Creating Resilient Communities in the Face of Manmade and Natural Disasters

Making an impact with Collaboratory for Resiliency & Recovery at RIT

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In the ten years since Hurricane Katrina, we have become much more aware of the vulnerabilities in our communities. Events at home and across the globe have taught us that the creation of resilience -being robust yet flexible to a challenge- at the community level and at a global level, is a determined walk forward, not a dash toward a finish line.

After 9/11, the United States began to focus efforts toward the plethora of risks that abounded in our world, first by updating emergency communication systems and response capabilities. These were the right steps to improve our ability to respond and recover from a crisis or disaster, but a longer view requires that we go beyond post disaster recovery toward prevention. Much of that prevention strategy relies on the mitigation of risk and hazard through robust infrastructure.

The overall rating of our national infrastructure is D+ according to the American Society of Civil Engineers (ASCE)'s Report Card for American Infrastructure (**http://www.infrastructurereportcard.org/**). It is easy to see the risk created when we fail to maintain these systems. We have seen that infrastructure comes apart in many local instances, including Hurricane Agnes, in 1972, the 1991 Ice Storm, the more recent storms Irene and Lee, and even the weather events that have especially hit our region's southern and western reaches in the past year.

Certainly, robust infrastructure is the literal foundation of our community.

In 2010, a team of professors and researchers at RIT began working with public and private leaders of our community to evaluate the criticality of our infrastructural assets. Understanding these assets and their functional relationship to each other can guide investments to improve security, response and recovery in the event of a manmade or natural disaster. Not only did this effort result in a better understanding of our infrastructure and its vulnerabilities, it also became the model for other mid-sized urban areas to follow. Especially for smaller urban centers like the Rochester region, it can be difficult to determine what is actually 'critical' in a community; many times, we just do not understand how much we rely upon infrastructure until access to it and to the services it provides is interrupted.

Evaluating infrastructure criticality requires applied systems thinking that employs expertise across multiple disciplines, and in fact, the RIT research group initially brought together expertise in risk management and hazards, cyber systems, data mining, and the life-line infrastructures of transportation engineering, water, power, telecommunications, etc. If there is anything we've learned post-9/11 and Katrina, it is that it takes a cooperation to develop and implement crucial preventive measures and recovery efforts.

This research group has since evolved into the Collaboratory for Resiliency & Recovery (CRR) at RIT (**http://www.rit.edu/cast/crr/**). CRR's mission is straightforward—to increase the community's ability to prepare for, respond to, and recover from a crisis. As our work has progressed, we have become aware of the ever-growing interrelationships among our infrastructures, and how risk straddles the physical, operational and social divide.

We have witnessed growing vulnerability that is created by the cyber physical interactions that govern infrastructural systems. We even added a sociologist to our team when it became clear that decreasing much of our vulnerability, and increasing our resilience, will rely upon the thoughts and actions of our citizens, both daily and in the midst of crisis.

RIT believed critical thinking to be so important that it established the Eugene H. Fram Chair in Applied Critical Thinking (ACT), leading a university-wide initiative to build that competency through curricula, scholarship and the student experience. Disasters certainly highlight the need for critical thinking, but the RIT effort goes beyond thinking in crisis. Critical thinking is accomplished by analysis of information to assess veracity and relationships; use of hypothesis and experimental results; application of multidisciplinary methods to support evaluation and possible creation of new ideas, products or views. Critical thinking also seeks to resolve weaknesses in thinking such as insufficient inquiry, ambiguity, unexamined assumptions, biases, and subjectivity. At RIT, ACT is an active form of engagement, drawing from our diverse domains and deep expertise to address the questions and challenges that we face.

Application of critical thinking is necessary in our efforts to build a thriving, resilient community. It requires more than building of robust infrastructure. Risk engineering is guided by the 'maximum probable event' and relies on our ability to predict that event. This method has served us well. However, as the uncertainties and the magnitude of impacts increase in our complex world, we must now consider a wider range of possible outcomes. To do this well, we need to employ thinking that draws from multiple, diverse domains to more fully inform our evaluation and resultant strategies.

The CRR's work continues in several related fronts:

Critical Infrastructure & Key Resources (CI/KR):

These are the literal backbone of any community. The Department of Homeland Security defines 16 sectors, from the life-line infrastructures mentioned above to critical manufacturing, dams, financial services, etc. as described in the updated Presidential Policy Directive, PPD-21. (**https://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil**)

It is important to understand that infrastructure is critical due to the services that it provides, and not simply because it exists. Any analysis of infrastructure services must examine the processes and outputs in the sector and their interconnectedness to each other. Each linkage, or inbound, outbound or internal connection, then represents a risk or resultant vulnerability of the system.

The process of examining this risk can be thought of as pulling a string on a sweater, and watching it unravel. In our local analysis, we found over 300 CI/KR assets that have community level impacts. Risk and vulnerability are measured relatively simply, the greater the potential impact, the more critical. As you can imagine, however, criticality is also an extremely local experience—failure of that small culvert crossing at the end of a rural road would not be highly rated to the region. But to the local residents, that washout is certainly a crisis.

The next step in such an analysis is to then surmise the opportunity for wide-scale failures, or multimodal 'super-storms' of one form or another. In most regions, including our own, failures arise from water weather events of ice, snow or flood, while externally borne events are typically technology based, cyber physical in nature and propagate across multiple regions.

The transportation sector is an important example in this regard, both as a literal 'bridge' along a path and a necessary component of a coherent response. Preservation of physical systems such as roads, bridges, and systems, supports evacuation and restoration through improved logistics to deliver key resources such as medical capacity and food. Transportation systems are also a physical reminder of the options we consider as we seek the best path for resources as we rebuild. RIT's Laboratory for Environmental Computing and Decision Making (**LECDM: http://www.rit.edu/gccis/lecdm/**) provided helpful capacity as we built our analyses for transportation systems.

Education:

As a multidisciplinary laboratory at a university, our work must support the core mission of education. We have implemented curricula across the university, including many courses like ***Disaster Science,*** to advance student critical thinking across a transdisciplinary problem. Over the past three years, we have created and validated infrastructure protection educational modules for use by high school, community college and university level instructors (**http://nsf_cip.csec.rit.edu/**). This effort, funded by the National Science Foundation (NSF), DUE-1303269, teaches that our students and future professionals must understand their role in mitigating the risks in the systems they create and live with. Technology is now part of almost every interaction and process within our community, and we must be mindful of our relationship to those processes.

Informational Support and Decision-making:

If there is good news in this discussion, it is that the rise of technology also gives us data that can be used to improve our response and resilience. For a generation or more, we have added technology to legacy systems, and could not take full advantage of our increasing capabilities. The design of a new generation infrastructure allows us to build forward, and allows us to gather data on performance that can be used for more informed decisions.

Here again, there are bimodal forms of risk and vulnerability. The first is chronic and slow moving, and is exemplified by the gradual decline of our transportation infrastructure. As with most chronic risk, the pace of oncoming failure is slow until a certain point is reached, and then the actual disruption occurs very quickly. In contrast, the other type of vulnerability arises from a pinpoint and is an acute risk. A specific catastrophic event propagates disruption rapidly across a system. In both cases, there is an opportunity to take advantage of data and information to mitigate these failures.

We now live in a data-rich world, however, taking advantage of that data to turn it into information we can use to mitigate and respond to risk is challenging. Effective and responsible decision-making depends upon our ability to identify and tease out the appropriate data, assess the veracity of the data we then use, and consider the context that underlies the problem we are wrestling with.

In each step of the process, we must evaluate the uncertainty and the potential impacts of the decision. This all comes down to time, in the best of all worlds we will have the luxury of sufficient time to fully consider, however, particularly in the case of the acute risk or the unseen chronic risk, it may not be noticed until the after crisis has occurred.

At RIT, we have built systems to inform current decision-making, including leveraging of historical operational data across infrastructures and generation of semi real time data both in the CRR and in collaboration with the NSF-funded Information Products Laboratory for Emergency Response (IPLER: **http://ipler.cis.rit.edu/**), part of the Center for Imaging Science at RIT. Our work shows that a typical crisis or emergency requires seven levels of informational 'fusion', and that each level requires multiple data inputs (1).

Combining historical, experiential data with crisis-generated data is powerful. It supplements field experience, supports consideration of options, and allows for improvisation and creativity, to resolve the crisis.

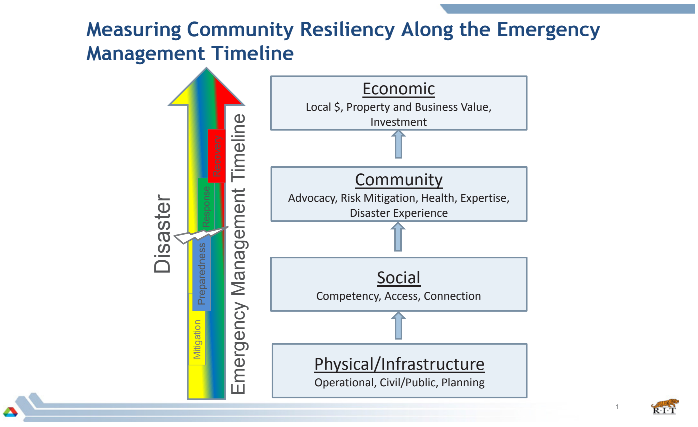
Once we have developed the information, it can be difficult to share it across the actors in a crisis, and in a new funded effort, (NSF: EAGER 1450854), we are building methodologies, developing and evaluating network architectures to support sharing of information during a response cycle. Within any crisis, an operations center has different information than the field and each responder has unique informational needs. This effort seeks to streamline the technology that supports the movement of information from one platform to another.

Metrics of Performance and Creating Resilience:

There is a difference between operational actions to mitigate crisis and measures of overall resilience. Resilience is the ability to "anticipate, … absorb, respond, adapt to and recover from a disturbance" (2). Resilience is grounded in being robust and flexible, to be able to withstand the changes and perturbations in our world.

There are at least 20 proposed models that seek to elucidate community resilience, and just as many efforts underway to increase resilience across our world. The most notable are the Hyogo Framework for action, created by the United Nations as a result of the 2004 tsunami in Southeast Asia, and the updated Disaster Resilience scorecard, published in spring 2015 by the UN as a companion to the International Strategy for Disaster Reduction.

RIT's CRR and our research partners at the Center for Resiliency Analysis at Argonne National Labs have provided input into the scorecard. Each effort is a step in the right direction, however, much remains to be done to create resilience.



As you can see in the graphic, infrastructure is the foundation for community resilience at the local level (2). In fact, the Rockefeller Foundation is in their third year of the "100 Resilient Cities Challenge" (**http://www.100resilientcities.org/#/-_/**). This is an interesting 100-city effort to create resilience, in critical infrastructure, systems and then whole communities, through Foundation seed funding and shared learning.

Final thoughts:

Similar to sustainability, our long term success in resilience will depend on our ability to embed resilience thinking into the fabric of society. Further, efforts in sustainability, in support of the environment and ecosystem function, enhance and inform our engineering solutions to improve resiliency of the built environment. Essentially, we can learn from and work with nature, rather than trying to outcompete it.

Our thinking, designs and adaptions must continue to reflect the new reality both our natural and built systems face. It will take international resolve coupled with local implementation to make progress. On a daily basis, and post crisis, we expect our communities to function and support our way of life. As our world becomes more complex, uncertain and crisis diverse, we must seek ways to leverage our limited resources to build infrastructure that supports a stronger, safer and more resilient community.

References:

(1) Schneider, J., C. Romanowski & K. Stein, "Decision making to support local emergency preparation, response, and recovery," IEEE Conference for Technologies for Homeland Security IEEE (HST 2013), Boston (November 2013).

(2) Martinez-Moyano, I., Hummel, J. & J. Schneider, "Community Resilience & the Role Played By Critical Infrastructure" *Disaster Resilience Conference*, Denver (August 2014).

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