping) is both usual and essential. Since performance variability is needed, the coping problems cannot be explained by eradicating variability, as in simplifying sociotechnical interactions, since this will have the effect of removing the basis for effective interaction as well.

3. Controllability and complexity of socio-technical and dynamic systems

In order for a system, as a social group or a population, to be controllable, it is indispensable to identify what runs 'inside' of it. More tangibly, it is essential to have an adequately strong picture of the system and how it works. he similar condition must be encountered when a system is to be studied, for instance in disaster risk reduction. That this must be so is palpable if we think the opposite. If we do not have a strong picture of a system, and if we do not see what goes on 'inside' it, then it is impossible successfully to control it as well as to analyze it. We can seize these traits by making an otherness between controllable and complex systems.

A social system, or even a disaster, is said to be controllable if the principles of operation are identified, if explanations are straightforward and with limited details, and most significantly if the system does not vary while it is being defined.

Taken together these settings mean that a system can be defined both in principle and in practice. Equally, a system or a disaster is complex if the principles of functioning are just partially identified or even unknown if explanations are developed with several details, and if the system may vary before the explanation is accomplished.

3.1 Disasters view as Instable and Dynamic Systems

Most people describe complexity regarding the number of elements or conceivable states in a system. In disaster reduction, for instance, optimally predicting new situations for disaster reduction is highly complex, but the complexity lies in discovering the preeminent answer out of an exorbitant number of options.

However, most situations of systemic resistance result from dynamic complexity—the performance of complex systems that results from the interactions of the elements (individuals, policy, government, laws and regulations, etc.) over time.

Where disasters are the result of a dynamic, changing, and interrelated world, we incline to make decisions using mental models that are static, limited, and reductionist. Amongst the elements of dynamic complexity, individuals discover most challenging are feedback loops, time and delays, resources and stocks and flows. That is the case in disaster reduction when time and resources are limited.

3.2 Feedback and dynamics

Comparable to organisms, sociotechnical systems comprise sophisticated networks of feedback loops and processes, both self-reinforcing (positive) and self-correcting (negative) loops. Though, research shows that individuals identify limited feedback loops; instead, people habitually reason, in short, causal chains, incline to undertake each consequence has a specific cause, and frequently stop their search for clarifications when the first satisfactory cause is found (Doner, 1996)(Plous, 1993).

Failure to concentrate on feedback in policy strategy has unfavorable effects, and the world responds to interventions.

There are feedback loops: our activities change the environment and, consequently, the decisions we take. Our activities may generate adverse effects that we did not expect. Other individuals, striving for achieving their objectives, behave to reinstate the equilibrium that we have troubled; their activities similarly create planned and unplanned effects. Objectives are also endogenous, changing in reaction to evolving circumstances.

Policy resistance occurs because we do not comprehend the full range of feedback loops surrounding—and shaped by—our decisions.

Disregarding the feedbacks in which we are surrounded conducts to policy resistance as we obstinately respond to the signs of trouble, occurring at low influence purposes and activating delayed and vague outcomes. The difficulty increases, and we respond by pulling those similar policy levers still trickier in an unpredictable malicious rotation. Policy resistance causes skepticism about our aptitude to modify humanity for the better. Systems thinking obliges us to realize how our activities feedback to influence our environment.

The more significant challenge in disaster reduction is to act so in a condition that encourages, instead of supports, the conviction that we are powerless victims of influences that we neither affect nor understand.

3.3 Delays (time) and disaster reduction

Delays in feedback loops are frequent and especially problematic in disaster reduction. Most palpably, delays reduce the stock of indication and risk-based information. More challenging, the short- and long-run influences of our policies are frequently unusual. Delays also generate instability and variations that defeat our aptitude to learn. Driving a car and drinking alcohol involve delays between the beginning of a control action and its consequences on the state of the system. As a result, decision-makers regularly persist to amend deceptive inconsistencies between the necessary and real state of the system even after adequate remedial actions have been taken to reinstate balance.

3.4 Stocks and Flows (resources)

Stocks and the flows that change them are fundamental in disciplines like disaster reduction. The movement and alteration of flow (information, energy, material) among states are essential to the dynamics of complex systems and disasters.

In physical and biological systems, resources are typically perceptible: the stock of glucose in the blood; the number of smokers in a population. The performance of disaster management systems, though, is also influenced by resources such as expert skills, agent's knowledge, population norms, and other forms of human, social, and political resources. Research explains people's perceptive interpretation of stocks and flows is inadequate in two fashions. First, restricted mental model limits mean that individuals are habitually ignorant of the networks of stocks and flows that provide resources.

Second, people have deprived intuitive perception of the process of accumulation and stock. Most people undertake that system inputs and outputs are connected (e.g., the higher the federal budget deficit, the higher the national debt will be) (Booth, 2000) Nevertheless, stocks incorporate (accumulate) their remaining entries. Stock growth even as its net inflow reduces, as long as the inflow is positive: the debt rises even as the deficit decreases. Inadequate comprehending of accumulation and stock has essential outcomes for disaster reduction.

3.5 Obstacles to learning

Just as dynamics appear from feedback, so to all learning is contingent on feedback.

As we observe inconsistencies between wanted and real states, we behave that (we believe) our actions will trigger the real world to move toward the wanted state. Additional information about the state of the world offers us to amend our sensitivities and the decisions we make in the future. Decisions are the outcome of using a decision policy to information about the environment as we observe it. (Forrester, 1961)

These policies are influenced by institutional organizations, structural approaches, and cultural rules, which, in turn, are designed by our mental models (fig 1.).

Single-loop learning is the development whereby we learn to attain our current targets in the context of our prevailing mental models. Single-loop learning does not stem in a profound alteration in our mental models— the time horizon we believe relevant—nor in our ambitions and values.

Profound alteration in mental models or double loop learning, (Argyris, 1978) occurs when evidence not just modifies our decisions within the context of prevailing frameworks, but also feeds back to alter our mental models. As our mental models change, we modify the structure of our systems, generating various decision rules and original strategies.

The equivalent information, understood by a different model, now produces a clear decision.

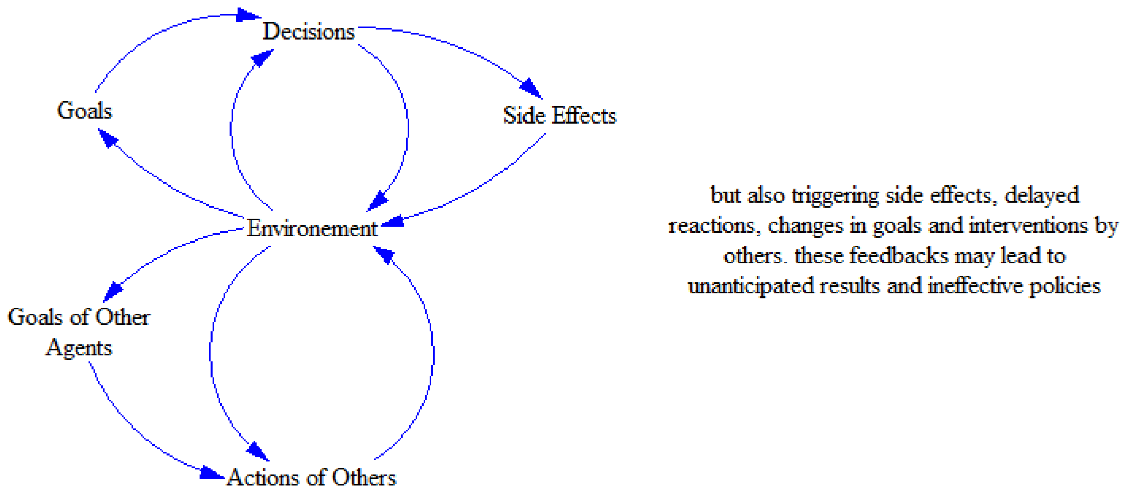

Fig 1. Sources of Policy Resistance within complex systems. Adapted from Sterman, 2006.

Arrows designate causation, e.g., our actions change the environment. Arrows exhibit the essential feedback through which we get to bring the state of the system in line with our targets. Policy resistance happens when we fail to account for the so-called "side effects" of our actions, the answers of other agents in the system (and the unexpected effects of these), how understanding outlines our purposes, and the delays frequently existing in these feedbacks.

Systems thinking is a learning process in which we replace a reductionist, restricted, short-run, motionless view of the world with a holistic, global, long-term, dynamic understanding, re-inventing our policies and organizations consequently. For learning to arise, each connection in the single- and double-loop learning processes must operate successfully, and we must be capable to cycle around the loops quicker than variations in the real world make present knowledge out of date. These feedback loops frequently do not function well. Each connection in the learning loops can disappear.

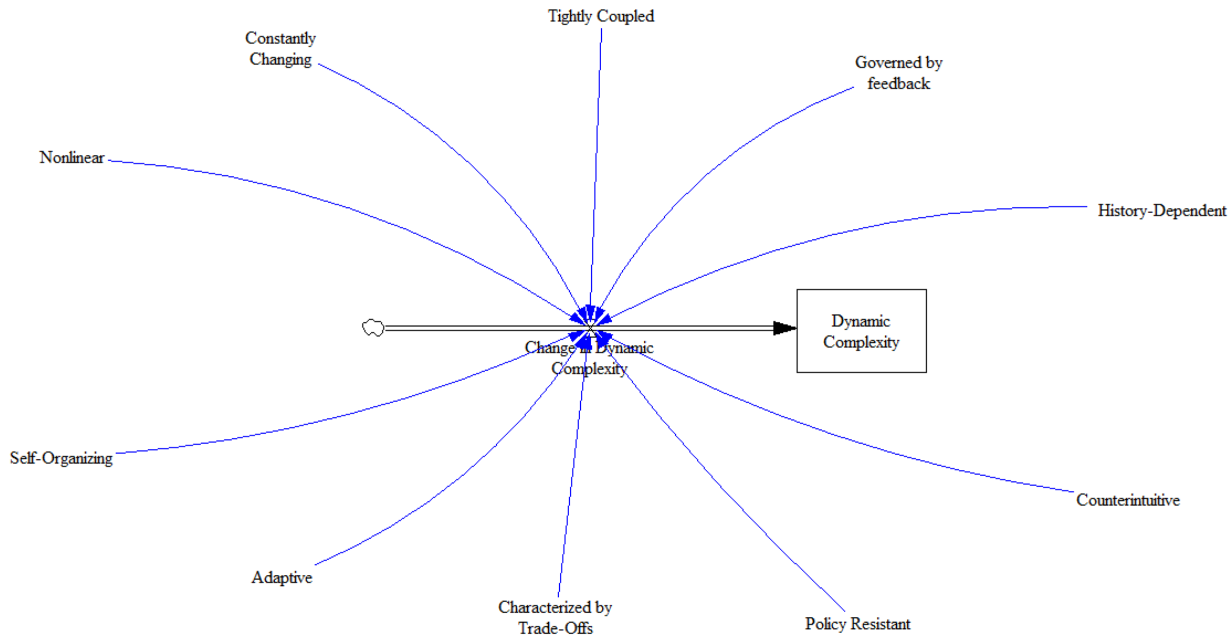

Fig 2. Factors influencing dynamic complexity. Adapted from Sterman, 2006.

Policy Resistance Appears Because Systems Are

• *Constantly changing*. Heraclitus said, "All is change." What seems to be invariable is, over a longer time horizon, seen to fluctuate. Change happens at many time scales, and these different scales sometimes interrelate. A star changes over billions of years as it burns its hydrogen fuel, but can blast as a supernova in seconds.

• *Tightly coupled*. The actors in a system interrelate intensely with one another and with the natural world. Everything is connected to everything else. "You cannot do just one thing." • Ruled by feedback. Because of the tight couplings among agents, our actions feedback on themselves. Our decisions modify the state of the world, initiating variations in nature and activating others to act, thus giving rise to a original situation, which then impacts our next decisions.

• *Nonlinear*. The effect is infrequently proportional to cause, and what occurs locally in a system (close to the current operating point) regularly does not apply in distant regions (other states of the system). Nonlinearity habitually starts from basic physics but also arises as multiple factors interact in decision making.

• *History-dependent*. Many events are irreversible: you cannot unscramble an egg (the second law of thermodynamics). Stocks and flows (accumulations) and longtime delays habitually mean doing and undoing have essentially diverse time constants.

• *Self-organizing*. The dynamics of systems occur naturally from their internal structure. Often, unimportant, casual agitations are augmented and shaped by the feedback structure, creating configurations in space and time. The bands on a zebra, the rhythmic contraction of heart, and the real estate market all occur spontaneously from the feedback loops among the actors and components of the system.

• *Adaptive and evolving*. The aptitudes and behaviors of the actors in complex systems change over time. Evolution leads to selection and propagation of some agents while others become inexistent. People adjust in response to knowledge, learning new ways to attain their goals in the face of difficulties. Learning is not always helpful, however, but irrational and narrow, exploiting local, short-term purposes at the expense of long-term accomplishment.

• *Characterized by trade-offs*. Time delays in feedback mean the long-run answer of a system to an intervention is distinctive from its short-run response. Low-leverage policies often create momentary development before the problem grows worse, whereas high-leverage policies often produce worse-before-better behavior.

• *Counterintuitive*. In complex systems, cause and effect are isolated in time and space, whereas we incline to look for causes near the events we seek to explain. Our consideration is drawn to the symptoms of trouble rather than the primary cause. High-leverage policies are often imperceptible.

• *Policy resistant*. The complexity of the systems overcomes our aptitude to comprehend them. The result: many apparently clear solutions to difficulties fail or deteriorate the situation.

3.6 Inadequate information and uncertainty

We face the real world via filters. No one identifies the present occurrence or pervasiveness of any disaster. As an alternative, surveillance systems convey approximations of these data on the basis of sampled, and delayed measurements. The act of measurement presents misrepresentations, delays, biases, inaccuracies, and other inadequacies, some known, others indefinite and incomprehensible. Especially, measurement is an act of selection. Our sensations and information systems choose but an insignificant portion of imaginable skill.

3.7 Bounded rationality and the misunderstandings of feedback

Individuals are not computers, imperturbably calculating opportunities and possibilities. Sentiments, reaction, oblivious inspirations, and other nonrational or illogical aspects all participate in a big part in our decisions and performance.

However, even when we find the time to consider, we cannot act in an entirely convincing way (that is, make the paramount decisions imaginable assumed the existing information).

As amazing as the human intellect is, the complexity of the real world reduces our intellectual abilities.

Herbert Simon expressed these restrictions in his well-known theory of "bounded rationality," for which he earned the Nobel Prize in economics in 1978:

The ability of the human mind for expressing and resolving complex problems is negligible compared with the dimension of the problem whose resolution is essential for empirically rational behavior in the tangible world or even for a realistic estimate to such impartial rationality.(Simon, 1957)

Confronted with the overwhelming complexity of the real world, time pressure, and imperfect mental abilities, we are pushed to fall back on repetition actions, routine, rules of thumb, and uncomplicated mental models.

While we occasionally struggle to make the best choices we can, bounded rationality signifies that we repeatedly fall short. Bounded rationality is mostly crucial in dynamic systems like extreme events and disasters.

Experimentations indicate that individuals do pretty inadequately in systems with even low levels of dynamic complexity.

Identifying the power of system structure to affect behavior does not discharge us of individual accountability for our actions. Contrarywise, it allows us to focus our attempts where they have uppermost influence— the design of systems in which ordinary people can attain unexpected results. (Repenning, 2001)

3.8 Inadequate investigation abilities

Learning successfully in a world of dynamic complexity necessitates the keen application of the systematic method. Regrettably, people are mediocre instinctive scientists. We do not create various clarifications or control for annihilating variables. Our discernments are sturdily shaped by the structure in which the information is given, even when the intention information is unaffected.

We suffer from brashness in our decisions (underrating uncertainty), ambitious thoughts (measuring preferred results as more likely than unwanted consequences), and corroboration predisposition (pursuing confirmation coherent with our presumptions). Scientists and professionals, not just “normal” people, suffer from many of these critical preconceptions (Plous, 1993) (Kahneman, 1982)

Some discuss that, while people stumble in considering the principles of logic, as a minimum they welcome the aptness of scientific elucidation.

Regrettably, the situation is considerably worse. The scientific worldview is a topical development in the human period and lingers erratic.

Many individuals place their conviction in what Dostoyevsky’s Grand Inquisitor named “miracle, mystery, and authority” (Dostoyevsky, 1950); for example, astrology, creationism, Elvis sightings, and cult leaders pledging Armageddon. The permanency of such fallacies is strappingly self-reinforcing.

Such irrationality aside, there are more disquieting purposes for the pervasiveness of these learning letdowns. Human beings are more than reasoning information processors. We have a profound necessity for emotional and spiritual nourishment. However, from Copernican heliocentrism through relativity, quantum mechanics and evolution, science has stripped away ancient beliefs, putting humankind at the epicenter of a world planned for us by the highest authority. For many people, science leads not to explanation and emancipation, but to existential anguish and the irrationality of human irrelevance in an unintelligibly huge universe. Others trust science and technology are the shock troops for the achievement of materialism over the blessed and divine. These antiscientific corollaries are formidable influences. In many ways, they are significant certainties. They have conducted to many of the most in-depth creations of art and literature. However, they can also lead to tedious new-age waffle and radical fundamentalism. Systems thinking compels us to scrutinize issues from numerous standpoints, to enlarge the limits of our mental models, to reflect the long-term outcomes of our actions, including their environmental, cultural, and ethical propositions (Sterman, 2002) (Meadows, 1982).

3.9 Disaster Reduction as adequate management of a dynamic system

Interaction and emergence are fundamental principles of complexity theory and emerged in the discussions of how society and population-environment regularly change.

This argument can be viewed as 'dynamic milieu', which variations in response to the reorganization, political and administrative pressure, emergent hazards, production of information, fluctuations in human desires and abilities, and the effect of intensified situation awareness. The features affecting the milieu of a society or population in all stages of a disaster have different directions, and they network with the culture and norms of a population. Dogmatic priorities affect financing organizations and down to the local level, while at the same time regular citizen initiatives apply rising pressure to influence dogmatic priorities. Disasters stress variances in social systems and encourage transformation in procedures to plan for the following disaster.

Developing risk-based information and skills, social systems, emergent opportunities for cooperation, growing connections, lessons learned from preceding tragedies, and altering mindsets with amplified awareness, all participate to the dynamic milieu of society and the complexity of the efforts that conduct to an adaptive response.

4. Toward a new model for an effective disaster reduction system: time and resources

Complex sociotechnical systems resources habitually show vulnerabilities or challenges as well. It illustrates non-linearity in complex systems and how interconnectivity emerges as resources, but also responsibilities at the time the system becomes disturbed.

The good side in each society was the extensive lists of existing resources, mostly the knowledge within the response organization. The adverse side, or challenge, was how to manage the coordination of resources. Connectivity and interaction are judged to be an asset and good news for disaster reduction, as it increases potentials for resource allocation, training, and access to risk-based information.

Though, the fundamental challenge with the more significant engagement of social organizations is that the improved awareness induces more stresses for readiness training, information, and support.

New technologies present benefits because they increase options for interoperability between social systems, but technologies also show vulnerability because of the dependencies that are generated (thigh coupling).

Many technologies, such as resource databases, transportation, surveillance, and electronic systems, and social media, help with disaster response but are dependent on power, hardware and equipment, and the abilities and preparedness and motivation of people to operate them.

When systems are disturbed, processes and resources such as communication protocols, emergency and surge capacity, access to information systems, risk analysis and management, and supply chains contingent on transportation structures, are all touched because they depend on interoperability between humans and technology.

Mapping of collective resources which identifies the opportunities and threats associated with diverse resources or aspects of the social context allows population and support personnel to be flexible and adjust to fluctuating conditions and difficulties.

There is frequently ambiguity about the roles and responsibilities of various actors, the desires of the population, and possible resolutions to minimize the damage and reestablish systemic purposes as quickly as imaginable. Individuals need risk-based information about what to do in an emergency and how to plan, while organizations require to know about resources and continuity preparation, and how to align organizational plans with those at the strategic level.

The disaster management necessitates becoming aware of the resources and needs of high-risk populations and how to integrate them into contingency planning activities (fig 3.).

The accessibility of innovative communication technologies has modernized many operations in disaster reduction management. However there is complexity surrounding the allocating of information, both vertically and horizontally, formally and informally. Peoples' abilities in exploiting new technologies also impact the interoperability of information systems. Though, it is indispensable not to offer the population with too much information that it becomes overwhelming and the communication unclear.

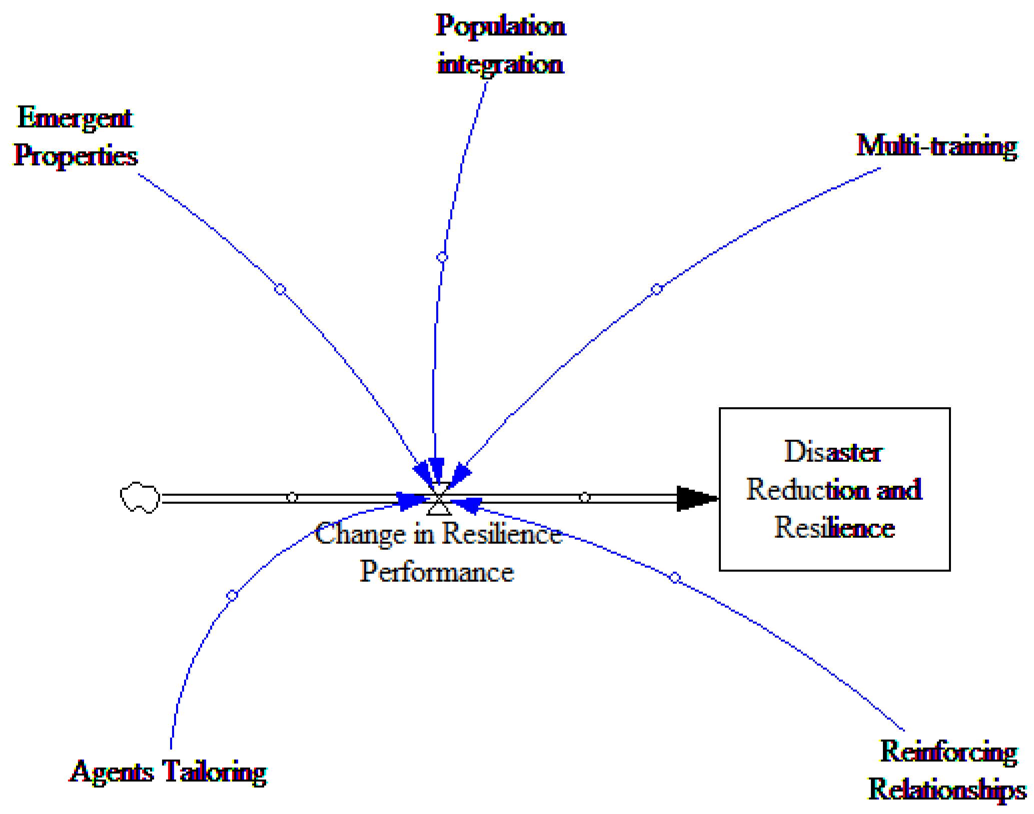

Fig 3. Factors influencing disaster reduction and resilience performance.

4.1 Interaction with the population for an effective disaster reduction

High-risk populations need to be involved in disaster reduction management actions, mainly offering leadership on specific practical needs and resources and how disaster managers can detect and act when delivering assistance.

Social system and population can propose new strategies for communicating with perceptive or emotional restrictions during evacuation operations, such as enquiring the individual how best to support them.

People and their aptitudes and networks are part of the social system. The motivation of populations is not always an easy mission.

Opportunities for interaction, partnership and sharing information require an investment of resources, time and money, which in turn necessitates advanced, reliable support and organization. Nonetheless, the push for action to identify expertise among the population, and to encourage them to be part of preparation and planning for the social response. Exhaustiveness is a central precursor for people to be willing to disclose their expertise and donate to their community.

4.2 Multi-Training to face changes

Social resilience entails diversification of skills and systemic redundancies to guarantee critical roles are supported. It stresses a paradigm shift where people are qualified to do tasks required for their profession as well as other occupations, in case a worker becomes incapacitated. This marks the principles of emergence and non-linearity in complexity theory.

The goal is to build redundancies within the social system and capitalize in human professional and personal development, so people can step in and offer an adaptive response when situation fluctuates or the people classically responsible for a specified task are incapable of responding.

4.3 Tailoring the actors

The emergence of networks within a social group is one aspect of the complexity.

The importance of promoting a general culture must compete with the inherent challenges of getting a vast list of disaster management activities.

This aspect is to promote a culture where the presence of people with different useful competences is appreciated, wanted and projected.

4.4 Reinforcing relationships.

Durable, reliable relationships were recognized as the basis on which partnership, communication, deployment of resources, and information of population requests are founded. The expansion of confidence happens as people identify other peoples' capabilities and purposes, and have to work together. 'Knowing' that you can trust someone for information or support participates to believe in relationships to ease original solutions and collective accomplishment.

An intrinsic complexity in teamwork is the prerequisite to spend time in maturing and raising contacts. Investing time and resources in encouraging relationships and creating trust is a key aspect for a sustainable and resilient system.

4.5 Emergent systemic properties and dimensions

Integrated complexity influences the category and accessibility of resources, the synchronization of resources, and the readiness of the population to cooperate, before, during and after a disaster.

All of these components interconnect to shape social ability at a given time, and within a given context, and eventually impact the situation awareness and adaptive response.

Because dynamic environment and milieu necessitate recurrent modification, a 'new normal' is incessantly outlined within a social system and shapes its resilience at any time. When a disaster impacts a social system, the alteration involves a tailored response update situation awareness and adjust to the changes.

Discussion

Complexity happens across different times and between and within different systemic resources, including individual complexity, structural complexity and intra and inter-complexity (between organizations and across jurisdictions). Prior studies have stressed the necessity to unpack complexity and recognize levers to improve community resilience (Chandra et al., 2011).

In this article, we investigated the complexity of disaster to determine how to enable collective action and encourage disaster reduction and resilience complex sociotechnical systems. The solution to handling complexity in disaster reduction management is to understand how systems interconnect and develop interaction to improve social ability and encourage collective actions, to encourage situation awareness and simplify adaptive responses to dynamic, complex disasters.

The goal is to support the purposes 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 highlight "engaged partnership; tiered response; scalable, flexible and adaptable operational capacity; unity of effort through unified command; and readiness to act". There is extensive works on the necessity for coordination and teamwork for a unified, comprehensive response to disasters, and national frameworks for disaster response with a need for multisectoral commitment and accomplishment.

Disaster reduction requires collaboration to ensure there is adequate capacity and resources, as well as practical and operative communication, particularly when infrastructure and operating systems are interrupted (Chandra et al., 2011; FEMA, 2008; Okros et al., 2011; WHO, 2009).

References

Argyris C, Schön D. (1978) Organizational Learning: A Theory of Action Approach. Reading, MA: Addison- Wesley

Chandra, S., Acosta, J., Stern, S., Uscher-Pines, L., Williams, M. V., Yeung, D., et al. (2011). Building community resilience to disasters. Santa Monica, CA: RAND Corporation, Accessed December 20, 2011. http://www.rand.org/pubs/ technical_reports/TR915.html.

Dörner D. (1996) The Logic of Failure. New York, NY: Metropolitan Books/Henry Holt.

Federal Emergency Management Agency. (2008). National Response Framework, Department of Homeland Security. Accessed December 20, 2011. http://www. fema.gov/pdf/emergency/nrf/nrf-core.pdf.

Forrester JW., (1961) Industrial Dynamics. Cambridge, MA: MIT Press;

Kahan, J., Allen, A., George, J., & Thompson, W. (2009). Concept development: An operational framework for resilience. VA: Homeland Security Studies and Analysis Institute, Accessed December 20, 2011. http://www.homelandsecurity.org/ hsireports/Resilience_Task_09-01.pdf.

Kahneman D, Slovic P, Tversky A. (1982) Judgment Under Uncertainty: Heuristics and Biases. Cambridge, UK: Cambridge University Press;

Dostoyevsky F. (1950) The Brothers Karamazov. Garnett C, trans. New York: Vintage Books;

Meadows DH, J. Richardson J, Bruckmann G. (1982) Groping in the Dark. Chichester, England: John Wiley & Sons;

National Center for HIV, STD, and TB Prevention. Tuskegee Timeline. 2005. Available at: http://www.cdc.gov/nchstp/od/tuskegee/time.htm.

Okros, A., Verdun, J., & Chouinard, P. (2011). The meta-organization: Research and conceptual landscape. Ottawa, Canada: Defence Research and Development Canada and the Centre for Security Sciences.

Perrow, C. (1984, 1999). Normal Accidents: Living with High-Risk Technologies. Princeton, NJ, Princeton University Press.

Plous S. (1993). The Psychology of Judgment and Decision Making. New York, NY: McGraw Hill;

Pringle JWS (1951). On the parallel between learning and evolution. Behavior 3(3):175–215

Rasmussen J, Lind M (1981). Coping with complexity (Risø-M-2293). Risø National Laboratory, Roskilde

Repenning NP, Sterman JD. (2001), Nobody ever gets credit for fixing problems that never happened: creating, and sustaining process improvement. Calif Manage Rev. 2001;43:64–88.

Simon HA. (1957). Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations, 2nd ed. New York, NY: Macmillan;

Shaughnessy D. (1987) Bogged Down. Boston Globe.

Sterman JD. (2002), All models are wrong: reflections on becoming a systems scientist. Syst Dyn Rev;18: 501–531.

Wiener N (1948). Cybernetics: or the control and communication in the animal and the machine. The MIT Press (1965)

World Health Organization. (2009). Whole-of-society pandemic readiness: WHO guidelines for pandemic preparedness and response in the non-health sector. Geneva: World Health Organization, Accessed December 20, 2011. http://www.who.int/influenza/preparedness/pandemic/2009/808_wos_pandemic_readiness_final.pdf