NIST GCR 15-917-37

International Resilience Symposium

Understanding Standards for Communities and Built Infrastructure Resilience

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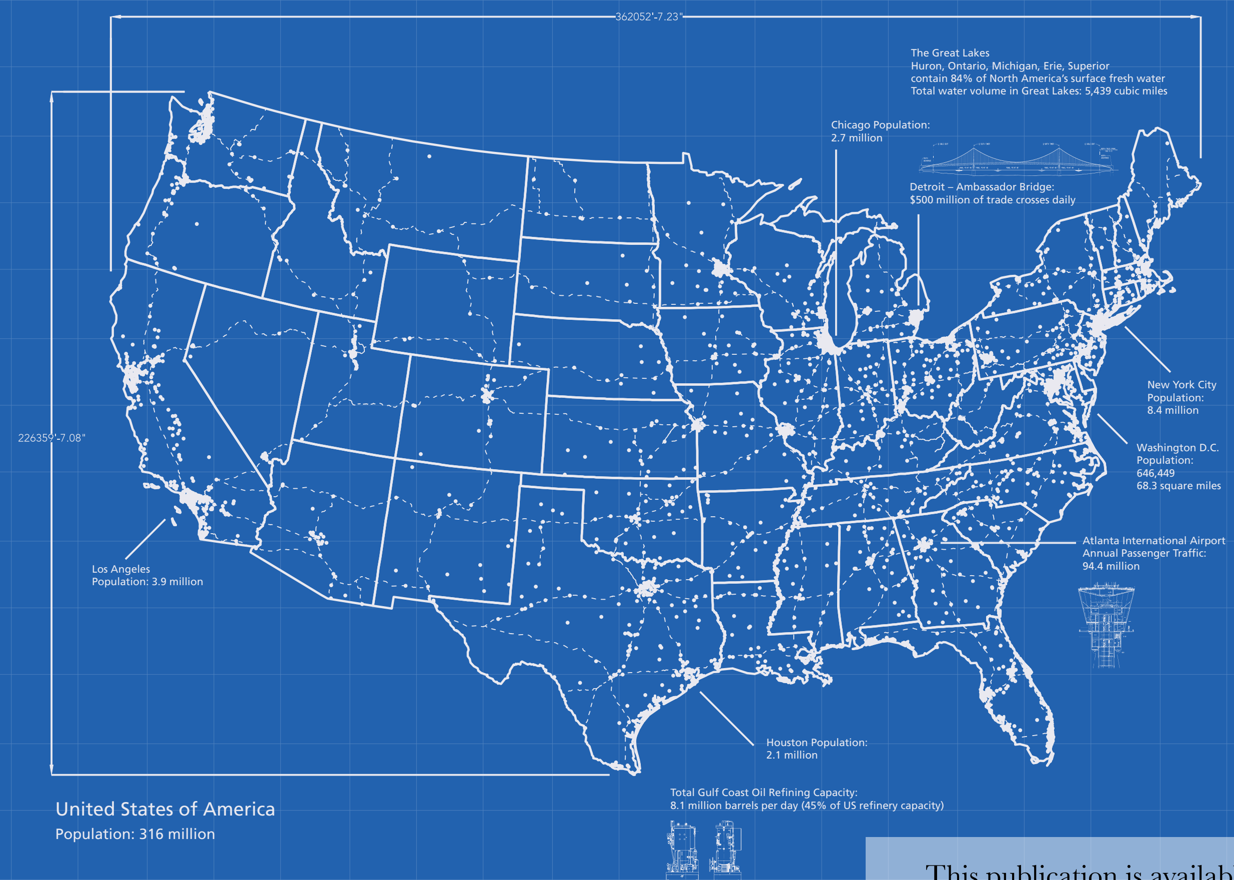

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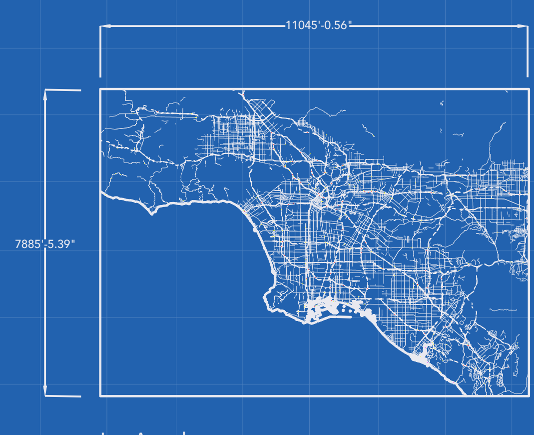

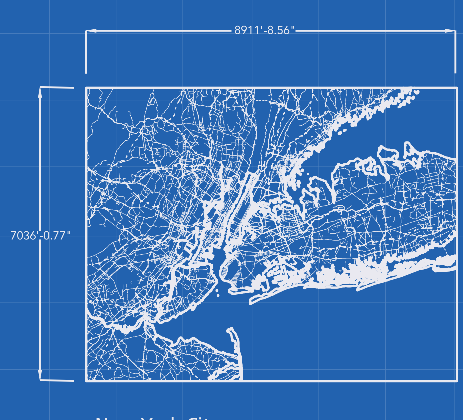

United States of America

Legend:
- State Borders
- Major Highways
- Minor Roadways
- Major Cities

Total length of Interstate Highway System: 46,876 miles

Length of Mississippi River: 2,340 miles

U.S. Disasters

Average Annual Landfalling hurricanes (Atlantic Basin): 1.7

Average earthquakes >5.0 magnitude per year (2000-2010): 65.5

Average brush, grass and forest fires per year: 334,200

Average annual tornadoes: 1,200

Northeastern University
Center for Resilience Studies

KOSTAS
George J. Kostas Research Institute for Homeland Security at Northeastern University, LLC

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

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Prepared for
U.S. Department of Commerce
Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-8615

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June 2015

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1.0 Executive Summary

Under President Obama's Climate Action Plan, the National Institute of Standards and Technology (NIST) is developing a comprehensive, community-based disaster resilience framework. The disaster resilience framework is focused on buildings and lifeline infrastructures such as communications, water, and power supply. Resilience is inherently complex and involves interdependent capabilities within and across local, regional, national, and even international jurisdictions. Accordingly, the NIST framework includes such factors as societal needs, performance goals for buildings and infrastructure lifelines, emergency communication systems and plans, and economic factors. The framework aspires to inform and enhance the ability for communities and critical systems to better manage disruptions associated with human-made and naturally-occurring disasters.

To assist the development of this framework, NIST has held a series of public workshops to hear from community leaders, private sector representatives, non-governmental representatives, owners and operators of infrastructure systems, and other community stakeholders. Input from these public workshops has helped to shape the content and approach of the framework. In addition to the public workshops, NIST commissioned Northeastern University's Center for Resilience Studies at the George J. Kostas Research Institute for Homeland Security to convene an international symposium to draw on new research and global best practices that can inform the development of community and infrastructure resilience standards. Given the objective of having new resilience standards widely adopted, the international symposium was also asked to explore policy and financial incentives that would encourage communities to embrace them. These two topics – devising resilience standards and incentives – served as the organizing constructs around which the symposium participants, format, and discussions were designed.

115 leaders from fourteen countries, representing private industry, academia, finance, insurance, policy, non-profits and government attended and actively participated in the two-day session.

Four plenary panel sessions were organized to frame the important issues involved with establishing and implementing resilience standards and serve as the basis for discussions at breakout workgroup events.

The first plenary session highlighted important lessons from Superstorm Sandy to include unanticipated cascading failures arising from storm damage to multiple interdependent infrastructure systems. Superstorm Sandy demonstrated the important stakes involved with advancing infrastructure and community resilience. The lessons drew from four previous symposia dedicated to uncovering national-level findings and recommendations from Sandy that was conducted by Northeastern University and other university partners with funding support from the Alfred P. Sloan Foundation.

Plenary 2 looked at the general trends in community resilience and the current societal barriers for creating new resilience standards. Plenary 3 focused on the nation's built infrastructure and the role that metrics and standards could play in increasing resilience. Plenary 4 examined the critical aspect of devising incentives for local and state governments and the private business sector to invest in measures that will bolster community and infrastructure resilience.

With the plenary discussions as reflective and thought-provoking backdrops, breakout sessions were designed to engage participants in distilling the most important issues that should be considered by NIST in developing resilience standards and in supporting incentives that would stimulate their adoption and use by local communities.

Over two days of very intense and wide ranging discussions, this diverse group of global resilience thought leaders coalesced around four themes with implications for the NIST resilience framework:

- Resilience building efforts need to focus on devising performance-based standards that better assure the continuity of functions that are critical to the safety and well-being of communities.
- Performance-based community standards should acknowledge the regional and multi-jurisdictional context within which lifeline infrastructures operate.
- Standards for built infrastructure need to go beyond addressing the relevant technical and engineering issues to include the wider social context within which decisions about the built environment are made.
- There are currently insufficient incentives to stimulate the creation and adoption of standards; in fact, there are significant barriers that must be overcome.

These four consensus themes can be highly useful to NIST in informing the successful development of the final community-based resilience framework.

2.0 The NIST Disaster Resilience Framework

According to NIST[1], the purpose of the Disaster Resilience Framework is to:

- Define community-based disaster resilience for the built environment;
- Identify consistent performance goals and metrics for buildings and infrastructure and lifeline systems to enhance community resilience;
- Identify existing standards, codes, guidelines, and tools that can be implemented to enhance resilience; and
- Identify gaps in current standards, codes, and tools that if successfully addressed, can lead to enhanced resilience.

At present, NIST's framework begins with a discussion of "community" (based on Bronfenbrenner's Ecological Systems Theory), which acknowledges how critical it is that a community and its systems possess the ability to respond to its functional and social needs following a disaster.[2] These functions and social needs can be categorized, at least initially, in three groups:

- Human or Social/Cultural services
  - Healthcare (physical and mental health)
  - Education
  - Local governance
  - Social services (e.g., welfare)
  - Public safety and security, including emergency management
  - Arts and recreation
  - Spiritual
- Economic or Business/Industry services
  - Financial
  - Businesses
  - Industry (including agriculture and manufacturing)
  - Trade
- Physical/Environmental Services
  - Transportation
  - Natural Environment
  - Water/wastewater
  - Energy
  - Communications
  - Housing
  - Air Quality

1 The NIST Disaster Resilience Framework Document can be found at http://www.nist.gov/el/building_materials/resilience/framework.cfm

2 NIST Disaster Resilience Framework Chapter 2: http://www.nist.gov/el/building_materials/resilience/upload/Disaster_Resilience_Chapter_2-Community_50-Draft_102014.pdf

The framework also posits that when these three groups of services are able to meet the needs of individuals, households, and groups within a given community, the needs of the community as a whole are satisfied. Building off of Abraham Maslow's seminal work, NIST's framework suggests that these needs are hierarchical, moving from survival, safety and security, to belonging and then growth and achievement. When a disaster disrupts a community, the priorities for restoration and recovery of functions typically follow this hierarchy (Figure 1).

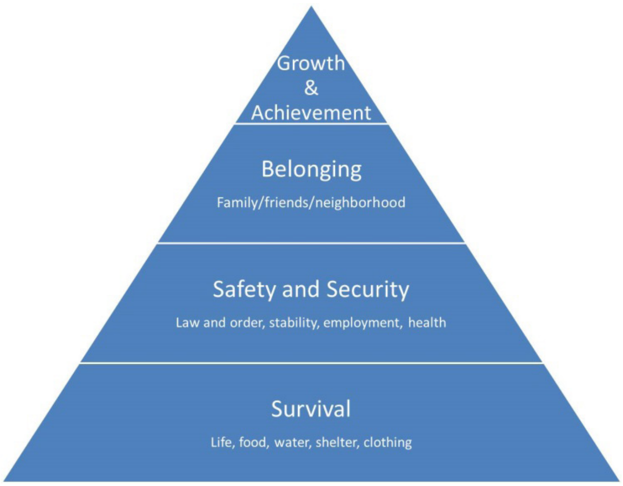

Figure 1. NIST's Hierarchy of Community Needs

NIST proposes performance goals for community functions that fall under three hazard levels (routine, expected, and extreme events). This approach recognizes: 1) there are a range of functions that must be available to meet communities' needs, 2) those needs can be arranged in a hierarchical order, and 3) the recovery process involves distinct time intervals (Response: 0-3 days; Workforce/Neighborhood Recovery: 1 to 12 weeks; Community Recovery: 4 to 36+ months). These performance goals define the "desired performance of a particular social system within a community and the requirements of that system within a particular time frame during the recovery process."[3]

Because so many of the fundamental needs of the hierarchy are met by physical/environmental functions, the majority of the NIST framework is devoted to performance goals for the built environment. These goals "become the metrics for resilience, and are used to compare to the existing conditions to define gaps that represent opportunities for improvement."[4] Specifically, the framework addresses the development of performance goals for Buildings, Transportation, Energy, Communication and Information, Water and Wastewater systems with additional attention devoted to infrastructure interdependencies and cascading effects, as well as economic considerations that impact these performance goals. The goal of this framework is to provide standards and metrics which, if adopted, will help communities to consistently meet their functional needs before, during and after disaster disruptions.

The development of this framework has been informed by a series of public workshops that have allowed NIST to hear from community leaders, private sector representatives, non-governmental representatives, owners and operators of infrastructure systems, and other community stakeholders. NIST decided to supplement these U.S.-based workshops with an international symposium and commissioned Northeastern University's Kostas Research Institute for Homeland Security and the Center for Resilience Studies, along with their partner, Meridian Institute, to organize, convene and lead a two-day event that included researchers and policy makers from fourteen countries. The Kostas Institute and Center for Resilience Studies (CRS) are leaders in resilience theory and application and in the built environment.The Meridian Institute, through its Community and Regional Resilience Institute (CARRI) and other work has been an active leader in informing and advancing community and infrastructure resilience for the better part of a decade.

Identifying policy and financial incentives that will help encourage early and widespread community adoption of resilience standards was another key imperative that animated the convening of this international symposium.

3.0 Process Background and Design

As the event sponsor, NIST's overarching objective for the international symposium was to have successful practices and standards from other countries inform U.S. domestic efforts to advance community resilience. To this end, the panels and workshops were designed to provide NIST staff with knowledgeable viewpoints from global experts on key questions relating to the creation and use of resilience standards. The participants were drawn from a variety of domains and viewpoints – researchers, community practitioners, government, policy and private sector. In addition, sponsors and organizers desired that the Symposium be constructed to stimulate active participant engagement – as opposed to more typical symposia relying on long presentations and delivery of formal papers.

Additionally, NIST saw the value of leveraging the 18-month effort to examine the aftermath of Superstorm Sandy for lessons learned that was led by the Kostas/CRS/Meridian team. This case study helped to "ground" the Symposium discussions by highlighting the significant societal stakes associated with meeting the resilience imperative. Indeed, insights from the largely unanticipated cascading failures of lifeline infrastructure sectors and the post-Sandy recovery provide a compelling national "teachable moment." The need for new practices, collaborations, policies and investments that advance the development and adoption of resilience standards could not be more timely.

Armed with this mandate, the organizers focused their energies on meeting the four requirements of a successful symposium: 1) designing well-calibrated sessions for investigating the selected topics; 2) enlisting moderators and facilitators who are able to successfully stimulate thoughtful conversations among participants; 3) actively recruiting a highly selective group of participants who can provide the diversity, knowledge, and experience necessary to effectively address the topics; and 4) conducting significant pre-event outreach and engagement with panelists, discussants, and participants so that everyone arrives prepared to make meaningful contributions towards meeting the program's objectives.

The Kostas/CRS/Meridian team devised four questions around which the Symposium was organized:

1. What are the practical, measurable standards for community resilience?
2. What are the practical, measurable standards for infrastructure and buildings resilience?
3. What processes should be created to adopt and implement standards for community, infrastructure and buildings resilience?
4. What political, economic, and social incentives can be created that would cause significant investment by the public sector, private sector, and the individuals in bolstering community, infrastructure, and buildings resilience?

With these framing questions in mind, organizers determined that a two-day format would provide optimal time for information sharing and discussion. Day One focused on the introduction of the Superstorm Sandy case study and issues surrounding developing community and infrastructure standards. Day Two focused on policy and financial incentives for widespread adoption of standards and integrating international perspectives. The symposium benefitted from having the NIST conference facility serve as the venue. This outstanding facility

3 NIST Disaster Resilience Framework Chapter 2: http://www.nist.gov/el/building_materials/resilience/upload/Disaster_Resilience_Chapter_2-Community_50-Draft_102014.pdf

4 NIST Disaster Resilience Framework Chapter 3: http://www.nist.gov/el/building_materials/resilience/upload/Disaster_Resilience_Chapter_3_Community_50-Draft_102014.pdf

reduced the "transaction time" that goes with moving participants between sessions, dining, breaks, etc. It also provided an excellent environment for maximizing the opportunity for participants to engage in both the formal session discussions as well as more informal networking and information sharing during breaks.

Process Design

The Kostas/CRS/Meridian team devised a process for inquiry and discussion that drew on the knowledge and insights of all the attendees. The Symposium's topically divided structure used plenary panels over the two days to frame key issues regarding community and infrastructure resilience standards and then convened work group sessions to allow participants to engage more deeply on key questions of the resilience standards.

Four panels of leading experts were used to "tee up" key issues for the three framing elements: Superstorm Sandy as a salient event to ground discussions of standards and incentives; issues related to developing standards for community and infrastructure resilience; and issues related to devising incentives for the adoption and implementation of resilience standards. Panels were moderated by Dr. Stephen Flynn and Mr. Warren Edwards who led panelists in conversational dialogues regarding key issues. With the exception of the opening session to present the Superstorm Sandy case study, there were no formal presentations or papers. Instead, panels, moderators and participants engaged in a structured conversation that highlighted elements to be focused on in working sessions.

The use of small working group "breakout" sessions provided a way to draw on the expertise of all the participants in generating ideas and recommendations. As with the panel discussions, working sessions did not use formal presentations. Rather, each group was led by a facilitator and assisted by two to three lead discussants who were pre-selected from the participants assigned to that work group. Each day had four working groups:

- Day One
  - Infrastructure Resilience Standards A
  - Community Resilience Standards B
  - Establishing and Adapting Resilience Standards C
  - Infrastructure Resilience Standards D
- Day Two
  - International Perspectives on Resilience Standards and Incentives A
  - Policy Incentives to Support Resilience Standards B
  - Economic Incentives to Support Resilience Standards C
  - International Perspectives on Resilience Standards and Incentives D

The team developed specific discussion questions that each work group would address, ensuring robust discussion of the critical issues. Reporting back to the assembled plenary, work groups were asked to identify two to four key discussion points from their deliberations and three to five action steps the group would recommend for consideration by NIST. Appendix A provides the overall annotated Symposium Agenda; Appendix B presents the key discussion elements for each of the eight work groups.

Participant Selection

With this format and process design, the Kostas/CRS/Meridian team assembled an impressive participant roster that drew from a range of community domains and viewpoints, anchored in the U.S. community resilience experience. More than 100 leaders from U.S. private industry, academia, finance, insurance, non-profits, policy and government were selected for invitation to the Symposium; approximately 90 were able to attend and participate in the two-day session. While the outcomes of the discussions were geared towards informing the development of U.S. resilience standards, organizers also gathered notable resilience theorists, researchers and practitioners from around the world, with approximately 25 international representatives participating in Symposium discussions, bringing the total participation to 115.

The backgrounds and experiences of the potential invitees were carefully reviewed and outstanding participants were identified who could serve as panelists and help to set the tone of the overall Symposium and surface insightful themes. Others were specifically identified to serve as lead discussants in the work groups, ensuring that vibrant and thoughtful conversations were sparked in the smaller sessions. Several additional participants with special experiences or knowledge were asked to provide written input following the meetings. These white papers were to build off meeting discussions, incorporating their personal knowledge of community and infrastructure resilience – thus, providing a more organized and documented response to the questions of the Symposium. Appendix C provides copies of these white papers. Altogether, approximately 60 of the attendees engaged in discussions and input as a panelist, discussant, or writer – an exceptional mix of active engagement that contributed to robust discussion and thoughtful recommendations throughout the process.

Participant Preparation

The organizing team worked with each of the participants in advance of the Symposium to ensure that all arrived having thought ahead about the topics and issues. This preparation included extensive pre-Symposium communications, the development of a package of read-ahead materials, and interviews with selected participants to help develop common understanding of Symposium goals and outcomes and to identify key knowledge or learning that would helpfully inform the event's proceedings.

The organizing team developed a website for registration and Symposium information and provided annotated agendas which helped describe the focus of Symposium discussions, desired outcomes, and key issues. The Kostas/CRS staff prepared extensive and thought-provoking read-ahead materials that helped to highlight key issues and provided a common knowledge base for all participants. Importantly, the read-ahead package included the current draft of the NIST framework so that all the participants arrived having a solid sense of how the Symposium discussions would best support NIST's overall mandate.

Finally, and most importantly, one-on-one pre-interviews were arranged by the Kostas/CRS/Meridian team with all the participants who were selected to be either panelists or discussants. For the panelists, these interviews involved a minimum of 30-minute discussions to assist the moderators in understanding the details of the panelists' experiences and knowledge base, supported the moderators in constructing questions that would effectively highlight key issues, and allowed panelists to provide their unique perspectives on many of the thorny issues surrounding devising resilience standards and the need for generating meaningful incentives. For those discussants and participants who were asked to produce white papers, these interviews focused on helping them to understand in advance the process design, their roles as discussants, and the specific elements on which they would be asked to provide their written reflections. This approach ensured that all those who were formally asked to address the Symposium had time to think about important examples, details, practices, or policies that would be helpful in creating resilience standards or incentives. Together, these pre-Symposium interviews prepared participants to arrive ready to engage, set a conversational tone that could be built upon in the formal Symposium sessions, and gave the participants time to develop more meaningful input. Further, the insights and examples gained from these interviews provided yet another source of input to inform the final Symposium outcomes.

4.0 Plenary Discussions

Each plenary panel session was designed to frame the important issues involved with establishing and implementing resilience standards. The Symposium opened with a panel of leading researchers who had studied the aftermath of Superstorm Sandy to identify lessons that could usefully inform the advancement of critical infrastructure resilience. The specific findings and observations that this panel presented provided tangible examples of where standards might have helped mitigate storm-related disruptions and post-storm delays in recovery. The panel also provided the participants with a compelling recent example of a major disaster around which ideas for potential standards might be realistically reflected. The second panel discussed current trends in community resilience, with experts helping to both provide context and to surface issues that should be considered in the working group sessions in devising recommendations for NIST on the development of community resilience standards. The third panel played a similar role in framing issues and approaches to creating resilience standards for the built environment. The final panel explored questions regarding the need for and the mechanics of creating incentives to stimulate early and widespread adoption and use of resilience standards. What follows are the highlights of the panel conversations and commentary.

Plenary 1: Superstorm Sandy Case Study

Background

The first plenary session of the Symposium presented Superstorm Sandy as a case study that could usefully inform a discussion of many of the challenges of building infrastructure resilience. While the subsequent Symposium plenary and working group session went well beyond this one example, this examination of a specific, recent disaster helped to ground the Symposium participants in the complex political, economic and social environments that surround any large-scale catastrophic event. Specifically, the plenary session provided an overview of the post-Sandy resilience lessons learned generated by four major workshops led by Northeastern University and convened at Columbia, NYU, Stevens Institute of Technology, and the Wharton School with funding from the Alfred P. Sloan Foundation. Stephen Flynn, Director of the Center for Resilience Studies, and principal investigator for this project, provided an overview of this significant disaster and moderated the session. The four co-organizers of the Sloan workshops discussed the major findings and recommendations from each of the workshops.

Overview of the Superstorm Sandy Case Study

Superstorm Sandy was important both because of the scale of the event and because it struck one of the most complex and concentrated metropolitan regions in the United States. Sandy brought the resilience challenge into stark relief, to include generating the need to create more resilient infrastructure as a part of the recovery effort. It also reinforced our understanding of many of the current barriers for investing in building more resilient infrastructures and communities. These barrieres include:

- There is a pervasive lack of recognition about the current inability to adequately handle foreseeable risks and uncertainties. Current capabilities for coping with disasters are grossly overestimated and there is a bias that discounts leading indicators of future disruptive events. Additionally, stationarity assumptions that were embraced in 20th Century designs are obsolete. Often, elected officials view publicly acknowledging risks to be a political liability if they believe they lack sufficient resources to adequately respond to those risks.
- Too few incentives exist to create resilience. There are few rewards for investment and in too many cases there are actually penalties. Society values routine efficiency and optimization over investments in continuity of function in the face of anticipated and unexpected disruptions. Transferring risk and not working collaboratively to take risk on directly has become common practice. It is not clear how to measure resilience so rewarding efforts to enhance it is inherently difficult.
- Consensus on how to measure resilience does not exist. There are a lot of isolated stories in disparate domains but not yet an overall set of best practices for resilience. Various academic disciplines provide insight but an integrative framework is still lacking.
- There are organizational or governance barriers to creating resilience. Among them are the facts that lifeline infrastructures (e.g., transportation, energy, communications and water) are almost always regional; infrastructure sectors are inherently interdependent; and regional infrastructure sectors are vulnerable to multiple hazards. Yet in the face of these facts, society remains organized around state and local jurisdictions, individual infrastructure sectors, and too often, myopically focused only on the most recent hazard that the community experienced.

Superstorm Sandy was a knowable event. The mindset that envisions random, rare and unknowable events can sometimes obscure the fact that these events are often not so rare. Hurricanes have approached and hit the eastern seaboard many times before and will again. The fact that they usually hit around the Outer Banks area of North Carolina and southward does not negate the knowledge that they have also moved much further north and periodically struck New York and New Jersey. There are tools to understand the likely consequences of these events on the built environment. It is possible to anticipate how water that is pushed by wind and tide is likely to flood specific locations. In complacency, however, Superstorm Sandy was largely imagined to be a relatively minor wind event and not the major water event it became.

An example of one company who largely got it right was Goldman Sachs, which stacked 25,000 sandbags around their corporate headquarters in Manhattan, located just a block away from the Hudson River. This significant effort paid real dividends when after the floodwater receded, their building was one of the few in lower Manhattan not to incur major water damage. However, because the surrounding transportation and energy infrastructures were not adequately protected, Goldman Sachs found that most of their employees were unable to come to work. Many of their employees' homes were damaged, roads were closed, transportation systems were inoperative and without reliable electricity and communications, telecommuting was not possible. Their foresight and investment in safeguarding their headquarters was rendered partially ineffective because of the failure of regional, interdependent systems that were outside their direct control.

Figure 2. Goldman Sachs' Manhattan office prepares for Superstorm Sandy's storm surge with sandbags piled high. Source: Victor J. Blue, Bloomberg

Other examples abound. Verizon headquarters did not invest adequately in flood protection and suffered serious water damage. This was compounded by the failure of a drowned air compressor that was mistakenly located in the basement cable vault. The air compressor existed solely to keep the conduit that surrounded their copper telecommunications lines under pressure so that water would not seep into the cable should they be exposed to flood water. However, because the compressor was co-located with the cables, it failed once floodwaters entered the basement. The result was multi-million dollars in damages that could have been avoided if the air compressor had been placed on a higher floor.

The transit systems in the metro-New York/New Jersey region were particularly vulnerable to storm surge but reacted in very different ways. The New York Metropolitan Transportation Authority (MTA) took both physical and operational actions to mitigate damage and recover quickly. First, they positioned their trains in areas safer from flooding. Second, they realized that many MTA employees would have a very difficult time commuting to their workplace following the storm. As a result of that understanding, the MTA director authorized overtime in advance for all the employees who agreed to stay on the job including the time they would need to sleep – and he provided them with bunks to sleep on. As a result, virtually the entire MTA workforce was on-hand to support the response and recovery both during and after the storm.

Unfortunately, the leadership of the New Jersey Transit System ended up focusing on the lesson they learned from their most recent experience with a hurricane and prepared for a wind event instead of a water event. A year before, when Hurricane Irene struck the region, the system had moved much of their train fleet into central New Jersey to get them out of the flood zones. However, while their was little flooding from Irene, the storm generated wind damage to many of the power lines which translated into many of these trains being stranded far away from their most active routes for several days. For Sandy, New Jersey Transit decided to reduce the risk of having service disrupted by wind-damaged power lines by this time ordering that the trains be placed near Hoboken and the Meadowlands. But these locations are both in low-lying areas that were very exposed to flooding by storm surge. As a result, 345 train cars suffered significant damage.

What are some key lessons to be drawn from Sandy? First and foremost is the imperative to begin taking a Resilience-Centric Approach to safeguarding critical infrastructure and communities. This means:

- Distinguishing amongst elemental capacities, essential functions and full or normal functions
- Identifying and adopting resilience design features, processes, and protocols that together mitigate the risk of disruption and speed recovery when mitigation measures fail
- Weighing resilience design options that include:
  - Cushionability – the graceful degradation of non-essential functions during periods of stress
  - Resistance – redirecting threats and hazards away from elemental capacities and essential functions
  - Robustness – hardening elemental capacities and essential functions
  - Redundancy – having spares to provide elemental capacities and essential functions
  - Graceful Extensibility – creating the capacity for the infrastructure to adapt to deal with an uncertain future

Vastly improving communities' ability to put resilience into practice is vital. This must be done in all phases of disaster planning, response and recovery.

- Pre-event communities need:
  - Better modeling, particularly visual models that can transmit the right story to decision makers and help them make "what-if" decisions in advance of disasters
  - Resilient design based on both predictive risk and surprise rather than solely on experienced risk
  - Creative and effective incentives for investing in resilience measures
  - Better, more realistic, and more frequent contingency planning and exercises
  - An enhanced ability to maintain situational awareness prior to, during, and after a disaster
- During the event it is necessary to be resourceful. Decision-making and actions should be done nimbly and competently so as to mitigate consequences and to support rapid recovery.
- In the aftermath of events, communities must:
  - Restore elemental capacities and essential functions in a rapid and integrated manner
  - Restore full/normal functions as rapidly as possible
  - Learn from the event, adapt and improve resilience design accordingly

Discussion and Significant Recommendations from the Bolstering Energy Resilience Workshop

Stephen Flynn outlined one of the major lessons learned from a workshop hosted by New York University's International Center for Enterprise Preparedness (InterCEP):

Figure 3. Superstorm Sandy knocked out power to over 2 million New Yorkers. Source: Iwan Baan, New York Magazine

In the aftermath of Superstorm Sandy, over 8 million people were affected by power outages across the metro-New York/New Jersey region. Without reliable access to power most other infrastructure systems are unable to operate or do not operate effectively.

Access to fuel was a huge problem. The region's fuel system is large, complex and little understood by most decision makers who are not directly involved in the operation of the system. In addition to local refineries, most of which are on or in close proximity to shorelines and are therefore vulnerable to storm surge and power outages, much of the fuel for the region comes through pipelines that originate from as far away as the Gulf Coast or is transported by sea on oil tankers and by tugs and barges. The New York and New Jersey region consumes on average 42 million gallons of fuel a day. Vessels that transit to the port of New York and New Jersey provide over 60 percent of that fuel, regional refineries provide approximate 20 percent, and 15 percent arrives by pipeline. In the immediate aftermath of the storm, decision makers were slow to realize that the entire fuel supply distribution system had essentially collapsed. This was partly due to the fact that few public officials, including emergency managers, understood just how the systems worked. It was also due to these officials receiving conflicting and incorrect information. Successfully managing the disruption of the fuel system was hampered by a general lack of awareness of the interdependency of lifeline infrastructures and the cascading effects generated by a major disaster. Gasoline stations cannot operate without the power and telecommunications networks that support them. Emergency crews need fuel for their vehicles in order to assess damage and make repairs.

The bottom line is that an inadequate understanding of complex, interdependent energy systems inhibits appropriate resilience investments and reduces the effectiveness of disaster planning, response and recovery.

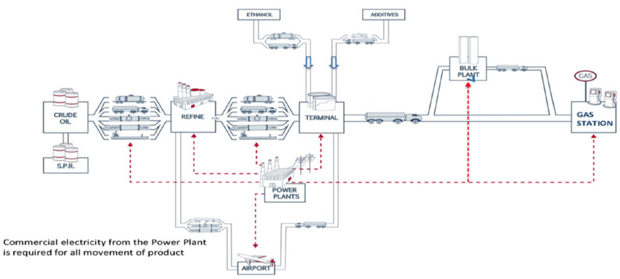

Figure 4. Modeling the elements of the oil supply chain. Source: American Petroleum Institute

Discussion and Significant Recommendations from the Health Systems and Services Workshop

David Abramson, Assistant Director, National Center for Disaster Preparedness, Columbia University, provided a summary of the insights and recommendations developed at the post-Sandy workshop on resilient health systems and services. These included the following:

During and in the immediate aftermath of Superstorm Sandy, about 10 percent of New York City's hospitals' bed capacity was lost. Since there are 58 acute care hospitals in the metro-New York area, that loss to the health system was substantial. Even hospitals that were not evacuated were severely strained and exhibited significant creativity and inventiveness, but the system turned out to be far more vulnerable to disruption than planners had anticipated. Most of the successes were the result of individual facility and staff heroism and not the inherent resilience of the medical system. Outside of the hospital system, the failures reflected even less resilience. Shelters filled with unexpected patients from nursing homes without medical records or required medications and many of them were not able to explain their conditions to shelter personnel.

The challenges that the metro-New York health systems faced in the aftermath of Superstorm Sandy highlighted a significant challenge for health systems nationwide. Increasingly, the majority of patients are no longer receiving medical care primarily in hospital settings. Instead, that care is being dispersed through a community in nursing homes, adult care facilities, dialysis centers, outpatient clinics, and via home health care. However, most regulations that govern the management of disasters impose standards almost exclusively on hospitals. What this translates into is that for most major disasters, the community health care system is woefully unprepared and inadequately resourced to handle the large load placed on it before, during and after a storm. This includes the stress induced by the planned evacuation, discharge or movement of patients from hospitals into the community prior to a storm making landfall. Indeed, in preparation for or in response to a major disaster, there is a strong incentive for hospitals to transfer their patient load into the community for community health service providers to manage. Too often, this has the effect of moving patients from a highly regulated environment into a much less regulated environment without the support structures to manage the surge. Patients often arrive at community care facilities without medical records or medications. These facilities are likely to have an inadequate supply of trained health care professionals on hand. (For example, many health care providers not affiliated with a hospital in the NY/NJ area had no credentials that identified them as essential personnel. As a result, they were unable to get gasoline for their vehicle or get past police barricades to gain access to their patients.) Elderly patients from nursing homes and adult home facilities are often evacuated to shelters with no capability to adequately care for them and few resources to meet their special needs.

Some of the standards that are most relevant to community health resilience in a disaster that came from the health systems and services workshop included:

- Ensuring an adequate health provider workforce during and after the event. This includes providing support to manage their personal family circumstances and issuing credentials so that they are in a position to report to work during and following a disaster.
- Ensuring robust and effective communications among the various sectors of the health care system. This includes transportability and transparency of medical records and medication requirements as well as physical communications links when most normal systems are not functioning. It also includes general risk communication to the public at large to ensure that an additional health emergency does not arise during the crisis (how to handle contaminated water, for instance).
- Ensuring the reliability of energy to maintain required medical technologies and both hospitals and other health care facilities that provide essential medical services (i.e., dialysis center, radiation treatment centers, etc.).
- Ensuring the continuity of other lifeline infrastructure including water, wastewater and sewage.

Other considerations that deserve additional study and emphasis are:

- How does the built environment contribute to risk mitigation and resistance efforts in the public health care system?
- What are the most relevant considerations for patient evacuation or shelter in place decisions?
- What are the human measures of a resilient public health care system – mortality; excess morbidity; individual and household recovery?

Discussion and Significant Recommendations from the Developing Economic Incentives for Advancing

Howard Kunreuther, Co-Director, and Erwann Michel-Kerjan, Executive Director, of the Wharton Risk Management and Decision Process Center provided a synopsis of the incentives workshop.

One of the primary questions in building infrastructure resilience is, "who pays?" Normally this implies a risk management approach – the need to quantify the risk to the infrastructure and understand what is now known about that risk. That risk assessment is followed by considering the options – what are they now and what might they be in the next five to ten years? Then, who are the public and private partners that can be brought to the table to make these options real?

Superstorm Sandy ranks fifth amongst the most costly global disasters over the past 60 years. In fact, most of the largest disasters have occurred in the past 10 years and Sandy was not an outlier. It is essential to determine who is paying for the costs associated with recovery. The Stafford Act that governs major disasters in the United States allows state governors to request a Presidential Disaster Declaration, which gives them access to federal funds to cover a portion of the losses the state incurred. That portion has grown in recent years. In Hurricane Diane (1955) the federal government paid for 5 percent of the losses; in Hurricane Hugo (1989), 25 percent; in Hurricane Katrina (2005), 50 percent; and for Superstorm Sandy (2012), 80 percent (See figure 5). However, the speed at which this emergency assistance is approved by the federal government is also changing. After Katrina, it took 3 days for the government to release $10.5 billion with an additional $50 billion in a few weeks. After Superstorm Sandy, it took 3 months for the U.S. Congress to release funding. In today's highly polarized political climate, rapid appropriation to meet even large catastrophes is not assured.

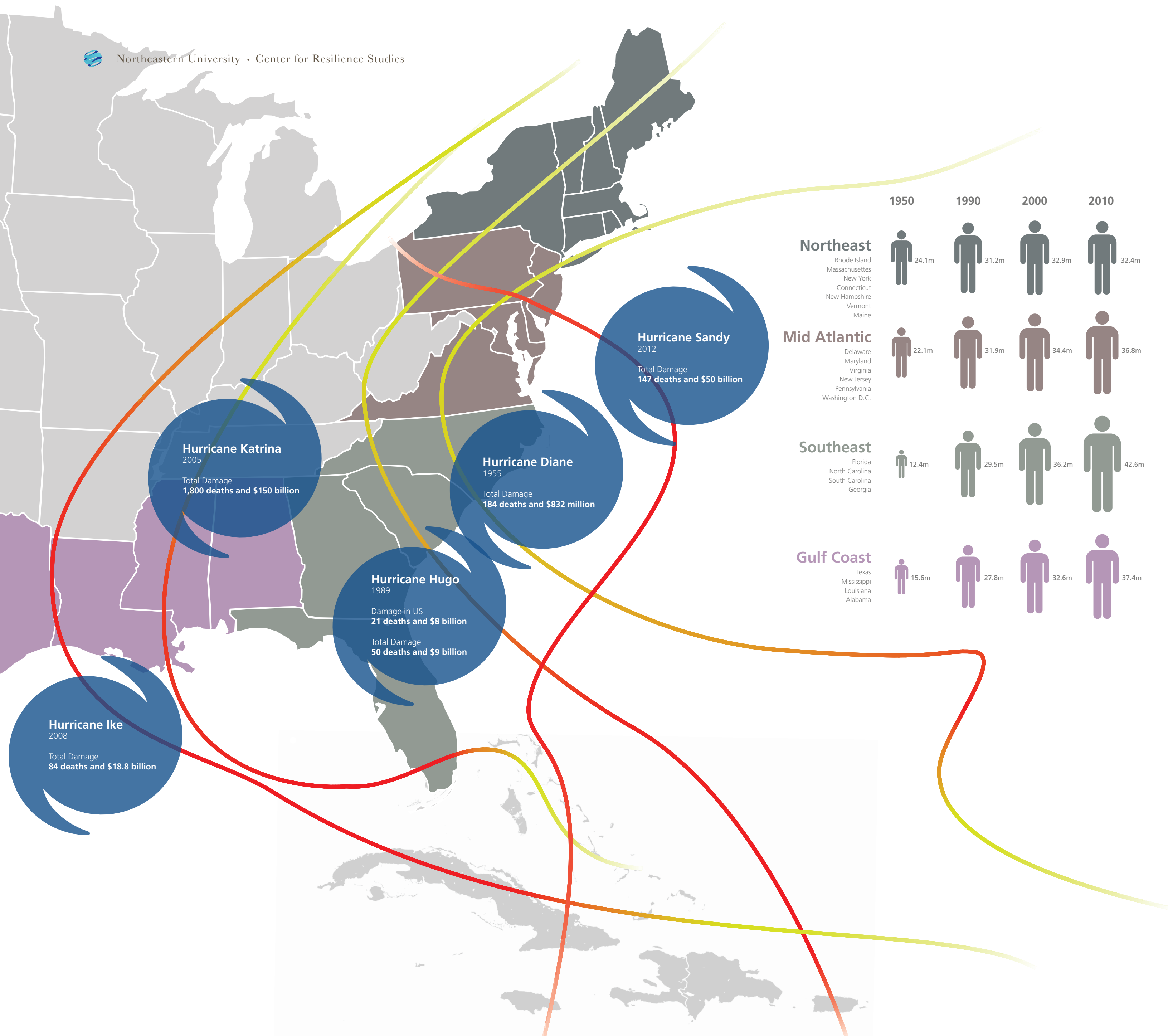

Figure 5. As coastal populations and storm intensity increase, so too does the cost of natural disasters. Source: CRS analysis of National Weather Service, NOAA and U.S. Census data

In addition to the issue of who pays, there is also the question of how the money will be used. There is a trade-off between restoring damaged property to its pre-disaster condition, and investing the time and often the additional expenses of rebuilding with additional resilience. The legislation governing storm assistance for Superstorm Sandy for the first time authorized FEMA and other federal agencies to fund reconstruction that includes new mitigation measures. But this effort has been complicated by the lack of agreed upon resilience-enhancing standards.

The growing uncertainty about the process associated with the extent and timeliness of post-disaster financial assistance as well as the lack of agreed upon standards to inform rebuilding efforts, works against building greater societal resilience.

Another barrier to investing in resilience is "availability bias" and imperfect information that translates into leaders, individuals and communities often misperceiving the likelihood of a disaster occurring and of its consequences. Leaders are often myopic and exhibit a "Not in My Term of Office" (NIMTOF) mentality.

In the face of these challenges, insurance can provide a potentially helpful antidote. Insurance often ends up encouraging investment in adaptation or mitigation measures by offsetting those investments with lower premiums since they lower the insurer's exposure to the risk of large losses.

The Wharton School's Center of Risk Management and Decision Processes has identified two governing principles for insurance to be used as a more effective catalyst for advancing resilience:

- Insurance premiums should reflect risk. This provides signals to infrastructure owners regarding the hazards they face and encourages investments in cost-effective adaptation measures to reduce vulnerability to catastrophe.
- In order to deal with equity and affordability issues, governments must assist communities in high hazard areas that may need special treatment. This assistance may be in the form of low interest loans or grants to accomplish adaptation and mitigation providing an incentive to upgrade facilities before the next disaster.

In general, insurance markets help spread risk and often provide incentives to reduce risk. Insurers can also encourage deliberative thinking for themselves and their policyholders by providing short-term incentives for acting now rather than waiting. Superstorm Sandy provides an opportunity to reevaluate the roles that insurance and adaptation measures and standards can play in reducing future loss to infrastructure.

Discussion and Significant Recommendations from the Bolstering Transportation Resilience Workshop

Michael Bruno (Dean, Schaefer School of Engineering and Science, Stevens Institute of Technology) provided lessons learned from the post-Sandy transportation resilience workshop.

Bruno told the story of an insightful occurrence when the directors of the New York City MTA and the New Jersey Transit Authority sat next to each other, and related their experiences: The New Jersey official had been severely criticized for his actions in preparing for a wind and not a water event and the subsequent loss of transportation capability by flooding. The director of the MTA said, "Do you know what the difference between being a hero or not is? It is 10 miles per hour." The MTA director had predicted a storm surge event and had positioned many of the MTA trains on elevated tracks with considerable wind exposure while the NJ director had assumed a wind event and positioned much of his rolling stock in wind protected but flood prone areas. If the forecast had been a little off – more wind, less water – their situations would have been reversed with New Jersey Transit ending up getting the praise.

> Over the past 60 years, Sandy ranks 5th globally in terms of economic damage with estimated costs of $50 billion. Others with higher costs are: the 2011 Japan Tsunami, $210 billion; Hurricane Katrina in 2005, $125 billion; the Japan earthquake in 1995, $100 billion; the China earthquake in 2008, $85 billion.
>
> Source: The International Disaster Database,
> Centre for Research on the Epidemiology of Disasters

Scientists are often overlooked by public officials and emergency managers. Of the primary lessons from Superstorm Sandy, one of the most significant was the importance of ensuring that understandable, threat-specific information got to the right decision-makers at the right time and at the right place. As an example, while the mayor of Hoboken understood that Sandy was a storm surge and not a wind event, she had a difficult time convincing the city's utility officials. The head of the water department, citing the city's new water pump system, was convinced that the city could handle local flooding. The mayor enlisted the help of ocean engineering professors at the Stevens Institute of Technology located in Hoboken. Those scientists were able to point out that the town was up against an 8-10 foot storm surge from the Atlantic Ocean that would submerge virtually the entire city. At that point, the city officials began to appreciate the likely magnitude of the storm surge and mobilized emergency workers to go door-to-door to ensure the evacuation of basement apartments and businesses, undoubtedly saving a number of lives.

It is important to find a way to scale substantive expertise so that all local and state officials have a better appreciation of the kind of hazards they face and their likely consequences. To this end, the federal government should invest in constructing models and simulation tools than can support visualizing risk and provide for "what-if" decision making by practitioners.

When it comes to transportation infrastructure, strengthening resilience requires a multi-hazard, multi-system approach. The transportation system brings together many different systems, facilities, owners and operators with different governance models, different capabilities and resources, and different incentives for taking preventative actions. The tendency is to assess and plan for one hazard and one part of the system. Each part of the system has its own vulnerabilities and capacities. Loss of capacity in any one part affects the whole system in ways that are hazard dependent and difficult to fully understand.

The single greatest action that could improve transportation resilience is regional transportation planning. To be truly resilient, the transportation system must have catastrophe planning that crosses jurisdictional and management silos. Further, this regional effort must include detailed analysis and planning that take into account the risk of low probability, yet highly consequential events.

To support transportation catastrophe planning on a regional scale, private sector owner/operators and communities across local, county, and even state lines should also institute a commitment to routine, joint regional exercises and tabletops. Only when exercises and tabletops assemble all the relevant private and public players will it be possible for officials to develop a full understanding of the dependencies and interdependencies that are most often the points of weakness leading to cascading failures.

The effects of transportation disruption imposed significant economic costs on the nation as well as on the region. Because of power losses, flooding and damage to facilities and cargo, Superstorm Sandy closed the Port of New York and New Jersey for a week. During that closure, container ship operators diverted their New York-bound cargo to Baltimore, Halifax and the Port of Virginia. These diversions were extremely expensive and the problems were compounded by the failure to waive the Jones Act for anything but fuel deliveries. The Jones Act requires that any cargo moving between U.S. domestic ports by sea be moved on U.S.-flagged vessels. Cargo in the port of Baltimore could be moved by rail at some cost. Cargo diverted to the port of Halifax could be moved on the next available vessel regardless of country of origin thereby speeding up its delivery time once the Port of New York was reopened, and reducing the cost of the diversion. Meanwhile, cargo diverted to the Port of Virginia required movement by U.S.-flagged vessels (rail lines between that port and New York and New Jersey are not sufficient to move large quantities of containers). Since there were few such vessels available to move this cargo, the result was to add considerable delay to deliveries while significantly increasing the cost. This is an illustration of not only direct damage to infrastructure, but also how inflexible rules can end up compounding the costs and slowing post-disaster recovery.

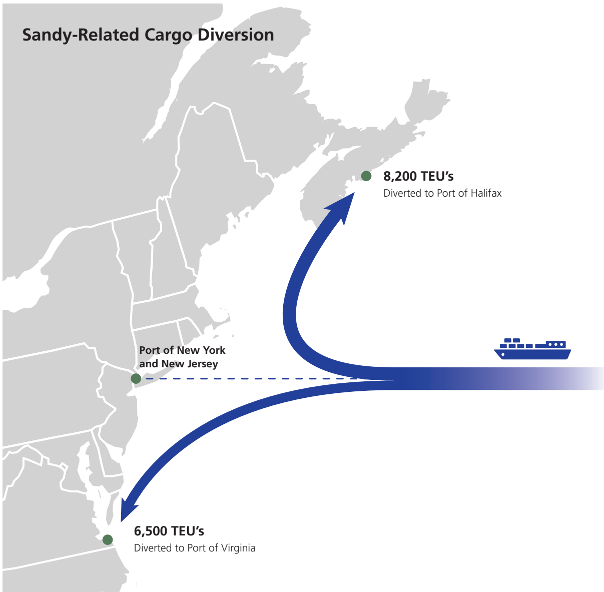

Figure 6. The majority of cargo originally destined for New York was diverted to the Ports of Halifax and Virginia. Source: CRS analysis of information provided by the ports of New York and New Jersey, Virginia and Halifax.

Plenary 2: Community Resilience Trends

Background

Plenary 2 broadened the discussion of resilience beyond Superstorm Sandy into the wider discussion of the state of community resilience research and practice in the United States today. It attempted to provide an understanding of the larger context into which NIST standards for community and infrastructure resilience must fit to have practical effects and introduce some of the uncertainties around creating incentives for resilience investments. The plenary consisted of opening remarks by Warren Edwards and John Plodinec of the Community and Regional Resilience Institute followed by a panel discussion. The participating panelists were Alice Hill, Senior Advisor for Preparedness and Resilience, National Security Staff; David Kaufman, Associate Administrator for Policy, Programs Analysis and International Affairs, FEMA; Susan Cutter, Director, Hazards Research Laboratory, University of South Carolina; Scott Graham, Mid-Atlantic Division, American Red Cross; and Meir Elran, Senior Research Fellow, Institute of National Security Studies, Tel Aviv University.

Framing the Discussion

Warren Edwards and John Plodinec from the Community and Regional Resilience Institute (CARRI) provided initial thoughts on the trends in community resilience in the U.S. today.

Resilience is a term that is widely used by government, academia, public and private officials at all levels. The concept of resilience has grown dramatically over the past ten years and is suggested as a way to solve many of the nation's most difficult challenges. However, there remains considerable confusion on exactly how resilience should be understood and applied. Often, different audiences see resilience in light of the problems they wish to solve.

There has been significant progress in the past decade in increased understanding of resilience as it applies to communities as well as to infrastructure. Much of that work has been within domains or within infrastructures.

There is a growing recognition of interdependencies between and among systems as a challenge in understanding resilience and in creating practical paths toward more resilient communities and infrastructures.

The federal government has adopted the concept and that adoption is reflected in national level documents. This recognition by the government can be a significant force in moving the concept forward toward wider adoption.

However, there remain many tasks to accomplish before resilience achieves its potential as a power to transform.

There is continued fragmentation of effort at all levels. The federal government has no formal interagency process to coordinate disparate and often conflicting resilience programs and projects. There are multiple and frequently overlapping efforts to find practical ways to advance resilience housed in local governments, non-profits and foundations, and in academic institutions. There is no recognized research priority agenda to help focus research on knowledge gaps in a way that can produce practical, usable tools and processes for building community and infrastructure resilience.

Figure 7. (Pictured left to right) Warren Edwards leads a panel discussion on community resilience with Alice Hill, David Kaufman, Meir Elran, Susan Cutter, Scott Graham, and John Plodinec. Stephen Flynn (standing) contributes to the discussion.

In many cases, the resilience efforts that are the most advanced are producing overly complex systems, processes and tools that communities are unable to realistically apply on their own. Limited resources in most communities prevent the use of complex instruments that require outside experts.

There are few incentives for community and business leaders to take on the difficult task of creating resilient communities or infrastructures. The "business case" for resilience has not been stated in a way that compels action.

Resilience requires action and action requires resources – financial and human. Communities face competing priorities for their investments and see resilience as a long-term, discretionary investment. Despite this, there are some investments being made in bolstering resilience. Much of this investment is by large businesses that are beginning to understand that resilience reduces their vulnerabilities to disaster as well as other significant disruptions. There is some investment by local government in continuity of service particularly where those communities own their own service infrastructures. The Department of Homeland Security (DHS) has made significant investment in security, some of which creates resilience. However, in most communities, small and mid-sized businesses and families have made no investments in creating resilience.

Panel Discussion Highlights

In the course of discussion panel members made these significant points:

- One of the challenges faced by the federal government is how to make resilience resilient. How can it be made a lasting term and a valuable, productive concept?
- Perhaps the most important high-probability, high-consequence challenges that must be embraced is the challenge of climate change. This challenge needs to be included in the model of resilience with an emphasis on making design and development decisions that mitigate the risk associated with climate change. In other words, resilience can't be viewed as simply "bouncing back" because the old conditions are not sustainable. Some of the changes will be lasting. The challenge is less about response and recovery and more about planning for the future. Any standards models developed for resilience must accommodate that reality.
- From a research perspective, resilience, while not new, has become more popular as a consequence of disasters, climate change and adoption of the term by the federal government. The federal government is leading the charge with researchers following behind. Part of the research effort should focus on capacity building; figuring out what information is needed in order to design more resilient systems. As resilient infrastructure systems should be able to adapt to changing conditions, it is important to understand the capabilities of these systems, the extent of their ability to adapt and the capacity to monitor the adaptive properties.
- FEMA has been advancing a community-oriented theme. Disasters and crises do not happen to government; they happen to communities and to the whole society – individuals, families, businesses, schools, etc. Cultural values and cultural norms are the social underpinning of our actions as citizens and members of society. These cultural values are important in determining how a community meets and deals with a crisis. One of the strongest pathways to building collective capacities is to build on the existing points of connection within a community.

Figure 8. A Napa County Library worker, Chris Geyer, tends to the mess left by the magnitude-6.0 earthquake that hit the San Francisco Bay area on August 25, 2014. Source: Peter DaSilva, European Pressphoto Agency

- From an international perspective, Israel has a highly resilient population tested over many disruptive (largely human induced) events. The people and the communities have very high capacities to continue operations and daily life in crisis. There are six reasons for this high rate of resilience:
  - A high rate of preparedness based on known doctrine and many exercises
  - Continuous systems and programs to mitigate the effects of the disruptions
  - Awareness and the effective dissemination of information
  - Leadership – the constituency must trust local leadership
  - The cultural norms of the society
  - Organization of the effort
- A theme that runs through the six Israeli points is responsibility - individual, family and community responsibility.
- The Red Cross is looking much more closely at the full disaster cycle rather than only at response and immediate recovery. It is pioneering the use of apps that can assist in disaster information before, during and after the crisis.
- Without relationships and trust, resilience doesn't work at the community level.
- Overcoming any lack of a sense of urgency requires finding hooks and incentive structures that need to be changed or the connection points that need to be bridged to impel action. Trust is the centerpiece of this effort.
- There have been significant changes to the Stafford Act following Sandy. FEMA now has the ability to replace destroyed infrastructure with better infrastructure. This takes away some of the disincentive to adaptation. However, this does not mean that the right financial incentives are in place. Insurance is a short-term incentive – rates are based on today's risk. It is necessary to look at long-term mitigation inducements and to understand the lending side of incentives – the financial inducement to resilience.
- All communities are different. A one-size-fits-all strategy will not work. Instead it is important to look at both top down and bottom up strategies that are adaptable to localities.

Plenary 3: Infrastructure Resilience Trends

Background

Plenary 3 steered the discussion of resilience into the much more specific topic of the built environment and how the concept of resilience was trending in that arena. It was intended to explore the current understanding of resilience as applied to the nation's large lifeline infrastructures and provide some ideas on how standards might be constructed to better measure and advance infrastructure resilience. The panel was also asked to consider the interdependencies of a community's systems and how those interdependencies related to overall community capacity to recover following a disaster. The plenary was opened with remarks by Stephen Flynn who also moderated the panel discussion. Panelists were Michael Bruno, Dean, Schaefer School of Engineering and Science, Stevens Institute of Technology; Najib Abboud, Principal and CTO, Wiedlinger Associates, Inc.; Jerome Hajjar, Chair, Department of Civil and Environmental Engineering, Northeastern University; Jalal Mapar, Director, Resilient Systems Division, DHS S&T; Stephen Conrad, Manager, Resilience and Regulatory Effects Department, Sandia National Laboratory; and Klaus Thoma, Director, Fraunhofer EMI.

Figure 9. (Pictured left to right) Jerome Hajjar, Stephen Conrad, Jalal Mapar, Najib Abboud, Michael Bruno and Stephen Flynn participate in the plenary session on infrastructure resilience trends.

Framing the Discussion

The major sources of risk to critical infrastructure are:

- More users that push or exceed infrastructure design capacity
- Aging infrastructure without adequate investment in maintenance and repair
- Rising urbanization particularly in coastal areas with substantial exposure to the effects of climate change
- External shocks from naturally occurring and man-made sources
- The absence of political will for undertaking the advanced planning and long-term investment in building, upgrading, and adequately maintaining infrastructure

All of this requires a new emphasis on bolstering critical infrastructure resilience.

There are significant challenges to creating critical infrastructure resilience:

- In most large infrastructure networks (e.g., water, power and transportation systems) a small minority of nodes or links carries a majority of the flows; i.e., they are built to optimize efficiency and not resiliency
- At the component level, national and regional design codes for buildings, bridges, and infrastructure components rarely address issues of resiliency for multiple hazards
- At the system level, inadequate models exist to predict the performance and impact of cascading failures on independent regional systems and networks to better enable them to withstand and more nimbly recover from major disruptive events
- Hazards such as those related to climate change, earthquakes, and terrorism have deep uncertainty that must be accounted for in strategies for resilience.

Figure 10. The I-35W Mississippi River Bridge collapsed in 2007 as a result of a design flaw. It carried appx. 140,000 vehicles per day. Source: Mike Wills, Flickr

There are several imperatives for advancing critical infrastructure resilience:

- Ensuring flexibility by designing for non-stationarity and accounting for deep uncertainty
- Characterizing interdependence by developing large-scale computational systems for simulations
- Proactively designing mitigation measures for cascading systematic failure or recovery
- Developing methods to characterize metrics for resilience
- Continuous monitoring of human-infrastructure interactions
- Learning from disasters when they occur

All of this leads to the conclusion that there are significant opportunities for advancing critical infrastructure resilience:

- There is no shortage of disasters to learn from
- Recent research and experience in climate change adaptation planning provides valuable approaches for dealing with non-stationarity and deep uncertainty
- The new paradigm of performance-based engineering has been evolving to enable new building technologies and structural design to better enable more reliable prediction and control of the performance of buildings exposed to a spectrum of natural or man-made hazards
- There are growing computational capacities to model complex networks across natural, engineered and human systems that can support "what-if" questions; i.e., developing problem-solving and response strategies that result in the best performances in different scenarios
- CyberGIS has emerged as a new-generation of geographic information systems comprising a seamless blending of advanced cyber-infrastructure, GIS, and spatial analysis and modeling capabilities, leading to widespread scientific advances and broad societal impacts

So, why have there not been significant investments in resilience?

- There is a lack of recognition about the current abilities to handle foreseeable risks and uncertainties.
- There aren't incentives to create resilience.
- Measuring resilience is difficult because there is not yet a consensus on how to create it.
- There are organizational or governance barriers to creating resilience.

Panel Discussion Highlights:

In a wide-ranging discussion, the panel highlighted these points:

- There is a growing body of new and more sophisticated, high resolution models to assist researchers and communities in the challenge of assessing mitigation needs and efforts. A concern, however, is the unintended consequences of mitigation efforts. In general, the engineering community doesn't think a lot about those effects. For example, in Superstorm Sandy flooding came close to causing truly catastrophic damage to the rebuilding efforts at the World Trade Center. It turned out that this disaster was likely averted because the Brooklyn Battery Tunnel filled and absorbed a significant amount of the flooding that would have otherwise generated additional flooding at the World Trade Center construction site. In the future, however, there are plans to plug the tunnel so that it will not flood. What does that mean for other nearby facilities?
- The concept of resilience is rarely being practiced today. Simply doing flood control does not equal resilience. Too often old practices are being disguised and relabeled as resilience. But there are some hopeful signs of change. For example, the Port Authority of New York/New Jersey recently completed a process that looked at projects planned before Sandy and scored them on a resilience scale.
- DHS S&T attempts to be forward looking and not just focus on past disasters. The world is in constant change. On the national side, climate change continues to be a significant worry and its effects on infrastructure are still not fully understood.
- The United States must look at risk in a different way. It is critical to consider and understand multi-dimensional risk.
- There is more to worry about than physical threats. Cyber threats and vulnerabilities are growing significant. Also, cascading effects and interdependencies affect our understanding of resilience.
- Measuring resilience is a well-recognized and serious challenge. There needs to be a commitment to developing appropriate metrics and creating a better measuring system.

- Performance based standards that focus on functionality should be the focus of resilience measurement. Lifeline infrastructures are more than simply assets; they are systems. Systems themselves need services and without them they fail. All of these systems have multiple stakeholders. Optimal resilience answers that work for some stakeholders may not work for others. All stakeholders in systems resilience are going to do cost analysis and if there isn't a clear benefit, they will resist participating.
- There is significant room for progress in codes and regulations. Engineers are resistant but need to start baking resilience into codes for built infrastructure. It is also important to adapt current codes to resilient practices. For example, Boston's building codes require all generators to be in the basement of buildings. But placing generators in basements of waterfront buildings that are at sea level is not a resilient practice.
- A lack of communication between state and federal authorities on bridge measurement regulations has resulted in instances of incorrect data being used to evaluate the nation's transportation system. Figure 11 on the next page shows not only are some of the country's most heavily trafficked bridges rated insufficient by the Federal Highway Administration (FHWA), but also, as in the case of the recently built St. Anthony Falls Bridge in Minnesota, the actual sufficiency rating can differ significantly between data provided by the state departments of transportation and the FHWA. An official at MNDOT emphasized that the St. Anthony Falls Bridge example is not unique.
- As the data necessary to conduct modeling and to actually build resilient infrastructure is amassed, there is an absolute requirement that it remain safe. The threat from malicious hackers is ever present. It will be necessary to provide a trusted regime so that data can be shared prior to disasters and to support investigations of infrastructure failures after disaster occur.
- One of the ways to get around the sensitivity of data is to sanitize it and create fictitious but realistic modeling data that can be integrated into simulations that support decision-making. It should be possible to put that realistic modeling data with real engineering systems models and essentially create something akin to a sandbox in which data and models can be shared and allow facilitated interaction.
- There is a strong tendency to produce systems and overly complicated models that communities cannot use. Modelers and engineers must listen to cities and communities to understand their needs and responsibilities – meet them where they are and understand what they think their resilience challenges are. This builds community trust. The same is true for private businesses.
- New models should use existing technologies that people are comfortable with like Google Maps. In that way, they can feel comfortable using new tools to visualize the impacts of potential disasters in their communities.
- Very few people actually understand resilience. It is imperative that resilience researchers and practitioners work to educate the public. Local communities, leaders and individuals need to know what resilience is and how it relates to them.
- It is important not to forget the social models as the engineering models are developed. Engineers are resistant to including social models because they are uncomfortable with the lack of codification, standardization and quantification of those models. It is important to find ways around this challenge.
- One of the challenges with resilience is that the benefit lies either too far in the future or the benefit lies with someone else. This is going to be a recurring issue. The analogy may be environmental issues. Sometime around the 1970's the country decided that the environment would be regulated. Perhaps resilience needs to fit into the same pattern.

Plenary 4: Creating Incentives for Resilience Investments

Background

One of the significant challenges discussed in all three of the previous plenary sessions was the issue of creating the right incentives for resilience investments. Plenary 4 was designed to tackle that topic. To get the panel discussion started, moderator Stephen Flynn related the basics of the New York Metropolitan Transportation Authority catastrophe bond story as a mini-case study. The panel for this session was composed of Eric Letvin, Director, Hazards Mitigation and Resilience Policy, National Security Council; Laureen Coyne, Director, Risk and Insurance Management, MTA; Roy Wright, Deputy Associate Administrator for Mitigation, FEMA; and Debra Ballen, General Counsel, Insurance Institute for Business and Home Safety. The panel's task was to examine potential policy, economic and social incentives that could be developed to encourage resilience investments in infrastructure, buildings and communities.

Framing the Discussion

The nation faces a counter-productive spiral of ever-growing federal government disaster relief and the related moral hazard that flows from it. Twelve of the most costly insured catastrophes worldwide between 1970 and 2012 occurred since 2000 and most of them were in the U.S. In the same time frame, U.S. presidential disaster declarations (allowing the federal government to cover a minimum of 75% of the losses) have grown from fewer than 20 annually to close to 100 annually in 2013. This trend is likely to be politically unsustainable.

Making sure that infrastructure owners and operators are properly insured is becoming critical. Following Hurricane Katrina, 3 days were required for Congress to fund an initial relief package of $10.5 billion followed by an additional $51.8 billion one week later; in the aftermath of Superstorm Sandy, approval for disaster aid funding of $50.5 billion took 3 months. Should New York City experience a repeat of Sandy in 2015, its request for disaster relief funding would likely be highly contentious and approval by Congress would be by no means a foregone conclusion.

There is a way forward: Critical infrastructure owner and operators should:

- Assess their risk accurately and determine a portfolio of cost-effective risk reduction solutions to support resilience investments
- Recognize behavioral responses to risks; and devise short-term incentives for adopting mitigation measures, and long-term risk management.

Insurance markets can be highly efficient and effective providers for cushioning the consequences of large losses. The key to this strategy is that insurance premiums must be based on risk in order to provide signals to infrastructure owners as to the hazards they face and to encourage investment in cost-effective adaptation measures to reduce vulnerability to catastrophes through premium reductions.

The New York Metropolitan Transportation Authority (MTA) provides an excellent mini-case study.

- Before Superstorm Sandy, an insurer provided the MTA with $1 billion in coverage against damage from floods and other causes. After the storm it was not possible to get that kind of coverage. Even half billion dollars would have been twice as expensive
- Following the storm, insurers were exhibiting predictable responses in two ways:
  - They exhibited an availability bias in that they focused on the enormous potential claim payments from another Sandy

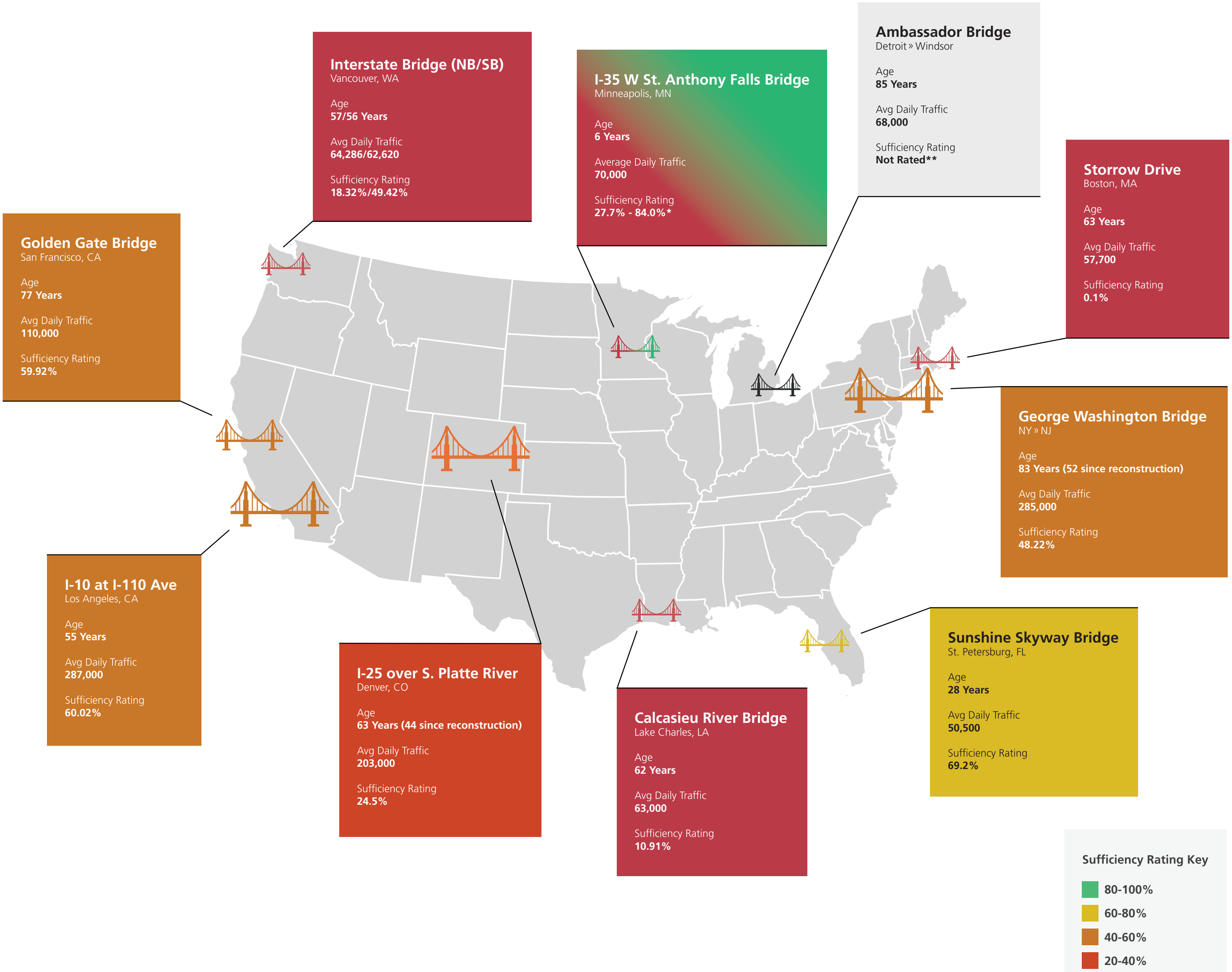

Figure 11. A look at some of the country's most heavily trafficked bridges. Source: CRS analysis of FHWA and MNDOT data. * The FHWA gives this bridge a sufficiency rating of 27.7% while MNDOT gives it an 84.0%. ** The FHWA has no legal authority to require private bridge owners to inspect and maintain their bridges.

- They demonstrated the effect of imperfect information in that they did not adequately consider the likelihood of future hurricanes when determining premiums to charge for coverage and how much those at risk would be willing to pay for protection
- The MTA decided to issue a Catastrophe Bond (Cat Bond) for $200 million for three years at $9.1 million a year. (The implied annual probability of damage of $200M or less is 9.1/200 or 0.45. The estimated annual probability of damage of $200M or less is .017.)
- The MTA prioritized their efforts around flooding associated with storm surge. They developed models with Risk Management Solutions (RMS) to structure a parametric cat bond and requested bids that covered losses should there be flooding above 8 ½ feet at Battery Park and 15 ½ feet in Long Island Sound.
- The private market responded positively at a price that the MTA could afford.

There is a role for both insurance and the federal government in creating economic and policy incentives for infrastructure resilience investments. Insurance guarantees claims payments with little delay and provides an incentive to upgrade facilities in advance of the next disaster through the promise of lower premiums after validation by independent inspections to ensure that upgrades have been accomplished. The federal government ensures accurate maps with respect to damage from future flooding. It also provides communities with low interest loans and tax incentives for reinforcing mitigation measures and provides well-enforced regulations and standards for infrastructure.

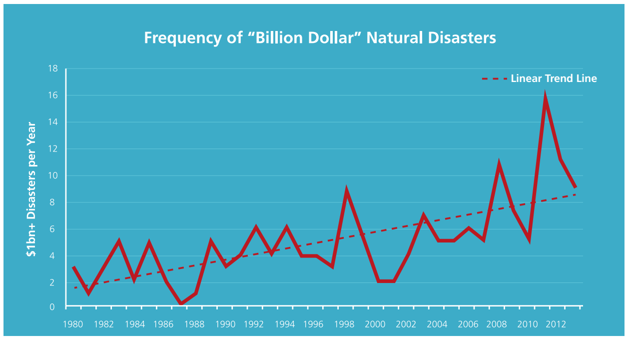

Figure 12. The frequency of expensive disasters has been increasing at a steady rate over the past 30 years. Source: CRS analysis of NOAA Billion-Dollar U.S. Weather/Climate Disasters 1980-2013

Panel Discussion Highlights

The panel discussion elicited these highlights:

- Prior to Sandy, the MTA had procured as much insurance as was available. Sandy's losses at the MTA were close to $5 billion, which was greatly in excess of the insurance coverage. The MTA immediately realized that the insurance market would contract because of the over exposure of investors in the New York area. The MTA has a long history of issuing and administrating finance bonds and has an entire department devoted to these activities. That allowed them to consider catastrophe bonds with some confidence and knowledge. Catastrophe bonds are relatively new financial instruments that are not provided by traditional insurance companies. The MTA decided to approach investment bankers rather than insurance companies and began conversations with Goldman Sachs. In determining what type of bond to issue, the MTA examined all perils and then focused on storm surge as the one that was most likely to affect them in a catastrophic way. Critical to the entire process was a clear evaluation of risk and the ability to measure effects accurately. The probability of a storm surge event that would trigger payment (based on the events described above) through this parametric bond instrument was evaluated at 1.67. Investors confirmed that probability. The final bond was for $200 million with an annual interest rate 4.5% above Treasury bills.

Figure 13. A portion of the Metropolitan Transportation Authority's NYC Subway Map. Source: Metropolitan Transportation Authority

- In a disaster, federal government funding through FEMA is primarily allocated to public infrastructure. One of the biggest challenges is that the government's (public's) exposure tends to be unknown in advance. Primarily this is because there is very little knowledge about the valuation of public infrastructures and there is even less transparency. In the case of the MTA, there was a very good understanding of the value of assets. That is not generally the case across the U.S. where there is little incentive for transparency. Transparency should breed self-correcting behavior but the federal system is not designed to incentivize that; it is designed to support the idea that someone will come in after a disaster and cover the costs. The nation has created a system that says if you are a public entity it is better not to know what your risk is. You can keep your risk behind the curtain because someone else (the federal government) will pay. Even in the case of the MTA, it understands that if after all of its insurance and catastrophe bonds there are still risks that remain uncovered, it is highly likely that the federal government will step in and pay the uncovered costs.

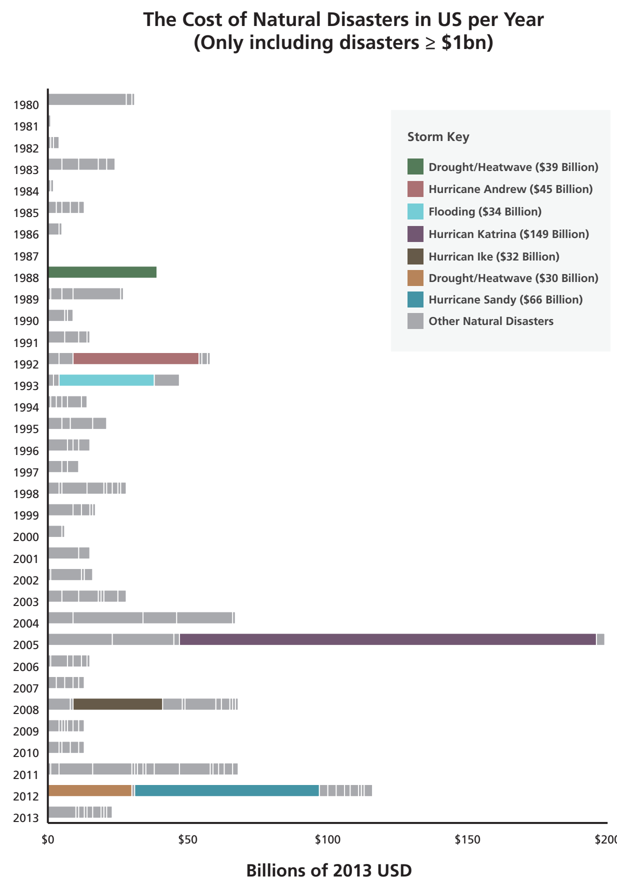

Figure 14. When adding disasters > $1bn, the five most expensive years have occurred in the past decade. Source: CRS analysis of NOAA Billion-Dollar U.S. Weather/Climate Disasters 1980-2013

- The Insurance Institute for Business and Home Safety (IBHS) is a non-profit supported by the insurance and reinsurance industries. It works to assist in developing and promulgating mitigation measures. The IBHS facility in South Carolina can replicate disasters – hurricanes, wild fires, etc. The IBHS board of directors is interested in understanding how to advance resilience. IBHS came up with a 3-phased plan: 1) get people aware; 2) get people educated on how to build better; and 3) change behavior. The U.S. needs to figure out what incentives can help change behavior. The government uses more carrot than stick incentives. The states never get less money during a disaster and that causes trouble over the long-term. It is important to determine what incentives the financial (banking) sector can bring to the table. Large retailers like Home Depot have a role. There is a political dimension to providing appropriate incentives and partisanship gets in the way of resilient activities. There is behavior at all levels that has to change for the nation to recognize risk and develop a resilient mindset.

- The federal government is actively looking for ways to reward good behavior. Resilience has been made a key theme in notices of funding availability post-Sandy. This has been done in the Department of Housing and Urban Development (HUD) Rebuild by Design program and the Sandy rebuild strategy. The federal government has a lot of climate data available including a sea level rise data tool kit that is about to be released. The government is working to make much more data available to planners and local officials. It is working on a federal flood risk reduction standard that should be ready soon. Government agencies are also working on a resilience standard for all federal actions and grants, not just federal buildings. They are investigating how the government can reward specific behavior tied to performance-based standards. There is now an updated climate assessment report available.
- As important as data are, there is a point where data meets hearts and minds. There is an extremely effective way to galvanize a community towards paying attention to their risk. FEMA could introduce a new flood map that shows an expansion to a community's risk that would "wake up the dead." But that is the point where science meets reality because as much as everyone likes resilience, they don't like to be told that they are risk prone. The U.S. needs to be investing more in handling this behavior challenge because the area of flood risk particularly is where the federal government is producing something valuable and the market can decide how it values it one way or another. Hard sciences can put together a map and statistical probabilities but it is important not to get confused and think that perfect data can change behavior.
- The U.S. has traditionally relied on lots of carrots but fewer sticks. In order to build, developers have to propose a plan for someone (zoning officials, siting commissions, etc.) to approve and oversee. Decisions are made in code and zoning agencies that could withhold approval to incentivize good behavior. It is not clear that many are capitalizing on those opportunities. This leads to questions about whether the federal government should impose standards and codes and withhold the use of federal money when states will not enact or enforce stronger codes and land use policy.
- Most participants seemed to feel that the nation is most likely to get legislative reform – to the Stafford Act for instance – on the backside of the next disaster. New legislation could require, as a condition to access disaster funding, that states and localities: 1) conduct a complete inventory of publicly-owned assets; 2) enforce standard model codes; and 3) obtain insurance for a portion of value of these assets that would not be covered by federal disaster assistance. One suggestion was that Stafford Act relief be converted from a federal grant to a loan that would need to be repaid by communities. This would provide a motivation for communities to resist making risky development decisions and to invest more in mitigation measures to reduce their exposure to disaster losses.

5.0 Breakout Discussions

With the plenary discussions as a reflective and thought-provoking backdrop, breakout sessions were designed to engage participants in distilling the most important issues that should be considered in developing resilience standards and in supporting incentives that would stimulate their adoption and use by local communities. Two series of work group sessions were devised to respond to the plenary ideas and the central questions posed by the Symposium. The first series of work group sessions focused around the creation of standards for community and infrastructure resilience. The second series of workshops addressed the importance of policy and financial incentives, as well as international perspectives on standards and incentives. Discussions below summarize the results from these work group deliberations.

Day 1, Work Groups A & D, Creating Infrastructure Resilience Standards

Given the level of interest on the part of Symposium sponsors and participants in establishing resilience standards for the built infrastructures of communities, two breakout groups concurrently tackled these issues. All together more than 50 participants and 8 discussants shared their ideas regarding the important issues for establishing infrastructure resilience standards.

Figure 15. Researchers at Northeastern University's STReSS Lab test structures and their components for resilience against natural and man-made disruptions. Source: George J. Kostas Research Institute for Homeland Security.

Key Discussion Points

Highlighted below are the important points from the work groups' discussion.

Develop Functionally-based Performance Goals

Participants in both work groups were strongly emphatic that any infrastructure standards developed would have to be "outcome driven" – supporting NIST's intention that standards should be based on the performance goals that support the continuity of the critical functions communities depend on for their safety and well-being. For example, infrastructure standards must help communities create infrastructure systems that support rapid return of the regional workforce but whose design and implementation do not drive owner/operators and local industry "out of business" in trying to afford the costs. Rather than being prescriptive, infrastructure standards should focus on desired outcomes within specified recovery time frames. Participants also noted, however, that once communities have established their performance goals, some minimal levels of functionality could and should be built into local building codes and other more "directive" mechanisms to ensure minimum thresholds of functionality are implemented within the community.

Address the Human Element in Standards and Performance Goals

Further, participants argued that even standards for built infrastructure must take into account the "human element," to include not just the community's desired performance outcome, but also how these goals will intersect with human behavior within different elements of the community. One participant noted that within their region's major port there were both national security and private business activities. These two elements had vastly different performance expectations for the port infrastructures; standards would have to be flexible enough to meet both sets of considerations without putting private industry in the port area at a competitive disadvantage. Because resilience is a complex quality that depends upon tangible elements (building codes, for example) and intangible elements (human behaviors, community culture, needs of the individual versus larger public good etc.), participants worried that the standards development effort would end up too narrowly focusing on only easily measurable aspects.

Accommodate the Impacts of Regionalism

Lastly, both groups were in firm agreement that infrastructure standards, while locally implemented, would have to recognize the impact of the wider region and the complexity that harmonizing approaches across multiple political jurisdictions bring to improving infrastructure resilience. Particularly in dense metropolitan regional environments, infrastructures for transit and power invariably cross many city, county, and state jurisdictions, yet standards would have to be implemented jurisdiction by jurisdiction.

Recommended Actions

Both work groups acknowledged that at the federal level, NIST personnel bring outstanding expertise to the process of building specific performance standards for built infrastructure elements (codes for building materials, performance requirements for components of transit systems, etc.). Therefore many recommendations were focused around steps that might make standards more understandable and acceptable to communities and residents. Key elements of recommended actions:

- Help educate communities on the need for resilience standards.
  - Create community case studies that illustrate key concepts of resilience standards within regions to include meeting community-based performance standards, pay off on investment for improved resilience, etc.
  - Engage stakeholders in testing and providing feedback on specific elements for standards, particularly on their view of the payback for any given investment.
- Provide stakeholders with tools that help them to visualize tradeoffs, conduct "what-if" scenarios, and understand the consequences of more or less improved infrastructure resilience.
- Ensure that standards are developed to consider varying sizes and types of communities. Setting standards that work only for a large urban megalopolis may not be helpful for small and medium size communities who lack both the complexity and the resources of the large urban centers.

Day 1, Work Group B, Creating Community Resilience Standards

This work group examined issues surrounding standards for community resilience, a label fraught with ambiguity and layers of meaning. Discussions in this group examined whether "standards" could be set for community-level characteristics. If so, could these characteristics account for the less "tangible" elements of community resilience? And if established, what are the essential elements that must be included in those standards?

Key Discussion Points

Issues of Variability and Complexity may Impede Successful Standards

This work group's discussion began with exploration of a key question: Could standards be developed and effectively implemented for community resilience? Both U.S. and international participants alike observed that variability of communities in size, scale, demography, cultural norms, income, risks, threats, etc. would make truly measurable standards difficult. When the variability of communities is coupled with the complexity of resilience as an attribute or outcome, most participants were doubtful that effective standards could be universally implemented. Instead, participants were more confident that standards could be developed for components of community resilience. The suggestion of one participant that NIST's efforts should be more accurately titled, *Physical Environment Standards for Resilience of American Communities*, was met by broad approbation.

Successful Standards must Address Intangible Qualities

Group members were also vociferous in their views that community resilience involves intangible elements that do not readily lend themselves to quantitative measurement. For most participants, the notion of "standards" implies an ability to quantify and measure, and most speakers doubted that community resilience would lend itself to quantifiable measurement. Group members strongly urged NIST to recognize that quality of community resilience as measured by positive outcomes in the aftermath of disruptive events is their ultimate product.

Community Resilience is a Process

Most importantly, participants urged that community resilience is not just a compilation of discreet standards but is a process. As one member noted, "How you get there, determines where you actually get to."

Necessary Elements of Community Resilience Standards

If community resilience standards are possible, participants expressed that they must address outcomes and expectations of what the standard is designed to achieve for the community. NIST's approach should recognize that successful community resilience standards must include:

1. "Top down" elements of expectation and include measurable component standards (such as those which might be set for buildings and lifeline infrastructures), and
2. "Bottom up" community processes that identify local performance goals and behavior standards.

Recommended Actions

As key observations were digested, participants identified two areas of recommended action. First, NIST should explicitly recognize a community-based process in establishing standards. The process should include engagement of the community in goal setting, understanding risks, and making informed decisions. This approach would incorporate shared responsibility for building resilience and also allow for different risk tolerances and norms across communities. Further, this approach would help to educate community members regarding resilience and the choices to be made that might strengthen it in their community. The approach should consider K-12 education as part of the process, so that over time the nation grows residents who have developed a resilient "frame of mind" – another important, but intangible, aspect of resilience in communities.

Second, participants urged NIST to consider setting principles or performance goals that might be used by communities to guide the establishment of local standards and requirements. Such performance goals should include behavioral goals or objectives – helping to address the more "intangible" aspects of resilience. Establishment of performance goals or principles should also include development of exemplars that model resilient behaviors for all sectors and elements of the community.

With these actions, work group members felt that NIST's development efforts could produce processes and goals that would be helpful to communities in improving their resilience.

Day 1, Work Group C, Establishing and Adopting Resilience Standards

While the first three work groups examined issues surrounding the notions of infrastructure and community resilience standards, Work Group C was designed to examine what might be required to actually develop standards which would be widely acceptable and effectively implementable. Members of this work group were asked to explore how NIST might advance a collaborative process among the multiple standards-setting entities that could play a supportive role in developing resilience standards.

Key Discussion Points

Build a Process that Helps Define Important Indicators of Resilience

Participants in this work group were united in their observations that NIST's efforts should be focused around defining indicators of increased resilience rather than coming up with new, technically-oriented, prescriptive resilience standards. Most participants voiced concerns that much effort would be spent on developing new resilience standards, rather than understanding how standards for technical performance of community resilience components, indicators of human/social aspects of resilience, and levels of desired functionality could be combined to provide communities with meaningful indicators against which they might assess their state of resilience.

Use a Development Process that Yields Community-based Performance Goals

Participants strongly supported the notion that defining the critical functions that communities depend on for their safety and well-being and how the continuity of those functions can be better assured is critical to the development of usable and non-ambiguous standards. As with other groups, these participants also felt that the development process should be constructed to yield community-based performance goals and objectives, rather than a scientifically-oriented process that produces prescriptive, technical standards. Further, participants felt the development process should be conducted in a way that its products would be scalable and able to meet the variability of community type and circumstance.

Build a Broadly Representative and Inclusive Development Process

Finally, participants observed that the process should include broadly defined stakeholders that included representatives from the "full fabric" of community resilience. Only with an inclusive process that resulted in broadly applicable, scalable functional goals would NIST's process yield an end product that answers the question, "so what?"

Recommended Actions

Work Group C offered two sets of recommended steps. First, the development process should remain collaborative, evolving and reflexive. Further, NIST should be deliberate in including a wide range of community resilience stakeholders – from emergency responders to ecologists, to urban planners, to economic developers – all must have a place in the process if performance goals or standards are to be accepted and acceptable. Additionally, group members urged the process designers to especially emphasize the involvement of the younger generations (millennials and Gen X'ers) both to build resilience thinking and mindsets and to ensure future continuity of resilience building efforts.

Second, work group members urged that whatever products resulted from the development efforts should be "vetted" for conflicts with existing codes and standards, reducing implementation conflicts and strengthening the impact of the products. In addition, the products should be robustly "road tested" to evaluate effectiveness and utility – before they are mandated for communities nationwide.

Day 2, Work Groups A & D, International Perspectives on Resilience Incentives and Global Issues

Work Groups A and D again addressed the same topic to make best use of the many international participants attending the symposium. These two groups were asked to share ideas on the use of policy, economic, and social incentives in the international arena to encourage resilient investments. While NIST's development process will yield products for application in U.S. communities, representatives from thirteen foreign countries were asked to share their perspectives and experiences with incentive approaches that have stimulated efforts to enhance resilience.

Key Discussion Points

This discussion focused on challenges to establishing incentives, issues to be considered, and the variety of incentivizing mechanisms that can be used to stimulate resilient outcomes. Highlights of the discussion are presented below.

Shared Global Challenges to Resilience Incentives

Participants across both groups recognized shared transnational challenges to the crafting and use of effective incentives for resilience. Multiple participants from several countries and cultures noted similar challenges with efforts to strengthen not just the resilience of the built environment, but also the resilience of social capital and the capacity of civil society to thrive in the face of disturbance. Further, numerous speakers noted that there was a global trend and interest in progressing from postures of protection and security to more forward-leaning resilience attitudes; however, speakers also noted that moving their countrymen from simple risk management behaviors and strategies to resilience-building actions is still a difficult transition to make. Additionally, regardless of country of origin, group members noted there were significant disincentives to resilient behaviors – sometimes legislative or legal barriers, sometimes management structures or approaches, and sometimes behavioral habits or norms.

Considerations for Effective Incentives

In order to incentivize resilient behaviors and actions, participants identified several considerations that would have to be incorporated. First, incentives will only work if stakeholders have reached consensus on the quality being measured, how it is being measured, and if there is demonstrable linkage to the resilience outcome. Second, the incentive must be relevant to the stakeholders and the desired resilience outcome. Third, the incentives must be culturally appropriate and applicable in addressing regional resilience issues.

Use a Range of Incentive Types to Stimulate Desired Resilience Actions

Finally, members from both work groups noted that there are many different forms of incentives; those desiring to stimulate resilient behaviors or outcomes should consider different models and types of incentives that could be useful in achieving the desired effect. Participants noted that some incentives are cooperative, that is, the incentive recognizes voluntary achievement of some state of enhanced resilience with financial or other tangible reward. These incentives are typically the "carrot" that elicits positive response in order to gain the reward. Several participants, however, noted that in some circumstances or cultural norms, incentives might be more regulatory; in these cases, the incentive is the "stick" that causes the desired behavior in order to avoid the consequences of inaction or improper action. In addition to these more conventional concepts of incentives, several speakers noted that in some instances, the presence of motivators may best act as stimulators of desired actions or outcomes. Most familiar of these types of incentivizers are "salient" events – that is the community actually has experienced or periodically experiences adverse consequences from some disruption (hurricanes, floods, earthquakes, etc.). In other instances, third-party resilience facilitators may help communities take steps to enhance their resilience. The engagement of non-state actors such as NGO's, private corporations, resilience researchers and practitioners can play important roles in spurring communities to adopt resilience performance goals and seek strengthened resilience. In this same regard, reputation, competitive advantage, and peer effects can also be powerful motivators that encourage communities to adopt resilient practices and standards.

Recommended Actions

With these observations in hand, participants from the two groups identified three areas of action. First, from an international policy standpoint, participants suggested engagement in processes around the Hyogo Framework as a means of increasing attention to resilience around the globe. With the framework's timetable coming to an end in 2015, there will be opportunities to influence what the post-2015 guidance will look like and to encourage broad, international adoption of the resilience principles embodied in the Hyogo Framework. Second, numerous speakers supported actions that would strengthen international collaboration among researchers. Most notably, group members suggested the establishment of both theoretical frameworks that could serve as a common language and technical infrastructures that would overcome barriers to transnational data to enable greater information, data, and lesson sharing. Establishment of such a global resilience network would empower resilience champions, support the study and transnational application of resilience innovations, and help overcome barriers for shared funding opportunities to flow across borders.

Figure 16. Following the Symposium, this group of international and domestic participants discussed the formation of a global resilience network

Third, participants recommended that leaders and champions of resilience capitalize on corporate interests of large multinational and global corporations. For these corporations, their global supply chain can be a source of vulnerability or a hallmark of their resilience building. Thus, these private businesses increasingly recognize a corporate social responsibility that can protect their "bottom line" and at the same time spur their willingness to lead resilience strengthening actions, provide expertise on resilience building or provide funding for resilience activities.

Day 2, Work Group B, Creating Policy Incentives for Resilience Investments

This group of participants was asked to consider how policy incentives could stimulate adoption of standards and consequent investment in resilience building actions. Ultimately, insight from their deliberations would help NIST and other agencies craft or recommend policy incentives that could encourage resilient investment in U.S. communities.

Key Discussion Points

Echoing a flow of ideas that had circulated throughout the Symposium, speakers in this discussion affirmed the connection between the use of incentives and the adoption of resilience standards or resilience improving behaviors. From this foundational belief, the majority of the group's discussions focused on necessary and effective roles that policy and policy makers could play in the creation of resilience incentives, illuminating three important roles:

Educate about resilience and risk management

First, policy must stimulate education and understanding of important concepts, a grasp of which is necessary for resilience improvement. Policy must be constructed in ways that assist people in understanding the risks they face and their options for managing that risk – accepting the risk and living with the consequences, transferring it through insurance, or buying it down through investment in pre-emptive, preventive, or mitigating actions.

Clarify desired resilience outcomes that balance "public good" risk management with local risk tolerance

Second, policy should help communities clarify the desired outcomes and behaviors that constitute resilience (setting standards or acceptable performance goals are examples of this role of policy). As part of clarifying these desired resilience outcomes, effective policy should also help communities define and understand their risk tolerance – how much risk they are willing to accept and the consequences and tradeoffs that accompany that level of risk. Third, effective policy should induce desired behaviors or penalize unacceptable behaviors by devising a combination of mechanisms that produce desired resilience actions. These mechanisms may involve use of taxing strategies, grants, cost shares, or other financial mechanisms.

Stimulate pre-emptive resilience actions

Finally, policy should encourage communities to take these pre-emptive, preventive, or mitigating actions well before disruption teaches more cruelly the wisdom of early investment (or as speakers in the Symposium phrased it, "Take action to the left of BOOM!"). Further, when effectively constructed, policy can stimulate investment in design and innovation that builds inherent strength and "bakes resilience in."

Recommended Actions

This work group outlined 5 specific actions that NIST and other agencies should take in designing policy that would incentivize adoption of resilience standards and investments in resilience-strengthening activities. First, policy makers should articulate the resilience behaviors that are the desired outcomes for communities. Second, policy makers should build an advocating constituency that engages all levels of decision makers, including state legislatures and the U.S. Congress. Third, policy should be constructed to drive disclosure of data regarding communities' choices and consequences – bringing transparency and understanding to the choices and consequences made by communities, which are increasingly felt by the nation at large. As one participant noted, "transparency drives self-correcting behavior."

Fourth, policy makers should explore and embrace the full range of mechanisms available to them in incentivizing resilience investments. Effective policy incentives will include grants, tax incentives, regulatory flexibility, and liability protection. Further, as a number of participants noted, setting internal resilience policies for their own buying power will have broad impacts on the private marketplace. Federal, state, and local governments have tremendous buying power just to meet their own operational needs – setting policies that support resilience strategies through their own buying power will drive change through their supply chains and vendors – ultimately exerting influence on the broader private markets.

Finally, policy makers must ensure that for those taking resilience actions, the investments must be revenue positive. To do that, policy makers must work closely with the private sector to develop the business case for resilience, demonstrating a value proposition that will entice public and private actors to adopt standards and implement strengthening actions.

Day 2, Work Group C, Creating Economic Incentives for Resilience Investment

Participants in this work group explored issues regarding economic incentives for resilience investment. While both government and the private sector can supply economic incentives, the initial conceptualization of the session was to explore incentives from the marketplace. Numerous speakers, however, noted that policy and marketplace incentives are hard to disentangle and function most effectively when both sides of the equation are pursuing the same end.

Key Discussion Points

Government and marketplace work together to create effective economic incentives

Much of this group's discussion explored the difference in roles between policy and marketplace incentives. Participants strongly supported the complementary roles of each and noted that marketplace incentives must often follow policy leads. Government often becomes the enabler of business incentives, stimulating public-private partnerships that increase resilience and the value proposition for both sides. This complementary behavior becomes a mechanism for enabling lower lending rates for the long-term investments required to really achieve heightened resilience and recovery capacities.

Recommended Actions

Participants recommended two areas of action to support development and implementation of economic incentives. First, discussants urged resilience champions and leaders to work together to create a national message on the value proposition of resilience investment in general. The message would help to enlist marketplace players in thinking about economic incentives that can stimulate broad adoption of community and infrastructure resilience standards and encourage communities to begin taking action. Key to this messaging campaign would be a deliberate focus on the younger generation, emphasizing the education and engagement of millennials.

Second, these participants recommended that efforts be made to identify early adopters from the corporate world to partner with in the creation of effective incentives. These organizations would be entities that recognize their risks, the threats to their communities, and the costly interplay between the two when a community is hit by a natural disaster or other disturbance. Because these corporations have "skin in the game," their own resources to invest and protect, and the ability to act quickly, identification of and partnering with these early adopters could help "jump start" the use and impacts of economic incentives. Once there are potent examples of incentives and the resulting positive changes in resilience behaviors, other communities and organizations will be encouraged to follow suit.

6.0 Participant White Papers

In addition to input through plenary discussions and work group deliberations, six participants were asked to provide reflections on standards and incentives, drawing from their experience and the discussions of the Symposium. These papers provide a range of viewpoints on the challenges of establishing community resilience standards, the roles that standards can play in increasing resilience to natural disasters, and issues that must be considered in establishing effective standards. These white papers can be found in Appendix C.

7.0 Important Themes that Inform NIST's Disaster Resilience Framework

Across the plenary sessions, work group discussions, and participant white papers, four major themes emerged from the symposium with significant implications for the NIST Disaster Resilience Framework.

Figure 17. Stephen Cauffman, NIST Lead for Disaster Resilience, offers concluding remarks as Day 2 of the Symposium comes to an end.

Theme 1 - Standard development needs to focus on community functionality and the creation of performance–based standards that support the resilience of that functionality.

Infrastructure exists to meet functional needs; it does not exist in a vacuum. Understanding that the importance of assuring the continuity of critical functions is critical to developing usable and broadly applicable standards. In the end, each standard must answer the question, "so what?" Standards that focus on desired outcomes will be much more effective than overly prescriptive, component-focused formulations.

Numerous speakers, presenters, and writers noted that prioritizing functional needs will vary from community to community based on the community's sense of what is most essential and critical. In general, participants noted that community members are concerned about continuity of service or function, rather than the inherent robustness or resilience of components and assets. As one participant noted, communities will denote infrastructure services as essential based on the community's intolerance for loss of the service. Community perception of essentiality and tolerance for disruption become the de facto performance requirements. Thus, NIST should recognize the variability likely to be present in communities' perceptions of functionality and their corresponding range of expectation regarding the adequacy of standards. Participants also strongly agreed that successfully standards or performance goals must address three critical issues.

(1) Infrastructure resilience to particular risks and threats is related to overall infrastructure health – a condition that is sometimes difficult to assess and measure, but which is widely regarded as fragile as the national inventory of infrastructure continues to age. Effective standards will have to address this differential "starting point" (that is, the differing health status of particular systems) when trying to apply standards across systems, jurisdictions, geographies, community types, etc., for each of these variables affects the "health" of the infrastructure system.

(2) The resilience of specific infrastructures is powerfully linked to interconnections between and among infrastructures, places, and systems; between different networks of infrastructures, such as energy, communication, and transportation; and across metropolitan areas and the regions around them. Thus, despite the prevalence of fragmented ownership and responsibilities, infrastructure in most communities is actually a complex regional web whose resilience is in many ways the sum of its parts, making the application of absolute standards for any one infrastructure or community difficult.

(3) Meaningful measures of and standards for infrastructure resilience will likely involve the use of several "types" of metrics. One discussant suggested that NIST consider a range of metric "types" similar to those used in the National Academy of Sciences/National Research Council, Climate Change Science Program (*Thinking Strategically*, 2005):

- Process metrics (measuring a course of action);
- Input metrics (measuring tangible quantities inserted in a process to achieve a goal);
- Output metrics (measuring products or services delivered);
- Outcome metrics (measuring results); and
- Impact metrics (measuring longer-term consequences).

Figure 18. Construction engineers analyze damage from a tornado in Tuscaloosa, AL. Source: Jeff Hanson, University of Alabama

Of particular significance for the NIST process, attendees counseled that if resilience metrics were to be most meaningful they would have to be developed through "bottom-up" processes involving community and infrastructure stakeholders whose wide-ranging goals and perspectives could result in metrics that are difficult to compare between communities and infrastructures.

Theme 2 - Standards for built infrastructure demand a larger social context within which the built infrastructure operates.

There was strong consensus that engineering standards for built infrastructure were insufficient to support a resilience standards regime for the nation. Symposium attendees were unanimous in agreeing that community and infrastructure resilience standards must reflect the social, intangible nature of resilience. One participant aptly observed: "…to community leaders, resilience is a social process, not a set of physical conditions. It is rooted in capabilities in a community to come together in a time of crisis and transcend typical barriers between public and private sector, city-wide structures and neighbourhoods, rich and poor."

There was also widespread support for more explicit recognition of the social nature of resilience than is currently reflected in the Disaster Framework.[5] Some suggested designation of specific "social infrastructures," which might also have performance goals or standards established for them. Multiple speakers indicated that such an approach would help communities to cultivate these important capacities – as well as pursuing robust and redundant built infrastructure systems. One discussant reflected that explicit treatment of social infrastructures could encourage communities to nurture and strengthen "adaptive and emergent qualities"– capacities that are generally expressed through a community's social functions (as opposed to built infrastructures which may express resilience through bouncing back to a previous state as a result of robustness, redundancy, etc.).

Others reflected, however, that even built infrastructure resilience is mediated by social inputs (that is, built systems have human operators, human users, functional operational protocols, etc. that affect the resilience of the physical system). Hence, even standards for built infrastructure must somehow reflect the social aspect, explicitly including both "structural and non-structural aspects" and the interdependencies of physical systems with social capacities.

Theme 3 - Performance-based community standards should acknowledge the regional context within which they operate.

One of the strongest themes throughout the Symposium was the universal recognition of the interconnectedness of lifeline infrastructures and social structures that almost always operate on a regional scale. Transportation, energy, communications and water and other critical infrastructures operate across multiple jurisdictions; infrastructure sectors are inherently interdependent, and regional infrastructure sectors are vulnerable to multiple hazards. Yet in spite of these facts, governance, resources and decision-making in the United States are organized around state and local jurisdictions and specific sectors. The discussions in plenary, in breakout sessions, and in participant white papers gave ample evidence that resilience standards must be developed on a basis that acknowledges this regional interconnectedness and that causes and accommodates transparent information sharing across infrastructure sectors.

To community leaders, resilience is a social process, not a set of physical conditions.

Creating standards on a regional basis is not without its challenges, however. Participants noted several difficulties in addressing "regionalism" in resilience standards. First, most attempts at metrics or at accumulating data to support resilience metrics have been on a jurisdictional basis – cities, counties, states metropolitan statistical areas, etc. A few (such as the Community and Regional Resilience Institute's Community Resilience System) have used regionally based assessment processes to help communities identify and evaluate its critical regional capacities and capabilities as resources for its recovery.

Second, the boundaries (e.g., geographic, social, economic) of regional communities are difficult to define. As speakers observed, people living in suburbia, for example, are members of their bedroom communities on most nights and weekends while their working lives and social lives are likely to revolve around their nearby urban area. Further, businesses in a regional economic cluster may all rely on a single supplier located several states away. In developing metrics and standards, NIST will have to consider how to "bound" regional communities.

Third, because many urban regions actually cross state lines, regional approaches to resilience are likely to be constrained by the welter of insurance, finance, building codes, and utilities regulations that are governed state by state. Thus, attempts by regional communities that span more than one state to adopt and implement NIST-developed standards may be stymied by differences in state laws and regulations.

5 The NIST Disaster Resilience Framework Document can be found at http://www.nist.gov/el/building_materials/resilience/framework.cfm

Theme 4 - There are insufficient and inadequate incentives to stimulate creation and adoption of standards; in fact, there are significant disincentives.

This theme was constant throughout both days of the symposium and generated some of the most intense discussion. There is also a clear linkage between this theme and the idea that infrastructure operates in a social context. Panelists and discussants all noted several challenges to incentivizing communities' adoption of standards and resilient actions: 1) there are few tangible rewards for investing in resilience, yet investment in resilience strengthening is sometime costly; 2) routine efficiency and optimization of infrastructures and community functions (e.g., eliminating redundancy and utilizing just-in-time delivery) are generally valued over continuity of function; 3) current business models emphasize the transference of risk to others (but not reducing or eliminating it); and 4) because it is unclear how to measure resilience (or what it is), it is difficult to know what behaviors should be rewarded. Symposium participant comments stressed the first, third, and last of these points in particular.

In addition to these challenges, plenary and work group discussions also pointed out that there are significant barriers to resilience that may undermine successful implementation of standards. Among the most prominent was the idea that federal government disaster relief, primarily but not exclusively through the Stafford Act, creates a significant and almost insurmountable disincentive to invest in resilience measures for large publicly owned infrastructure systems in particular. Specifically, participants pointed out that twelve of the most costly insured catastrophes worldwide between 1970 and 2012 occurred since 2000 and most of them were in the U.S. In the same time frame, U.S. presidential disaster declarations (allowing the federal government to cover a minimum of 75% of the losses) have grown from fewer than 20 annually to close to 100 annually, a trend that appears to be unsustainable.

Not only is the federal government's increasing role in funding disaster recovery a drain on national resources but participants pointed out that it also creates a significant national moral hazard – a psychological tension regarding responsibility for the cost of recovery. This tension establishes expectations of federal government "rescues" and undermines market forces, which might otherwise incentivize investment in resilient behavior and penalize poor resilience choices. As one participant remarked, "It is difficult to find anyone who is anti-resilient; but you do find people who believe that the federal government is going to, and should, bail them out."

Further, real risk is kept behind the curtain. Local, state and national leaders often remain willfully ignorant of the actual state of their risk and vulnerability within their jurisdictions. This is because to acknowledge risk creates a political liability where there is a public expectation for developing a response that elected officials may believe to be unaffordable or politically impractical prior to the actual disaster. This cloaking of actual risk further disincentivizes resilient behavior and may derail attempts to implement resilience standards. Transparency breeds self-correcting behavior. This moral hazard extends beyond leaders to individuals and households who refuse to accept a personal responsibility for ignoring risk and expecting the federal government to step in and absorb the loss for foreseeable disasters.

Behavior modification regarding risk is a clear imperative. Providing better models that can demonstrate to leaders, businesses, organizations and individuals sophisticated risk assessments and cost-benefit analysis in a practical, usable way may support good decisions on resilience investments.

There is also a significant lack of available information regarding national liabilities. One of the participants noted, "What is the exposure on the public side of infrastructure? We don't know. We can't price something in the market without knowing what it is and there is little incentive to find out."

Other than changes in policy, insurance was most often suggested as a way to incentivize resilience investments to mitigate risks and to get money back into a disaster area by guaranteeing claims payments with little delay. Insurance can, through premium adjustments, provide incentives to upgrade infrastructure before the next disaster. However, to be effective, the premiums must be allowed to reflect real risk and provide signals to infrastructure owners of the real hazards they face. To assist communities in high hazard areas, governments may have to increase the incentives by providing low interest loans or even public funding for investments in mitigation measures.

In summary, the powerful group of resilience thought leaders assembled at this Symposium gave careful and insightful consideration to the creation of community and infrastructure standards and the incentives required to induce use of standards and investment in resilience. Their discussions and deliberations provided a wide range of ideas and concepts important to development of meaningful standards and underscored the necessity of effective incentives if standards are to be successfully implemented. The Symposium panels, work groups, and written input surfaced four themes critical to NIST's on-going standards development process: 1) resilience building efforts need to focus on devising performance based standards that better assure the continuity of functions that are critical to the safety and well-being of communities; 2) social context is central to devising meaningful and lasting community and resilience standards; 3) resilience standards must be mindful of the regional context; and 4) it is vitally important to identify and eliminate barriers to building resilience and to establish policy and economic incentives that support early and widespread adoption of standards when making infrastructure investments. Devoting appropriate attention to these themes will significantly enhance the success of NIST's work in informing and advancing the resilience of America's communities and infrastructure.

APPENDIX A

Symposium Questions:

- **What are the practical, measurable standards for community resilience?**
- **What are the practical, measurable standards for infrastructure and buildings resilience?**
- **What processes should be created to adopt and implement standards for community, infrastructure and buildings resilience?**
- **What political, economic and social incentives can be created that would cause significant investment by the public sector, private sector, and individuals in bolstering community, infrastructure and buildings resilience?**

8:30-9:00	**Sign-in and Coffee**
9:00-9:30	**Welcome and Introductions** *Opening remarks from Steve Cauffman (Lead for Disaster Resilience, NIST,)Mel Bernstein (Senior Vice Provost for Research & Graduate Education, Northeastern University), and Steve Flynn (Director, Center for Resilience Studies, Northeastern University)*
9:30-11:00	**Hurricane Sandy Case Study** ***Session Discussion Leader:*** **Stephen Flynn***, Professor & Director, Center for Resilience Studies, Northeastern University* ***Panelists:*** ***David Abramson,*** *Director, National Center for Disaster Preparedness, Columbia University* **Bill Raisch,** *Director, International Center for Enterprise Preparedness, NYU* **Michael Bruno,** *Dean, Schaefer School of Engineering and Science, Stevens Institute* **Howard Kunreuther,** *Professor & Co-Director, Wharton Risk Management and Decision Processes Center, University of Pennsylvania* **Erwann Michel-Kerjan***, Executive Director, Wharton Risk Management and Decision Processes Center, University of Pennsylvania*
11:00-11:15	**Break**

11:15-12:30	**Community Resilience Trends** ***Session Discussion Leaders:*** **Warren Edwards,** *Director, Community and Regional Resilience Institute* **John Plodinec,** *Regional Technologies Associate Director, Community and Regional Resilience Institute* ***Panelists:*** **Susan Cutter,** *Director, Hazards Research Lab, University of South Carolina* **Scott Graham,** *Mid-Atlantic Division Disaster Executive, American Red Cross* **David Kaufman,** *Associate Administrator for Policy, Program Analysis, and International Affairs, FEMA* **Meir Elran,** *Senior Research Fellow, INSS, Tel Aviv University*
12:30-1:30	**Lunch**
Afternoon Sessions	
1:30-2:45	**Infrastructure Resilience Trends** ***Session Discussion Leader:*** **Stephen Flynn,** *Professor & Director, Center for Resilience Studies, Northeastern University* ***Panelists:*** ***Najib Abboud,*** *Principal and CTO, Wiedlinger Associates Inc.* **Jerry Hajjar,** *Chair, Department of Civil and Environmental Engineering, Northeastern University* **Jalal Mapar,** *Director, Resilient Systems Division, DHS S&T* **Steve Conrad,** *Manager, Resilience and Regulatory Effects Department, Sandia National Laboratories* **Klaus Thoma,** *Director, Fraunhofer EMI*
2:45-3:15	**Breakout Session Framing: Creating Resilience Standards – NIST Update** ***Steve Cauffman (NIST) will report on the progress of NIST's ongoing effort to develop a national framework for devising standards that support the measuring and advancement of resilient communities and infrastructure.***
3:15-3:30	**Break: Move to Breakout Sessions**

3:30-5:00	**Breakout Session A: Creating Infrastructure Resilience Standards** *This facilitated discussion will yield recommendations for devising standards to support the measuring and advancement of built-infrastructure resilience. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will present a 15-minute summary of its discussions and recommendations in plenary session on Day 2.*
3:30-5:00	**Breakout Session B: Creating Community Resilience Standards** *This facilitated discussion will yield recommendations for devising standards to support the measuring and advancement of community resilience. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will present a 15-minute summary of its discussions and recommendations in plenary session on Day 2.*
3:30-5:00	**Breakout Session C: Establishing and Adopting Resilience Standards** *This facilitated discussion will yield recommendations for advancing a collaborative process amongst the multiple standards-setting entities that can play a supportive role in developing resilience standards. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will present a 15-minute summary of its discussions and recommendations in plenary session on Day 2.*
3:30-5:00	**Breakout Session D: Creating Community Resilience Standards** *This facilitated discussion will yield recommendations for devising standards to support the measuring and advancement of community resilience. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will present a 15-minute summary of its recommendations in plenary session on Day 2.*
5:00-5:10	**Move to Wrap-up Session**
5:10-5:20	**Wrap Up and Adjourn for Day 1**

Day 2: Thursday, September 4, 2014	
8:00-8:30	**Coffee**
8:30-9:00	**Day 1 Recapitulation and Introduction to Day 2** *Hosts: NIST and Center for Resilience Studies*
9:00-10:00	**Creating Incentives for Resilience Investments** ***Session Discussion Leader:*** **Stephen Flynn,** *Professor & Director, Center for Resilience Studies, Northeastern University* ***Panelists:*** ***Eric Letvin,*** *Director, Hazard Mitigation and Risk Reduction Policy, NSC* **Laureen Coyne,** *Director, Risk and Insurance Management, MTA* **Roy Wright,** *Deputy Associate Administrator for Mitigation, FEMA* **Debra Ballen,** *General Council and Senior Vice President of Public Policy, IBHS*
10:00-10:15	**Move to Breakout Sessions**
10:15-11:45	**Breakout Session A: International Perspectives on Resilience Incentives and Global Issues** *This facilitated discussion focuses on the use of policy, economic, and social incentives in the international arena to encourage resilient investments. Several international participants have been asked to provide leading thoughts to spark ideas and discussion. The group will be asked to present a 15-minute summary of its discussions and recommendations in plenary session.*
10:15-11:45	**Breakout Session B: Creating Policy Incentives for Resilience Investments** *This facilitated discussion focuses on the creation and adoption of policy incentives for resilient investment in the United States. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will be asked to present a 15-minute summary of its discussions and recommendations in plenary session.*

10:15-11:45	**Breakout Session C: Creating Economic Incentives for Resilience Investments** *This facilitated discussion focuses on the creation and adoption of economic incentives for the United States. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will present a 15-minute summary of its discussions and recommendations in plenary session.*
10:15-11:45	**Breakout Session D: Creating Policy Incentives for Resilience Investments** *This facilitated discussion focuses on the creation and adoption of policy incentives for resilient investment in the United States. Several participants with expert and unique perspectives have been asked to provide leading thoughts to spark ideas and discussion. The group will be asked to present a 15-minute summary of its discussions and recommendations in plenary session.*
11:45-1:00	**Lunch**
1:00-2:00	**Breakout Group Reports – Creating Infrastructure Standards** *Breakout groups from Day 1 will have 15 minutes to present the results and recommendations of their discussions.*
2:00-3:00	**Breakout Group Reports – Creating Incentives for Resilience Investments** *Breakout groups from the morning will have 15 minutes to present the results and recommendations of their discussions.*
3:00-3:15	**Event Wrap-up & Next Steps** *Steve Flynn and Steve Cauffman will offer concluding remarks and their thoughts about how to put the Symposium's findings into action.*
3:15	**Adjourn Day 2**

APPENDIX B

Day 1, Breakout A: Creating Infrastructure Resilience Standards

1) Ask discussants to frame the group conversation with brief remarks that:
   a. Recap what they think are the most important performance goals for infrastructure resilience standards
   b. Identify standards/codes/guidelines that are being used or developed currently
   c. Provide examples of gaps in current codes or practices that should be ad dressed by standards
2) As conversation matures, questions to ask group:
   a. Can we define or describe criteria for critical infrastructure resilience?
   b. What standards must be developed in order to strengthen CI resilience? Are there some natural first standards that we should lead with?
   c. What are consistent performance goals or metrics for critical infrastructure?
      i. Buildings
      ii. Transportation
      iii. Energy
      iv. Water
      v. Communications and Information

Day 1, Breakout B: Creating Community Resilience Standards

1) Ask discussants to frame the group conversation with brief remarks that:
   a. Recap what they think are the most important considerations for establishing community resilience standards
   b. Help identify the important elements of community resilience to measure
   c. Identify steps/actions/approaches that address challenges to development of standards
   d. Provide examples of practices that are helping to develop community standards
2) As conversation matures, questions to ask group:
   a. Are there elements or approaches that MUST be part of any successful process to establish COMMUNITY resilience standards (in other words, if we don't do XXX, we will never get usable standards established)?
   b. What stakeholders must be involved?
   c. What standards must be developed in order to strengthen COMMUNITY resilience? Are there some natural first standards that we should lead with?
   d. What actions could YOUR organization take that would contribute to develop ment of resilience standards?
   e. What steps can be taken to ensure various domains/ jurisdictions adopt & use standards?

Day 1, Breakout C: Establishing and Adopting Resilience Standards

1) Ask discussants to frame the group conversation with brief remarks that:
   a. Recap what they think are the most important considerations for establishing community resilience standards

b. Help identify the important elements of community resilience to measure

c. Comment on which existing standard setting entities should be included in the development, validation and adoption process for resilience standards (community and infrastructure).

d. Identify steps/actions/approaches that address challenges to development and adoption of standards

2) As conversation matures, questions to ask group:

a. Are there elements or approaches that MUST be part of any successful process to establish CI or COMMUNITY resilience standards (in other words, if we don't do XXX, we will ever get usable standards established)?

b. What stakeholders must be involved?

c. What actions could YOUR organization take that would contribute to development of resilience standards?

d. What steps can be taken to ensure various domains/ jurisdictions adopt & use standards?

Day 1, Breakout D: Creating Infrastructure Resilience Standards

1) Ask discussants to frame the group conversation with brief remarks that:

a. Recap what they think are the most important performance goals for infrastructure resilience standards

b. Identify standards/codes/guidelines that are being used or developed currently

c. Provide examples of gaps in current codes or practices that should be addressed by standards

2) As conversation matures, questions to ask group:

a. Can we define or describe criteria for critical infrastructure resilience?

b. What standards must be developed in order to strengthen CI resilience? Are there some natural first standards that we should lead with?

c. What are consistent performance goals or metrics for critical infrastructure?

i. Buildings

ii. Transportation

iii. Energy

iv. Water

v. Communications and Information

Day 2, Breakout A: International Perspectives on Resilience Incentives & Global Issues

1) Ask discussants to frame the group conversation with brief remarks that:

a. Provide examples of policy, economic, or social incentives that support greater resilience investment

b. Identify an issue with resilience investment and suggest an approach for overcoming

c. Identify collaborative actions that could help address global issues with resilience investment

2) As conversation matures, questions to ask group:

a. Can we define or describe common criteria for effective resilience investment?

b. How can we strengthen public/private partnership in providing incentives for resilience investment?

c. What successful practices can be leverage/borrow from one another?

Day 2, Breakout B: Creating Policy Incentives for Resilience Investments

1) Ask discussants to frame the group conversation with brief remarks that:
   a. Provide examples of policy incentives that support greater resilience investment
   b. Identify an issue with resilience investment and suggest policy incentive for overcoming
   c. Identify collaborative actions that could result in improved policy incentives
2) As conversation matures, questions to ask group:
   a. Are there policy incentives that MUST be enacted in order to move resilience investment forward?
   b. Are there policy incentives that we can enact within current authorities?
   c. How can the private sector better support stronger policy incentives for resilience investment?
   d. What successful practices can we leverage or borrow?

Day 2, Breakout C: Creating Economic Incentives for Resilience Investments

1) Ask discussants to frame the group conversation with brief remarks that:
   a. Provide examples of economic incentives that support greater resilience investment
   b. Identify an issue with resilience investment and suggest an economic incentive for overcoming
   c. Identify collaborative actions that could result in improved economic incentives
   d. Identify disincentives to resilience investments that must be addressed so that economic incentives can be created
2) As conversation matures, questions to ask group:
   a. What are the economic incentives that MUST be enacted in order to move resilience investment forward?
   b. What policy or economic disincentives must be addressed to make new economic incentives realistic?
   c. Are there economic incentives that we can enact within insurance, financial, lending models?
   d. How can government policy better support stronger private sector incentives from insurance, banking, CI owner/operators for resilience investment?
   e. What successful practices can we leverage or borrow?

Day 2, Breakout A: International Perspectives on Resilience Incentives & Global Issues

1) Ask discussants to frame the group conversation with brief remarks that:
   a. Provide examples of policy, economic, or social incentives that support greater resilience investment
   b. Identify an issue with resilience investment and suggest an approach for overcoming
2) Identify collaborative actions that could help address global issues with resilience As conversation matures, questions to ask group:
   a. Can we define or describe common criteria for effective resilience investment?
   b. How can we strengthen public/private partnership in providing incentives for resilience investment?
   c. What successful practices can be leverage/borrow from one another?

APPENDIX C
PARTICIPANT WHITE PAPERS

Papers:

C.1: 'Resilience of what & to what; for whom & against what?', Jennifer Giroux, Senior Researcher, Center for Security Studies, ETH Zurich

C.2: Themes and Thoughts Arising from the NIST International Resilience Symposium, John Plodinec, Associate Director, Resilience Technologies, Community and Regional Resilience Institute

C.3: Reflections on Enhancing Community and Infrastructure Resilience, Tom Wilbanks, Senior Corporate Fellow, Oak Ridge National Laboratory

C.4: Resilience to natural disasters: the role of standards, Tim Davies, Department of Geological Sciences, University of Canterbury, New Zealand

C.5: Societal Resilience, Meir Elran, Senior Research Fellow, Institute of National Security Studies, Tel Aviv University

C.6: Reflections on the International Resilience Symposium, Russell E. Bowman

Several Symposium participants were asked to write papers (provided here in Appendix C) on resilience building standards and incentives, drawing from their expertise and their reflections on the Symposium discussions. These papers are solely the work of their authors and do not represent views held or endorsed by the Center for Resilience Studies, the George J. Kostas Research Institute for Homeland Security, Northeastern University, or the Meridian Institute.

C.1: 'Resilience of what & to what; for whom & against what? -- Reflections from the International Symposium on Disaster Resilience ', Jennifer Giroux, Senior Researcher, Center for Security Studies, ETH Zurich

In September 2014 a diverse group of practitioners and academics were brought together for the International Symposium on Developing Standards for Disaster Resilience of Buildings, Infrastructure and Communities, hosted by National Institute of Standards and Technology (NIST) in partnership with the Center for Resilience Studies at Northeastern University. This report features reflections on some of the key themes, findings and recommendations that flowed from the symposium.

Author

Jennifer Giroux is a Senior Researcher at the Center for Security Studies (CSS)/ETH Zurich. The views in this report are her own and do not necessarily reflect the views of CSS/ETH Zurich.

Acknowledgments

This paper was informed by key reflections from the symposium, many of which have been addressed while working on resilience topics at CSS/ETH Zurich where I work with the Risk & Resilience Team. My colleague Tim Prior also attended the symposium and together we discussed some of the key themes that captured our attention some of which are reflected in this paper.

Introduction

"What makes a city resilient? What enables a devastated metropolis to rebuild its physical fabric and recover its social fabric and cultural identity?" [1]

The symposium on 'Developing Standards for Disaster Resilience of Buildings, Infrastructure and Communities' was an excellent 2-day meeting that identified a number of the key themes and challenges that come with identifying and implementing the standards needed for building (or enhancing) the resilience of the built environment where socio-technical systems overlap. Of course this is no easy task given that the built environment is challenged by innate and systemic complexity, particularly in relation to the various issues that impact physical and social vulnerability. On one level these issues include increased and changing demands on services, meaning of infrastructure (for social systems) and its general deterioration (often caused by ageing). On another level these issues are caused by the effects of various hazards - from social unrest and terrorism to climate change and extreme weather events, to name a few. Consequently, Coaffee (2013) aptly describes how resilience has "come to symbolize the response to a range of environmental crises and economic recessionary 'shocks'."[2]

Over the course of 2-days the multidisciplinary group of participants covered numerous themes and issues, not all of which could or should be covered in this report. Rather the topics I will address here connect to my reflections during panels and the breakout sessions that I attended (day 1 group B; day 2 group A) as well as the themes/issues that I found most compelling based on my own background and experience. Overall, I often felt like the group was grappling with very basic questions, namely: 'resilience of what and to what; for whom and against what?' Given this, the reflections in this paper will connect to this theme that, for me, seemed to underlie many discussions and debates.

The following section will pick up the question 'resilience of what' by trying to untangle and contextualize the difference between the resilience of social and technical systems. While, reviewing the NIST documents and talking to NIST colleagues it's clear that factoring in the social system is an important one in the effort to build standards for the built environment. That said it seems that this effort is still a bit problematic. I suggest one way to better factor in the social system may be to distinguish between critical infrastructures and critical social infrastructures. Following this I will briefly discuss my observations regarding the way risk management is being used in the discussion on resilience. I think that this is a critical discussion particularly given that it informs the resource allocation process. Finally I use the concluding section that highlights a various recommendations that I found particularly compelling, such as: importance of engaging communities in the risk process, educational activities, international adoption of the Hyogo Framework, and the support of collaborative research activities that can fund info sharing, community case studies and rapid response research teams.

1 Campanella, T.J. (2006): Urban Resilience and the Recovery of New Orleans, Journal of the American Planning Association, 72(2), p141.

2 Coaffee, J. (2013). Rescaling and Responsibilising the Politics of Urban Resilience: From National Security to Local Place-making. Politics 33(4), p.241.

Resilience of What? Making a distinction between critical infrastructures & critical social infrastructures

"Resilient Cities are constructed to be strong and flexible rather than brittle and fragile… their lifeline systems of roads, utilities and other support facilities are designed to continue functioning in the face of rising water, high winds, shaking ground and terrorist attacks." [3]

As a social scientist with a background in Anthropology and policy I have found that my view of resilience is often different from my colleagues who come from a more technical background (e.g. those working on complex physical systems such as road networks, energy infrastructure and the like). For them resilience is a return to a previous state, it is, as Berkes (2007) defines, 'the ability to withstand or cope with a disaster by absorbing or withstanding the disturbance without losing core functionality.' But from a social (science) perspective, resilience is about movement, transformation, and (often) using the event as a catalyst for change. In this respect, in my understanding of resilience I question whether physical infrastructures can have adaptive, emergent capacities, which are inherent qualities of resilient systems? To illustrate it another way, while the former may refer to resilience as 'bouncing back' the latter increasingly uses the phrase 'bouncing forward'[4] Manyena et al. (2011) – a phrase which captures the participatory and adaptive capacity within social systems and the ability of communities to make meaningful choices about their recovery process.

In breakout group B on Day 1, such differences in understanding were clear. As a group we questioned whether it is even possible to set standards for 'communities'. Indeed as Alberti et al. (2003) aptly note, the built environment "has rich spatial and temporal heterogeneity—a complex mosaic of biological and physical patches in a matrix of infrastructure, human organizations, and social institutions."[5] Unpacking and understanding this complexity is challenging, let alone defining or understanding its resilience, particularly because complex socio-technical systems represent constantly evolving and dynamic spaces that cannot be simply understood as the sum of their parts. Resilience can and does mean different things to different parts of such systems, thus invoking questions like: resilience of what and to what? resilience for whom? and against what?.[6] Along this line, Giroux and Prior (2013) debated whether "resilience was about returning to a pre-disturbance state quickly? Or does resilience also involve change and transformation, which might result from experiential learning and the development of adaptive capacities?"[7] Table 1 distinguishes these two types of resilience.

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3 Godschalk, D.R. (2003). Urban Hazard Mitigation: Creating Resilient Cities. Natural Hazards Review, 4(3), pp.136-142

4 Manyena, S., O'Brien, G., O'Keefe, P. and Rose, J. (2011). Disaster resilience; A bounce back or bounce forward ability. Local Environment, 16, pp. 417-424.

5 Alberti, M. et al (2003): Integrating Humans into Ecology: Opportunities and Challenges for Studying Urban Ecosystems. BioScience 53(12), p.1171.

6 Hassler, U. & Kohler, N. (2014): Resilience in the built environment. Building Research & Information, 42(2), p.122.

7 Giroux, J. & Prior, T. (2013): Expressions of Resilience: From 'Bounce Back' to Adaptation. Factsheet, Risk & Resilience Team, Center for Security Studies, ETH Zurich, p. 4.

Table 1: Types of Resilience

	Resilience: Bounce Back	Resilience: Bounce forward/Adaptation
Results in:	Static outcome, where the objective is a return to existing function.	Dynamic process that results in an adaptive response to disturbance.
Temporal span:	Resilience is attributed if normal function is returned quickly.	Longer; characterised by social learning and reflection.
Applicable to:	Entities or system components whose value (or service) lies in a specific function.	Entities or system components whose value lies in the management and proper functioning of systems or system components.

One possible way to better anchor the social system into efforts to develop standards for the built environment might be to distinguish critical infrastructures (CI) and critical social infrastructures (CSI), the latter of which would include service such as informal and formal health services, relief organizations, etc., that often help communities cope with the impact of CI disruptions.[8] Rather than lumping those services into CI it may be helpful in this process to set standards for and distinguish CSI for the adaptive and emergent qualities that they possess (whereas CI systems are largely about bouncing back to previous state). Increasingly there is growing awareness that local residents are the first at the scene in the immediate aftermath of sudden on-set disasters. As discussed by Cole, Walters and Lynch (2011) they often constitute informal 'crowd-sourced' search and rescue teams and provide first aid assistance.[9] In the hours, days and weeks that follow, there is also evidence that spontaneous and informal networks may begin working more or less cooperatively with organizations that have formally trained for such events Brennan and Flint (2007).[10] In this respect, CI resilience within the built environment is better understood with an appreciation of the role that critical social infrastructures play in helping a community cope with the immediate and adverse effects caused by disruptions or damages to the built environment. In many cases, when CIs fail due to a hazard event, CSIs can be there to cushion the fall and provide another layer of support – or, to take a term from resilience studies, a type of redundancy – until CI can be restored. For instance, during a crisis the shutdown of hospitals often results in the social system shifting health services to other spaces, such as park or some other type of building that provides shelter, or providing mobile care. Another instructive example of the importance of social infrastructures lies in the danger posed by an epidemic: in such a case the built environment and technical infrastructures are left intact, but the social infrastructures are devastated, possibly including mass exodus of people, abandonment of critical infrastructures and their maintenance.

8 For a full discussion on the role of CSI within the context of urban resilience see: Giroux, J. and Herzog, M. (2014). Urban Resilience: considering technical and social infrastructures in complex human environments. SKI Focus Report 10, Risk & Resilience Team, Center for Security Studies, ETH Zurich, p. 4.

9 Cole, J., Walters, M. and Lynch, M. (2011). Part of the solution, not the problem: the crowd's role in emergency response. Contemporary Social Science: Journal of the Academy of Social Sciences, 6, pp. 361-375.

10 Brennan, M. and Flint, C. (2007). Uncovering the hidden dimensions of rural disaster mitigation; capacity building through community emergency response teams. Southern Rural Sociology, 22, pp. 111-126.

Setting standards for CSI's could be conducted by conceptualizing CSIs across the '4R' framework, which is well known in the disaster risk reduction (DDR) discussion:

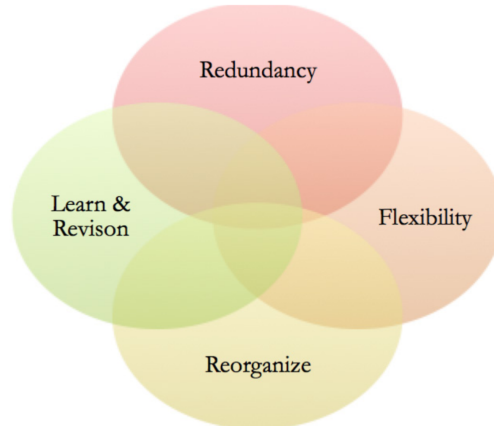

Figure 1: Four factors of resilient systems

- Reduction (or prevention): identifying and, if possible, eliminating or reducing risk through, for example, land-use planning that prevents residential development in flood zones.
- Readiness (or preparedness): Developing organizational and community-based operational systems (CSIs), capabilities and programmes before a disaster.
- Response: CSI actions taken immediately after disaster to save lives and property, and restore essential services. Examples include assembling and deploying search and rescue teams or sourcing potable water.
- Recovery: Reflection on the role of CSI in disaster; perform research and evaluation on effectiveness; incorporate lessons learned into strengthening CSI for future disasters. In the recovery phase, resilience is about both coping and using the event as a catalyst for positive change. To note one example, the small town of Kaiapoi that was impacted by the Canterbury earthquakes developed a 'Hub' that provided a range of council- and community-based services, and co-locating engineering and social recovery teams there, they enabled the co-production of short and mid-term solutions to take place. The goal of this approach was to enable the community to undertake their own recovery by empowering local service providers and using a full range of engagement strategies in their communications.

Another way to capture the role of CSIs that could inform standards is one that follows a framework noted by numerous studies on resilience, the main factors that must be considered include the following (as illustrated in Figure 2): redundancy, flexibility, reorganization, learning and revision. Discussion of CI resilience in the built environment often refers to the redundancy of CI systems, which is often referred to as linear and design-based concept. In our conceptualization, CI redundancy can refer to back-up power (e.g. generators), for example, but it can also refer to back-up CSI. For example, when power failures left half of New York City in the dark after the 2012 Superstorm Sandy, CSI services emerged to provide centers where people could gain access to electricity until traditional services were restored. Typically, redundancy measures are factored and built into the system before a crisis occurs.

Increasingly, many unique response measures are emerging that are signals of adaptive capacities and flexibility. In the Netherlands, for instance, a legal tool called "land re-adjustment" has been adapted to include areas that are below sea level and thus most at risk for flooding. According to Russell: "When a community is threatened, its land is re-allocated elsewhere and property lines redrawn."[11] Another example

11 Parry, W. Future Disasters: 10 Lessons from Superstorm Sandy. Live Science, 28 January 2013. http://www.livescience.com/26640-future-disasters-lessons-superstorm-sandy.html

includes relief and, more ad-hoc, volunteer efforts that emerge during a crisis. During the February 2014 flooding disaster in the United Kingdom a website was created within five hours that allowed volunteers to offer time, supplies and resources.[12] Such ad-hoc efforts operate alongside more traditional or formal relief efforts, such as those offered by the Salvation Army.[13] Both, however, are part of the portrait of critical social infrastructures that have self-organizing, emergent properties.

Indeed, examining the built environment holistically reveals an incredibly dynamic system that is able to absorb shocks in ways that avoid catastrophic failure – and in many respects this ability to avoid failure is very much a socially driven phenomenon. Individuals, and with that CSI, can be flexible during a hazard event, whereas there is less inherent flexibility and adaptability in fixed technical systems. In other words, where CI redundancy might fail during a hazard event, the partnered nature of CSI may confer the necessary flexibility to adapt the technical system to the circumstances and ensure the delivery of the essential services normally provided by CIs. For example, ad hoc shelters powered by generators can provide people with certain temporary services until power is restored.

Similarly, the ability to reorganize is another key component of the urban resilient system and one that is driven by the social elements of a system. Socio-technical systems have the ability to temporarily or permanently adapt, change and evolve in response to changing conditions because people drive them. As such, CSIs hold the ability to learn and revise actions and processes based on past experiences, and to identify and address relevant problems to ensure that actions are taken on the basis of relevant information and experiences. Within the urban space this factor is applicable to both CI and CSI as separate domains, but also in relation to each other. For example, during a hazard event, certain CI vulnerabilities can be illuminated, which then lead to actions that address those vulnerabilities post-event, by strengthening technical assets and implementing redundancy measures. These measures may include strengthening critical social infrastructures to help people cope during and post-crisis until CI can be restored, or to ensure CI can be restored.

From risk-based to resilience-based management

Despite all the talk of 'new risk environment', one which calls for a new approach that falls under the heading of 'resilience' we have yet to make the distinction between resilience vs. risk management but rather lump the two terms together. Risk Management processes begins with a review of risks (generated during risk estimation, characterization, and evaluation processes). From there, managers determine which risks are acceptable (no further management needed), tolerable (but risk reduction measures are necessary), or intolerable or contested. This process then informs the allocation of resources to mitigate and manage risks, particularly for the acceptable or tolerable risks but the intolerable or contested risks are more problematic in the risk-based resource allocation process. The term 'resilience' emerged within the context of a changing environment that is characterized by uncertainty, complexity, and ambiguity. In such contexts, risk management, and thus risk-based resource allocation, is not an effective process or mechanism to deal with the risk environ (since the risks are unknown or contested which means that resources will not be properly allocated to build more resilient infrastructures). Rather we need to distinguish resilience

12 See: http://floodvolunteers.co.uk/

13 See: http://www.salvationarmy.org.uk/uki/Northwest_floodrelief

management from risk management: with resilience management you do not start with defining the risks but rather with defining the system (e.g. its behavior and functions).

Indeed, many of the criticisms of traditional risk analyses and the risk management approach in the context of the shifting risk environment are closely associated with the formulaic and quantitative nature of the practice. In many ways, this approach seems a poor match to planning for and mitigating risk events, which are inherently characterized by a large variety of non-quantitative properties. In addition, the social element of disasters, and the socially driven processes associated with planning for disasters suggests the necessity to incorporate social factors into assessments of risk in the practice of risk management. The formulaic nature of the risk analysis step in the risk management cycle, while traditionally accepted and trusted, seems to fundamentally limit the application of these analyses to real-world risk management problems and situations. How to address this limitation is an important point of discussion:[14]

- How do newer approaches to risk management, like the development of national risk registers, improve planning processes by inherently incorporating planning and risk assessment processes? Do such approaches actually present better alternatives or increase the transparency of risk and planning processes?
- Can risk analyses be conducted in a community-based and deliberative fashion? Would this improve the way contextual characteristics in the 'risk system' are incorporated?
- With community/stakeholder involvement does awareness about planning practices and outcomes increase? Do processes and outcomes become appropriately transparent?
- How can qualitative scenario, forecasting or back-casting techniques be incorporated into risk assessments to better address uncertainties, unpredictability and interdependencies?
- Are scenario-independent resilience approaches prospectively better alternatives to dealing with and improving hazard event planning processes?

This debate between risk management vs. resilience management is an emerging debate in Switzerland within the context of allocating resources for unknowable, intolerable and/or contested risks. Switzerland's Federal Office for Civil Protection uses the generic risk management process shown in Figure 1, which highlights sequential relationships between disruptive events and activities (i.e. steps shown in figure 1 like preparation, intervention, Recondition, etc.) from the civil protection system, which are typically temporally variable. While the relationships between activities and events are clearly represented in cycles like Switzerland's, the process of negotiating the relationships, and determining how steps are made between the points on a risk management cycle are not always clear or transparent. However because this process is focused on the risk (i.e. center circle "assessing hazards and risk") rather than the system characteristics it does not always help in the allocation of resources for the more problematic and uncertain risks.

14 For a more in depth discussion on this see the forthcoming report: Prior, T. and Giroux, J. From risk analysis to preparedness planning: Linking consequence and likelihood; vulnerability and capability. Discussion paper: 4th D-A-CH Risk Workshop "Risk Analysis" 28.-30. April 2014, Bad Neuenahr-Ahrweiler, Germany Center for Security Studies, ETH Zurich (forthcoming)

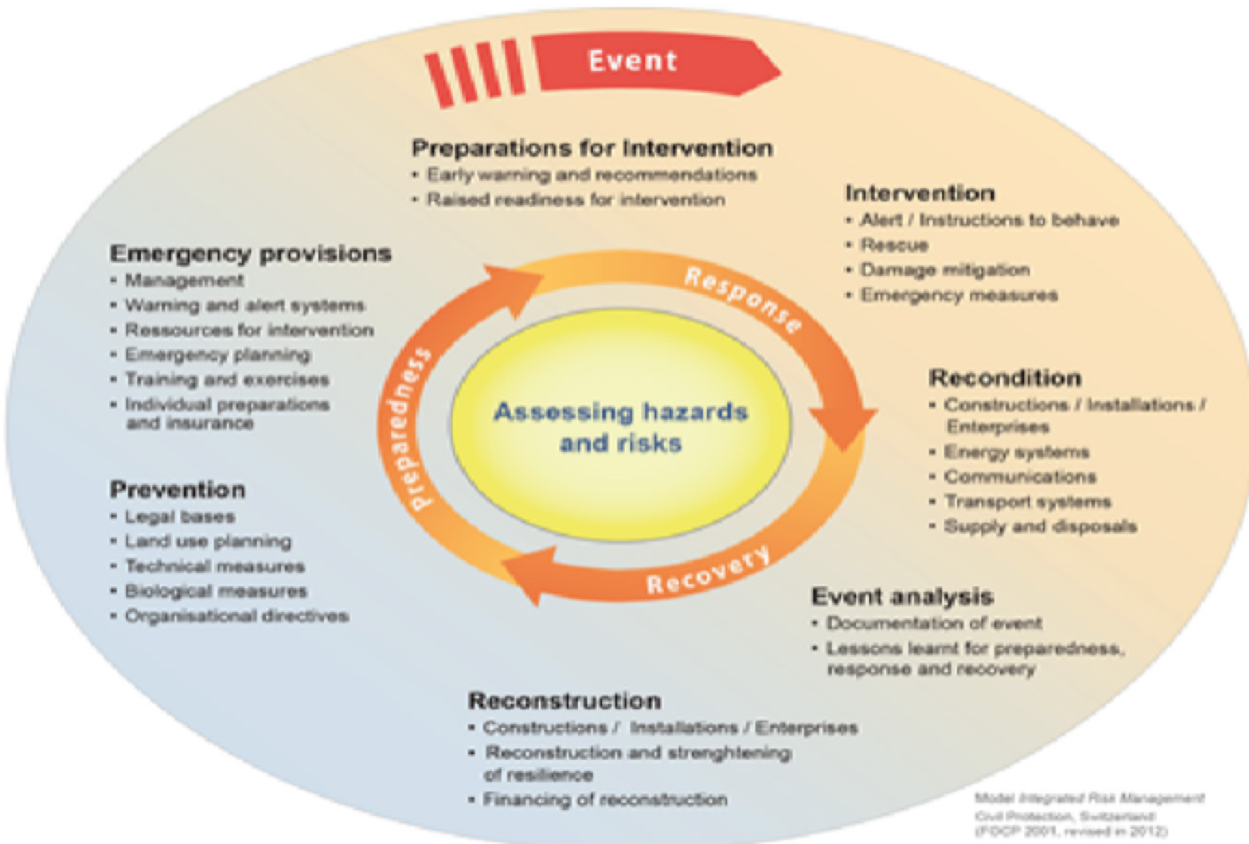

Figure 2: Risk management cycle used in Switzerland (from BABS).

A resilience management approach would begin with defining the system via modeling and simulation of complex systems in the built environment. Through this process you can determine the critical nodes, points of vulnerability, simulate behavior during various types of risks, etc. From there risk managers can focus on critical points that require more investment. However such a process requires changing mindsets. While technical risk managers may be aware of risk and consequence, the same cannot be said of the average person. In many cases the latter group are asked to hold faith in technical risk analyses, risk mapping and the like, without the ability to draw on their own experiences to supplement institutional advice and direction. Thus perhaps a way to develop more support for a resilience management approach and the allocation of, in some cases, significant resources would be to adopt a standard for discourse-based management which requires a participatory process involving various stakeholders; the goal being to produce a collective understanding of the system, how to interpret the situation (including changing risk picture), and how to design procedures.

Another related point pertains to the assumed relationship between risk analyses and planning, one that is founded on the contested notion that risk awareness and perception results in mitigation.[15] Risk communication has historically been the mechanism used to connect risk analyses and mitigation, but the

15 Ibid.

effectiveness of traditional (often passive) mechanisms that seek to increase risk awareness is now being challenged. While risk communication certainly must play a role in the risk analysis-planning relationship, new methods or techniques must be developed and adopted that adequately draw on information derived from risk analyses to inform effective planning and encourage mitigation activities.

Of course the risk analysis process is a standard practice in risk management. The practice has remained largely unaltered and is maintained as a central element in novel approaches to risk management like the development risk registers. Yet, the utility of traditional (and even more contextualized) risk analyses is limited when dealing with complex, uncertain or ambiguous risks, where drivers, dimensions, and technical characteristics are contested or unknown. In this case it is not possible to draw from historical data, which is inherently backward looking; rather, attention shifts to risk awareness and capability development. Risk governance expert Ortwin Renn has discussed the different approaches that are required for the management of more complex risks.[16] Renn (2008) highlights that effectively dealing with different types of risk (simple, complex, or ambiguous, etc.) necessitates varying approaches with respect to the participants and their level of involvement (figure 3). For instance, more ambiguous risks require a more extensive participatory process that includes actors from civil society, government, academia, and beyond. The goal here is not necessarily to identify/define and measure risks, but rather to reach consensus or tolerance for risk evaluation results and management options. Regarding this framework the following questions emerge:

- Does this framework represent a viable and effective means of actually linking risk analyses with planning processes in a practical way?
- Here the focus on risk analysis may become secondary to an assessment of the social, technical, economic and environmental characteristics of a system, and to an assessment of vulnerability and capability – could such a repositioning within the risk management cycle be valid or realistic?

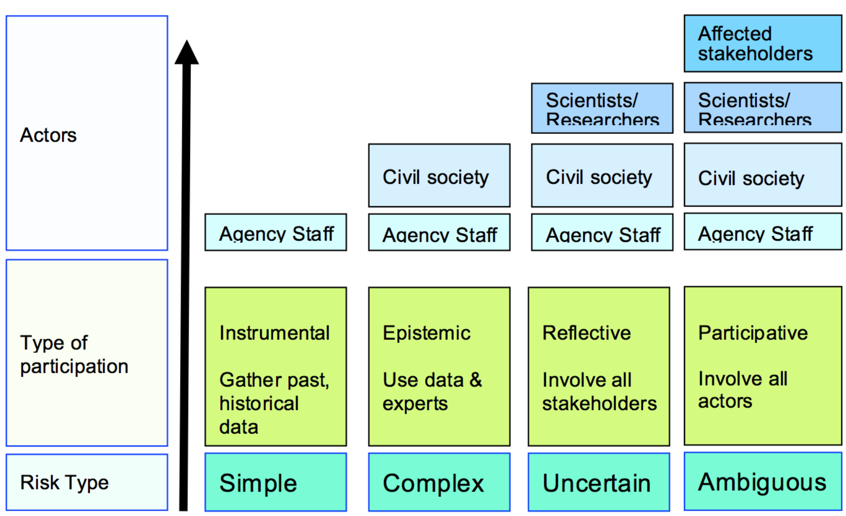

Figure 3: Risk governance framework for addressing different risks and the different types of strategies needed to gather information and measure (after Renn, 2008).

16 Renn, O. (2008) Risk governance: coping with uncertainty in a complex world. Earthscan

Final Reflections: Highlighting key action items

In addition to the points made in the two previous sections, I wanted to highlight specific recommendations that caught my attention during the symposium.

Education activities & engaging stakeholders in the risk process

I've already spoken quite a bit about engaging stakeholders in the risk process (in previous section) however one area that was not fully explored during the symposium is the role of education in general. In terms of setting infrastructure standards that incorporate the social system, the NIST could inform standards on resilience education that could be targeted towards a variety of different stakeholders. The uncertainty/complexity factor that is correlated with resilience thinking represents a starting point for an exploration and a systematic re-think of how we view, respond and manage our environment. As a few speakers noted, 'there is a need to meet people where they are' when it comes to building resilience. For me this implied incorporating resilience thinking and principles into areas that are part of their every day as well as designing educational programs that could be targeted to officials, students in K-12 and after-school programs, business owners, etc. Such programs can be helpful for increasing risk awareness, changing behavior, and have the social and political capital to support the funding needed to build/enhance resilience when resources need to be allocated. I would recommend looking at some of the insights provided in the RAND study "Building Community Resilience" which examines community education efforts, such as building public risk literacy (though focused on public health issues), activities to train agencies, etc.[17]

Additional points on the topic of engagement relate to how we view critical (physical) infrastructures vs. social infrastructures. In the former we have public private partnerships (PPP) whereby the private sector plays a role in decision-making, given their direct involvement in business continuity and contingency planning. However when we talk about community resilience we are finding that communities are being given "toolkits" & "guides for communities" that are created by government bodies. In the UK toolkit for building community resilience they even have instructions on developing leaders and volunteers and how they can organize. This state-centric approach made up of technical fixes basically goes against the principle of resilience. In a way, they read as though government is telling the community, on the one hand, to be resourceful and have self-help qualities but, on the other hand, it also telling them (through these explicit, detailed instructions) what their emergent behavior needs to be. In other words, it excludes citizens from decision-making process but also seeks to make them more responsible. In many respect this reveals how much government bodies are struggling with understanding resilience and adopting a resilience approach. By this I am referring to the tension between different types of management approaches: traditional hierarchical management is known as linear, structured, symmetrical, etc. But a resilience approach, especially when understood through the prism of complex adaptive systems theory, should be inclusive, dynamic, non-linear, etc. Thus, in considering ways to engage stakeholders in the process of building resilience it is important to reflect on the management structure and how that will impact individual and community agency. In this respect, agency means giving people the platform to first articulate what resilience means for their community and then developing the capacity for people to engage, make decisions and participate in that process. Indeed, not acknowledging the role of community agency in the process of developing community resilience could actually do more harm in the long run.

17 Chandra, A. et al (2011). Building Community Resilience to Disasters. RAND Technical Report.

Hyogo Framework

I appreciated the suggestion that as NIST embarks on developing resilience standards that they should examine the process underway with the Hyogo Framework for Action (HFA), which has been active since 2005 and will continue until 2015. The HFA was established in the aftermath of the Indian Ocean tsunami in 2004,[18] and represents arguably the most comprehensive attempt to set a global agenda for the reduction of disaster risks, and to monitor the implementation of that agenda. With the HFA coming to end in 2015, consultations and deliberations on all political levels are under way regarding a new international framework for the post-2015 period: commonly referred to as HFA2. During the symposium I questioned whether NIST had examined this process and to what degree it could inform this process in the US. As Roth and Prior note in the forthcoming report "The Hyogo Framework for Action successor and the prospects for international disaster risk reduction initiatives"[19] a critical contribution of HFA has been its contribution to the establishment of a global culture of safety and resilience:

> *"A case in point is the online website PreventionWeb,[20] run by UNISDR, which functions as a rich information resource and networking platform for practitioners and students in the field of disaster management, for example by providing shared definitions. Moreover, the HFA process has triggered the identification of best practices from all parts of the world that allows mutual and multicultural learning. A case in point is UNISDR's "Making Cities Resilient"[21] campaign." (pg 4)*

In this report they provided a useful table, provided here, that breaks down of HFA achievements and remaining challenges.[22]

	Achievements	Remaining Challenges
DRR as a political priority	Normative pressure; new institutions and legislations	Connection with global governance initiatives; binding implementation
Risk Analysis/monitoring	Multi-hazard; early warning	Social and economic vulnerabilities
Culture of safety and resilience	Growing conceptual consensus (resilience paradigm); International knowledge management (e.g. UNISDR)	Integration of local knowledge; Systematic scientific advisory mechanisms
Reduction of risk factors	(little achieved)	Appropriate resourcing Local reach
Disaster preparedness	Focus on preparedness and capacity-development	Inclusion of all relevant stakeholders

18 http://www.preventionweb.net/english/professional/publications/v.php?id=1037&pid:22&pif:3

19 Roth, F. and Prior, T. The Hyogo Framework for Action successor and the prospects for international disaster risk reduction initiatives. Risk & Resilience Team, Center for Security Studies, ETH Zurich, Forthcoming.

20 http://www.preventionweb.net

21 http://www.unisdr.org/campaign/resilientcities/

22 Roth, F. and Prior, T. (forthcoming), pg. 4.

Investing in research

Many of the recommendations provided at the symposium revealed that we are still lacking information and understanding of resilience in socio-technical systems. There is a rich literature of studies on critical infrastructure systems modeling and resilience as well as a rich literature on the qualities and behavior of resilient social systems. However there is little work that brings these worlds together. While I agree with the suggestion to carry out case studies or even deploy rapid research teams (following a disaster) there needs to be a common framework used for such an effort in order to compare the different cultures of resilience and enhance the modeling and simulation of social systems in the built environment. Just as systems modeling identifies component parts, research on the social system embedded in the built environment needs to, as Paton et al (2014) note, "identify the capacities that exist at personal, community, and societal levels and how they are integrated to facilitate individual and collective ability to cope, adapt, recover and learn from environmental hazard consequences."[23] One interesting framework developed by Paton et al (2014) could be useful for such comparative analysis (see figure 4), however it would need to be modified/adapted to incorporate more elements (or factors) of the built environment as well as the critical social infrastructures (previously discussed) that exist in the social space.

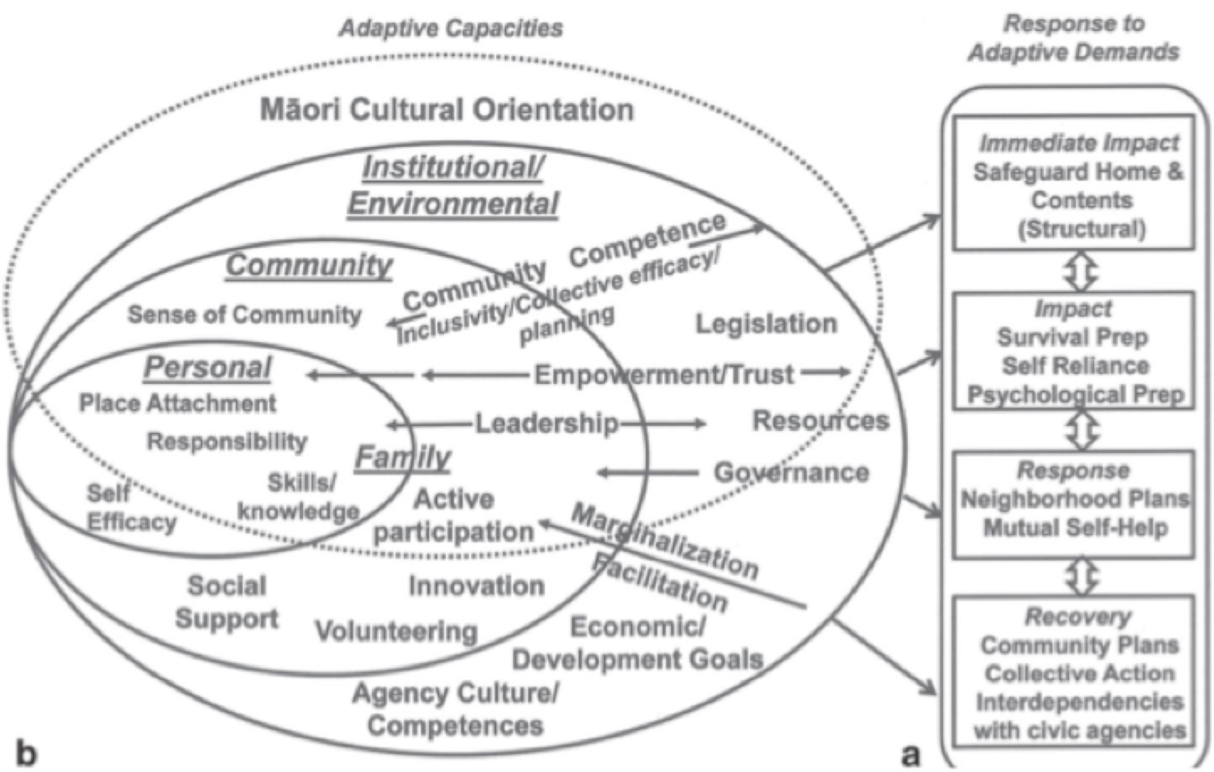

Figure 4: Paton et al framework[24] that shows responses to adaptive demands (over time) as well as adaptive capacities and interdependencies at various levels.

23 Paton. D. et al (2014). Chapter 15 Recovery and Development: Perspectives from New Zealand and Australia. In N. Kapucu, K. T. Liou (eds.), Disaster and Development, Environmental Hazards, Springer International Publishing Switzerland, pg. 256.

24 Ibid, pg. 259.

C.2: *Themes and Thoughts Arising from the NIST International Resilience Symposium*, John Plodinec, Associate Director, Resilience Technologies, Community and Regional Resilience Institute

Themes and Thoughts Arising from the NIST International Resilience Symposium

INTRODUCTION

The Center for Resilience Studies at Northeastern University and the National Institute of Standards and Technology held a two-day International Resilience Symposium 3-4 September, 2014. The purpose of the Symposium was to provide illumination on four questions:

- What are practical, measurable standards for community resilience?
- What are practical, measurable standards for infrastructure and buildings resilience?
- What processes should be created to adopt and implement standards for community, infrastructure and buildings resilience?
- What political, economic and social incentives can be created that would cause significant investment by the public sector, private sector, and individuals in bolstering community, infrastructure and buildings resilience?

A few themes seemed to weave the presentations and breakout sessions together. In the following, some of the more important themes are presented along with my observations from the perspective of a practitioner in community resilience.

Theme: *Communities should take a "resilience-centric" approach to their built environment that considers*

- *Cushionability.*
- *Resistance.*
- *Robustness.*
- *Redundancy.*
- *Graceful extensibility or failure.*

Observation:

There seemed to be general support for this concept. However, there is no unique mix of these five properties, i.e., when a community applies the concept to their particular situation, they may choose to emphasize one or more of these and ignore the rest. Further, the community's policy choices are likely to also depend on the specific part of the built environment being considered.

For example, when the Charleston, SC, region looked at the resilience of its health care system to earthquakes it quickly concluded that perhaps only 20% of its hospital beds would be available. Rather than trying to make its hospitals and clinics more resistant, the regional community chose to position "redundant" health care assets (essentially conex boxes adapted to medical use) at eighteen locations around the community. Conversely, when the bridge over the Cooper River was rebuilt, resistance was emphasized - the bridge was designed to withstand a magnitude 7.4 earthquake.

The key is that communities, in general, seem to focus on *functions*, not *assets* (e.g., health care, not hospitals). This points directly to one of the major difficulties facing NIST as they try to setstandards and metrics for community resilience.

There are a variety of strategies that a community may choose to maintain some semblance of functionality during and after a disruptive event. Further, a community may choose different strategies for different functional areas. Thus, in developing standards NIST should take care it does not preclude valid approaches that communities might choose.

Theme: *NIST should consider developing three types of standards:*

- *<u>Process standards</u>, for inclusive processes that could be used by communities and other owners of infrastructure and buildings to develop and implement strategies to minimize suffering and maximize the rate of recovery of the community.*
- *<u>Component standards</u>, to assure the survival (or quick recovery) of critical assets.*
- *<u>Performance standards</u> that are focused on the rapid recovery of functionality rather than the resistance of a specific component.*

Observations:

The three types of standards were discussed during the meeting with little care to differentiate among them or to provide NIST with more detailed guidance about what might be considered and what NIST's role might be.

The following reflects the Community and Regional Resilience Institute's (CARRI) experience working with communities. It is intended to help NIST identify some areas where each of the types of standards could be useful.

Process standards

In CARRI's experience, **communities have great difficulty in identifying the types of disasters they may face, and then developing and implementing strategies to deal with them. NIST could provide real value if it promulgated standards that reflected proven processes for each.**

A standard for identification of the types of disasters a community may face should not be considered an exercise in risk management. First, it may not be possible to assign a probability that a particular disruption will occur. Second, even if probabilities could be assigned to single types of disruptions (e.g., hurricanes, earthquakes, floods) that might not be useful if a community potentially could face a combination of disruptions. Charleston, SC, was just recovering from the "Great Cyclone" of 1885 when it was smashed by the earthquake of 1886. New Orleans was hit by Katrina and also had levees fail at water levels below their assumed failure point. It would be difficult for a community to determine the joint probability of these events.

As was mentioned briefly at the Symposium, an alternative approach might stress "possibility," not "probability," and focus on effects, especially loss of functionality, rather than on single types of events. Thus, a standard for this identification process might focus a community on the types of damage it might suffer (i.e., effects or consequences) rather than the types of events the community might experience.

But it is even more important - and difficult - for a community to develop and implement strategies to deal with the hazards it faces. Uncertainties in the likelihood of disruptive events inevitably collide with the certainties of the problems faced by communities daily - poverty, education, and day-to-day crises. Resilient communities find ways to weave resilience- enhancing actions into the fabric of their daily actions; a standard to help communities do this routinely would be most beneficial. CARRI's Community Resilience System (CRS) has had success in helping communities to do this; other approaches have been used successfully as well. In this case, a standard for the attributes of a successful approach ("to be successful, a community process should have the following attributes...") could be quite useful. Such a standard likely would reflect those common elements to all approaches that assure success.

Component standards

Most of the participants seemed to think that setting component standards is straightforward (likely true), but the acceptance and implementation of new standards presents a real challenge to NIST. Currently, there is a plethora of standards for parts of the built environment. Some are embedded in building codes, some are ANSI standards, some are reflected in Miami-Dade County test methods, some in professional codes. **Before embarking on development of new component standards, NIST would do well to engage with each of the relevant "standard- bearers" to both identify gaps as well as the determining the coverage of existing standards. These "standard-bearing" organizations would then be involved in filling gaps and assisting in the development and implementation of new standards.** In some cases, NIST may choose to actually leverage the resources of these organizations to develop a new standard that would then be endorsed by NIST.

Deciding whether to focus only on new or to include existing structures is another challenge in setting standards for "components." This was only briefly touched on at the Symposium. Clearly it is more straightforward to develop and apply standards that only apply to new construction. However, given the turnover time of our infrastructure (in some cases, we have water infrastructure that dates back to the late 1800's) it is important that this issue is consciously decided and documented. **NIST might choose to take a two-tier approach – initial standards that apply to new construction followed by consideration of standards around the much more complicated** (and probably contentious) **set of issues around existing infrastructure.**

Performance standards

A community's performance requirements for its infrastructure generally reflect a functional perspective, i.e., the members of the community are more concerned about "Continuity of Service," and aren't particularly concerned about the robustness or resilience of individual assets. Thus, performance requirements and standards derived from a community's needs will reflect how long the community can do without the service.

Consider an electric utility that experiences a disaster. There is an initial loss of capacity, followed by a gradual return of service to its customers. In this case, the "new normal" level of service is the same as that provided prior to the disaster (electric utilities almost never add new generation in response to a disaster). This loss of service will impact its customers: smaller businesses, with fewer resources than larger businesses, are more susceptible to a loss of service

– some small businesses will fail if the outage is extended. Larger businesses with their greater resources are less susceptible to loss of power but even they may eventually fail without electricity. These business failures caused by a loss-of-service event in turn can cascade into loss of tax revenue for local government, a loss of jobs, and an eventual loss of other services. In other words, the businesses in community establish a *de facto* performance requirement for electric power. Health care, water services, and every other part of the community – even families – establish performance requirements for loss of electrical service in a similar way.

More generally, the same holds true for all of the essential infrastructural services: the ability of the rest of the community to tolerate loss of service sets performance requirements for that service. In general, these requirements are likely to vary based on the community's economic and social makeup, i.e., there is no reason to expect that a single performance requirement (for example, for the system that provides electric power) will be applicable for every community. **Thus, in setting performance standards, NIST should recognize that communities are interested in perceived functionality and that consequently there will be a range of expectations of what an adequate standard of performance might be.**

Hopefully, a NIST Center of Excellence for Community Resilience will help elucidate this further. Through simulations, it should be possible to determine whether there is a minimum time that seems applicable for all communities (e.g., a performance requirement for an electric power system might be that power must be restored within X hours) for a given infrastructural service.

Theme: *Communities are not defined by jurisdictions. In today's world, they tend to be more regional in character.*

Observation:

This statement was reiterated on several occasions during the meeting. Unfortunately, the implications for NIST were not mentioned.

- Nearly all of the attempts to develop resilience metrics have revolved around defined jurisdictions – cities, counties, or states. Further, these metrics are generally based on publically available statistical data (e.g., from the Census Bureau) for these defined jurisdictions. Thus, **NIST has few signposts to point them toward metrics for regional communities.** CARRI's approach to the development of "metrics" for communities on a regional basis is one of the few available. In the assessment process in the CRS, a local community (usually a jurisdiction within a regional community) identifies its regional linkages and interdependencies. The community then evaluates these ties in terms of their ability to help the community recover from different kinds of disruptive events. Thus, to a large extent, the "metrics" actually reflect the involvement and engagement of regional entities with the local jurisdiction.

- It is difficult to define the boundaries (e.g., geographic, social, economic) of regional communities. People living in suburbia, for example, are members of their bedroom communities on most nights and weekends. However, their working lives and much of their social lives is likely to revolve around their nearby urban area. Further, businesses in a regional economic cluster may all rely on a single supplier located several states away. **If NIST chooses to develop metrics and standards for regional communities it will need to consider how to "bound" regional communities.** Use of membership functions (a la Lotfi Zadeh) could be a useful way to surmount this challenge.
- Many regional communities are located in more than one state. This means that regional approaches to resilience are likely to be constrained by the welter of regulations around insurance, finance, building codes, and utilities; as well as the many approaches to home rule. **Thus, attempts by regional communities that span more than one state to adopt and implement NIST-developed standards may be stymied by differences in state laws and regulations.**

Theme: *While local (or regional) government is usually an important component of a community, government can't make a community more resilient by itself. Each of the significant stakeholders in the community has to be involved. Engagement of the business sector is especially important since the business sector owns a majority of our nation's infrastructure and buildings and often has resources that the public sector does not have.*

Observations:

In many ways, local government is at the heart of a community. It is usually the Great Convener for the community, gathering people together to identify and solve problems. The leadership of the local government is often seen as the leadership of the community. Local government has a role in almost every aspect of a community's life.

However, having a role is not the same as being the sole – or even the main – actor in every specific aspect of community life. For example, local government regulates businesses and collects taxes and fees from them. But the economic health and resilience of the community generally have little to do with the involvement of local government. Government does not own most of the buildings in a community; usually does not provide the community's electricity; may not provide the community's water; and may not even be responsible for upkeep of many of the community's major transportation arteries. In fact, local government often is not the driving force that propels the community to greater resilience.

The reinvention of Charlotte, NC, in the '70's and '80's offers an instructive example. Throughout the first two thirds of the twentieth century, Charlotte's economic health was intimately tied to textiles and regional trade. When the textile industry began its slow decline in the '60's, the private sector – led by financier Hugh McColl and retailer John Belk – spearheaded the transformation of Charlotte from a regional center of trade to the second largest financial center in the country, and the home of eight Fortune 500 firms. Local government did play a role (e.g., John Belk eventually became mayor) but it was the private sector that was the key to the city's resilience. **Thus, in developing standards and incentives, NIST should seek to engage all stakeholders, especially the business sector.**

Theme: *Standards and metrics for community resilience should consider a community's financial, environmental (both built and natural) and social capital.*

Observation:

At the Symposium, there was general agreement that infrastructural resilience involves both engineering and non-engineering aspects. However, as Kristen MacAskill and Peter Guthrie state, "The reality is that both *structural* and *non-structural* approaches have value; the challenge is in finding the right balance." NIST received little guidance at the Symposium about how to strike that balance.

In his talk, David Abramson indirectly indicated an important part of striking that balance: the **resilience of any one part of the community will depend on and/or have an impact on the resilience of all of the other parts in some way**. **Thus, resilience standards and metrics have to be embedded in the context of the Whole Community.** No part of modern communities can be considered an isolated island - all are connected in some way. Abramson pointed out the communication difficulties especially communication overload, the unavailability of the work force, problems with technology and energy, challenges to the water system, poor governance (as opposed to government) due to a lack of prior planning, and the challenges faced by those with special needs in the aftermath of Sandy. In his talk, Michael Bruno illustrated how an institution of higher education can impact the rest of the community.

In striking the balance, NIST should also recognize that the risk management and resilience strategies a community employs reflect both the community's resources and its competence – its maturity. A simple model of community maturity might envision three community types.

At the lowest level are communities with few resources. These are likely to be focused on simply surviving a disruptive event. Their resilience strategies will entail garnering external resources as rapidly as possible after an event. These communities would most likely take little action to prevent or mitigate disruptions simply because of the lack of resources. With good leadership a community at this lowest level may be able to ascend to a higher level; without it, the community is doomed to live poised on a knife's edge.

Communities at an intermediate level have enough discretionary resources to take significant action to become more resilient. These almost certainly include prevention and mitigation, and sometimes include more forward-looking actions (e.g., maintaining a reserve fund; providing the supplies the regional transportation system needs in order to accommodate pet owners during an emergency; organizing evacuation so that community leaders maintain contact with evacuees no matter where they are). In general, these communities are focused on bouncing back from disaster. Almost always, the leaders of these communities are competent managers.

There are relatively few communities at the highest level of maturity. They recognize that resilience requires investment and have the resources to do so. These communities are not only prepared for disruptive events but are actively seeking opportunities to improve themselves; i.e., acting as agents of change. The leadership of these communities – including leaders from each part of the community – is able to work as a team to improve the entire community. The leadership's overall approach is that "a rising tide lifts all boats;" thus, investment in one part of the community is not seen as a zero sum game.

A model that explicitly includes both the structural and non-structural aspects of resilience as well as reflecting the interdependencies among the various parts of the community is another key component in striking the right balance. Hopefully, NIST's Center of Excellence for Community Resilience will provide that sort of model.

An example is the very simple "practitioners' model" that CARRI has used to guide its work. In this model, the community is parsed into "service areas," each providing a core service to the community (e.g., energy; water; health care; finance; local government). The focus is on functionality not individual assets.

For each service area, its response to a negative change occurring at time t=0 is considered to follow a loss-recovery curve that can be deconvoluted as follows:

$$F_i(t) = F_i(0) - L_i(t) + w_i(t) \bullet R_i(t)$$

where

$F_i(0)$ is the functional capacity of service area "i" immediately before the negative change occurs, L(t) is the loss of capacity as a function of time, $R_i(t)$ are the resources available to the community for recovery of service area "i," and $w_i(t)$ is the efficiency with which those resources can be used.

A model such as this has the following advantages in terms of striking the balance.

- It explicitly considers each part of the community. Thus, it reflects that different parts of the community may recover from disruption at different rates and to different levels, i.e., one part of the community may be more or less resilient than other parts.
- For the infrastructural service areas, it includes both structural and non-structural components in a fairly natural way. For these service areas, the loss function, $L_i(t)$ reflects the structural robustness of the system. The resources available for recovery of functionality, and the efficiency with which those resources can be used reflect the non-structural "strength" of the service area.
- Explicit inclusion of time is useful in pointing that a community will gain new resources over time and potentially learn to use them better.
- The efficiency function includes prior planning, leadership and connectivity reflecting the social capital for each service area, while $R_i(t)$ reflects the financial and human resources available for recovery.
- It also leads to a natural differentiation among the types of strategies that a community may follow to enhance its resilience. The community may choose to boost its initial capacity in order to have redundant resources (increase $F_i(0)$); it may choose to make its infrastructure more resistant to disruption (reduce $L_i(t)$); it may choose to increase the resources available for recovery (increase $R_i(t)$); or it may choose to increase its ability to use the resources available to it (increase $w_i(t)$).

This is not to recommend that NIST use this model, but to point out that a model that explicitly includes both structural and non-structural factors will be quite useful to NIST in striking the needed balance. As George Box famously said, "All models are wrong; some are useful."

Theme: *Acceptance of standards and metrics for either community resilience or infrastructure and buildings requires engagement of all of the stakeholders who will use the standards in any way.*

Observation:

As the preceding section indicates, it is highly unlikely that NIST can develop a single set of standards or metrics that will be applicable across all sectors. Different sectors are regulated in different ways. Ownership of assets varies widely across sectors – even within a single sector. For some types of infrastructure, "standards" effectively already exist (e.g., Miami-Dade County testing protocols are *de facto* standards aimed at minimizing the damage due to hurricanes). Thus, the thrust of this theme is that **NIST should consider developing standards on a sector- by-sector basis. In each sector, NIST should find ways to engage the "user" community – those who will be expected to be a part of either using or enforcing the standards.**

Theme: *Metrics are necessary to provide a "baseline" understanding of a community's resilience, and to indicate the community's evolving maturity in terms of resilience.*

Observation:

This statement was reiterated on several occasions during the meeting. Unfortunately, NIST received little guidance about how to develop metrics. NIST will face several challenges in developing resilience metrics (in addition to those already mentioned):

- A community's resilience is revealed through its response to and recovery from a disruption. In this sense, we can only be certain about a community's resilience after we see it come through a storm. This implies that resilience is displayed through the actions taken by the community.
- A community's resilience depends on the type of disruption, the magnitude of the disruption, how the community is structured and how it behaves. Carpenter and Walker a decade ago made a similar point. A natural disaster's first points of attack are the physical parts of a community; a recession first attacks a community's economic infrastructure; a pandemic's initial point of attack is the people who live in the community. Different communities have taken different paths toward recovery from the same event – but have still recovered from Katrina or, later, Sandy. Gulf Coast communities impacted by both Katrina and the BP oil spill followed very different paths in recovering from the oil spill than they took in recovering from Hurricane Katrina.
- Vulnerability is not always the opposite of resilience. It is well recognized that resilience has many definitions, but a common thread is action – bouncing back or at least adapting to adversity. Vulnerability may indicate susceptibility to a type of disruptive event – for example, coastal communities are susceptible to hurricanes. Two coastal communities may be equally vulnerable and yet one may be much more resilient than the other. Conversely, a poor community is generally more vulnerable than a rich one; in this case, vulnerability is a (negative) indicator of resilience. Or, to put it another way, resilience is a manifestation of strength; resilience metrics need to focus on a community's strengths and weaknesses (those areas where it lacks the strength necessary for recovery).

CARRI has found that providing answers to the following questions enhances the likelihood that the metrics will in fact be useful and used by a community.

What is the purpose of the metric, i.e., how will it be used?

Who will use the metrics?

Who will collect the data?

In what domains will data be collected?

How will data be collected?

When and how frequently should data be collected?

Is the validity of the metric established?

NIST should consider developing specific answers to each of these questions as the first step in metrics development.

Theme: *Incentives can play a major role in speeding the adoption of resilience standards, as can the elimination of barriers. Incentives may include innovations in project finance, in insurance or a smart restructuring of regulatory regimes.*

Observation:

These discussions were among the most spirited in the Symposium. The importance of innovation was stressed. For example, Laura Coyne's presentation on the use of catastrophic bonds by the MTA pointed out the value of non-traditional financing schemes. Mark Freeman, of Loughborough University (UK), briefly discussed a British program that allowed certain types of resilience-building projects to use a more favorable discount rate in order to secure project funding. This could be especially useful for energy efficiency projects in the US because it could increase the projected return-on-investment or decrease the payback period, thus, broadening the number and type of projects that to be considered.

Steve Flynn suggested changing the Stafford Act so that the community share of the funds needed to recover from a disaster would greatly increase. The rationale is along the lines that if the federal government is paying the lion's share of the costs of disaster, communities have little incentive to take actions to increase their resilience. If communities have to pay more of the costs, they will take action so costs go down. This argument is similar to one often made about the costs of health care – if patients have to pay more of the bill, they will be better consumers and costs will decrease. But health care costs continue their inexorable climb – it is not clear why the costs of disasters would behave differently.

It probably would be more useful to **identify the various components of the costs of disasters and seek ways to reduce each of them**. For example, debris management from Hurricane Katrina costs accounted for about five per cent of the total funds provided by the federal government to the affected states. The cost would be the same no matter who paid the bill.

However, if regulatory barriers could be overcome (e.g., pre-approval of waivers for disposition of certain types of wastes) then costs would be reduced. **While NIST is unlikely to be in a position to provide incentives, it could help to reduce the costs of disasters by working with other agencies (Corps of Engineers, FEMA, EPA) to develop innovative practices to reduce the costs of demolition, debris removal and other aspects of dealing with disasters.**

At the Symposium, there was also some discussion of resilience enablers. As noted above, modern communities are more regional in character than they used to be. **States could effectively incentivize greater resilience if they encouraged the formation of regional coalitions.** These can take many forms: regional technology clusters, encouragement of regional councils of government, or formulation of economic development strategies on a regional rather than a community basis. In this regard, Governor Cuomo's creation of Regional Economic Development Councils in New York, and provision of funding for each to forge a regional long-term economic development strategy, should prove to be a notable resilience enabler.

Theme: *There is a need for a Global Research Network focused on resilience.*

Observation:

After the Symposium was completed, more than 30 of the participants met to discuss formation of a Global Research Network (GRN) focused on community or societal resilience. There was agreement on the need to form such a group and by the attendees to participate in a GRN. There seemed to be a consensus that the Network could expedite the research and development needed to achieve greater resilience. However, there have been similar meetings held in the past that have had little lasting success.

In order to be successful, the organizers of the GRN should consider the following:

- The Network needs a home – some organization has to take ownership and responsibility for nurturing the GRN. Things like setting up listserv's and other communication channels, providing regular updates on progress, ensuring verbal commitments are commitments to act together, and other low-level tasks are "easy" but the sheer volume of work that needs to be done is daunting. Also, funding is required to make this happen. The founders should consider grafting the GRN onto an existing effort such as ANDROID (the EU-supported Academic Network for Disaster Resilience to Optimise educatIonal Development).
- The GRN needs an accomplishment – something tangible that shows that the members working together can provide value. Examples might include
    - o Building a path out of the quagmire of defining resilience. This could be done by identifying the characteristics of a resilient community (Meir Elran has provided a start on this.) or by developing a taxonomy of definitions that clearly delineates

their applicability (MacAskill and Guthrie at the University Cambridge have an interesting take on this in a forthcoming paper.).

  - Developing a “maturity scale” for communities in terms of their resilience.
  - Establishing a database of successful practices for communities to use to enhance their resilience.

- The Network needs a charter – a statement of what it intends to accomplish and how it will function.

CONCLUSION

Important themes developed in the far-ranging discussions at the Symposium have been summarized above. The possible implications of these and challenges they pose for NIST have been identified as well as suggestions that NIST may wish to consider. A few of these bear repeating.

- In developing standards and standardized metrics, NIST should engage early and often with the “user communities” – those who will use the standards or metrics, those who will collect the data for metrics, and those who will enforce standards. This of necessity includes both private and public entities.

- Perhaps the biggest challenge facing NIST is striking the balance between “structural” and “non-structural” (social, economic, environmental) factors.

- In crafting metrics and standards around community resilience, NIST must recognize the diversity among communities, and the variety of approaches different communities may take to resolve similar problems. Governance is a key part of this, particularly when considering regional communities.

- NIST should carefully consider whether standards it develops apply only to new construction.

NIST is to be commended for reaching as broadly as it has as it takes on these difficult challenges. This proactive approach bodes well for a successful outcome.

C.3: *Reflections on Enhancing Community and Infrastructure Resilience,* Tom Wilbanks, Senior Corporate Fellow, Oak Ridge National Laboratory

REFLECTIONS ON ENHANCING COMMUNITY AND INFRASTRUCTURE RESILIENCE

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Reflections on Themes, Findings, and Recommendations Resulting from the International Resilience Symposium, organized by the Northeastern University Center for Resilience Studies and the National Institute of Standards and Technology, September 3-4, 2014

September 2014

REFLECTIONS ON ENHANCING COMMUNITY AND INFRASTRUCTURE RESILIENCE

I. *Introduction*

Organized and sponsored by Northeastern University's Center for Resilience Studies and the National Institute of Standards and Technology (NIST), with logistical assistance from the Meridian Institute, an International Resilience Symposium was held at NIST on September 3-4, 2014, to bring together a diverse group of professionals from the US and other countries to share their thoughts about (a) the development of standards for community and infrastructure/ buildings resilience and (b) ways that incentives might be developed to catalyze investments in enhancing resilience. The symposium was actively and vigorously led by Steve Flynn, Director of the Northeastern center and a national leader in discussions of resilience needs and options.

The Symposium was one of a number of recent initiatives to try to improve the understanding of the powerful concept of "resilience," to try to move the concept toward operational metrics and strategies that would promote actual improvements in community and infrastructure resilience, and to broaden the community of researchers and practitioners involved in these processes.

As the discussion at the Symposium noted repeatedly, nobody is opposed to resilience; but, if so, why does progress toward realizing it seem to be so slow? If resilience is fundamentally a matter of existing and even thriving in a world pervaded by risks and surprises – which sounds both necessary and attractive – what can we do to make this a part of our national culture at all scales: from national and regional to local and even individual, family, and neighborhood attitudes and values?

II. *Revisiting the "Resilience" Concept*

"Resilience" has emerged in recent years as a term that captures what we seek in risk management for the human systems, built infrastructures, and environments that we value. It is more proactive than "vulnerability," which refers to threats rather than responses; or "adaptation," which tends to imply reactive coping with threats; or "emergency preparedness," which tends to imply readiness for disruptions rather than a reduction in the effects of disruptions. In fact, it includes all of these narrower concepts in a definition that looks forward not only to risk reduction but to sustained economic, social, and environmental development in the face of continuing risks from a variety of possible driving forces:

But if resilience is going to be a powerful force for action, it needs to be capable of evaluation. Is a particular community or infrastructure X more or less resilient than Y? Is it becoming more or less resilient through time? What might be the payoffs from a proposed investment in enhancing its resilience? This has led to a growing demand for resilience "metrics" that can be used for purposes ranging from (a) defining baseline conditions within a system and monitoring changes through time to (b) making decisions about the allocation of management and financial resources to promote resilience.

Efforts to respond to this demand have found the process to be frustratingly difficult. For example, "resilience" is relative: for what? for whom? why? who decides? Developing a metric is more tractable if the focus is relatively narrow, but the reality is that resilience is deeply imbedded in interdependencies between systems and scales. Narrowness misses the point. In addition, a metric has the most meaning if it is developed through bottom-up participation by community and infrastructure stakeholders, who tend to have a range of goals and perspectives; but such bottom-up processes result in metrics that are often difficult to compare between communities and infrastructures.

In introductory remarks at the symposium, [name redacted] suggested several reasons why progress has been so slow, aside from the difficulty of measuring resilience: (a) groups and individuals exposed to risks are too poorly informed about those risks: (b) most groups and individuals are too confident that risks will be managed by current capabilities, or at least by parties other than themselves; (c) talking about risks without practical ways to address them is uncomfortable for decision-makers; (d) incentives are lacking for actions to increase resilience; and (e) organizational structures are lacking for addressing systemic and scale interdependencies. Contributing to the fuzziness of the resilience concept has been its relatively independent use across communities of research and practice that are not well-connected with each other (e.g., communities, built infrastructures, and emergency preparedness) and its overlaps with related concepts such as adaptation and sustainability – problems that the symposium was, in part, organized to address.

A particular challenge is that resilience concerns are often focused not only on multiple threats but on possible exposures to episodic low-probability/high-consequence disruptions from such growing threats as climate change. Allocating significant resources to deal with possible threats in the future whose likelihood is surrounded by uncertainty, when there are many other competing needs for such resources in the present, is often a difficult decision – which can imply a need to associate actions that improve resilience to future threats with other kinds of payoffs from those actions in the more immediate future. An additional requirement is to increase the recognition of decision-makers and stakeholders that the future is very likely to contain different and possibly more surprises for communities and infrastructures than the past – combined with a likelihood that roles of government in coping with such stresses are likely to be constrained by budget limitations and other competing priorities, while governmental leaders are virtually certain to be a focus of criticism if those surprises are unpleasant. A very daunting predicament, where good ideas might be especially welcome.

Other challenges include:

(1) The fact that resilience actions are rooted in the sustainability of social processes that shape driving forces and implementation. Resilience actions in the absence of a supportive social context are likely themselves not to be sustainable.

(2) The fact that, in some cases, threats may be so large in magnitude that resilience can only be achieved through <u>transformational</u> change – significant changes in the nature, scale, and/or location of systems, facilities, and activities – which is a bigger challenge for decision-making and implementation than incremental change.

On the other hand, if resilience truly reduces risks for communities and/or infrastructures, then elements of society who value risk reduction (such as insurance and financial institutions, and social organizations who care about human well-being) should be prepared to reward it. A further challenge is to get to the point where resilience metrics are persuasive enough to "mainstream" such incentives, with broad social, market, and policy support.

III. Perspectives on Community Resilience

Community resilience has been a particular concern, following the experience with Gulf Coast hurricanes in 2005 and 2007 and with Northeastern storms such as Irene in 2011 and Sandy in 2012. It was a focus of the Community and Regional Resilience Insitute (CARRI) from 2007 to 2011, including a very effective Community Leaders Working Group; and it is the current focus of the NAS/NRC Roundtable on Risk, Resilience, and Extreme Events.

The fundamental reality is that communities are highly resistant to well-intentioned efforts by academics and others to develop quantitative metrics that might be connected with resilience standards or certification, based on available data on physical conditions and/or community well-being. In virtually every case, they believe that each community is in important respects unique in its threats, its needs, its ways of confronting challenges, and its relationships with state, regional, and national institutions the public private, and voluntary sectors. They tend to be less concerned about external financial rewards for resilience improvements and more concerned about how resilience makes their own communities healthier and better.

The tradition in seeking measures of community resilience has been to look for measures of community well-being, such as the number of hospital beds per capita, and/or of physical conditions, such as available evacuation routes. It has been especially attractive to try to populate metrics with variables based on county-level census data (e.g., Cutter). Many top-down approaches have been developed, generally aimed at critical community infrastructures; and there are a few bottom-up approaches as well, such as a NOAA coastal community resilience index (scorecard-based) and the Communities Advancing Resilience Toolkit (CART) (see NAS/NRC, *Disaster Resilience*, 2012).

But one insight from the CARRI experience has been that, to community leaders, resilience is a social process, not a set of physical conditions. It is rooted in capabilities in a community to come together in a time of crisis and transcend typical barriers between public and private sector, city-wide structures and neighborhoods, rich and poor. One can imagine a set of dimensions of "social capital" that would capture this perspective, e.g., (a) social engagement, connectivity, and inclusiveness, measured for instance by the extent and diversity of participation in community activities; (b) community resourcefulness: its capacity for collective action as one community vs. competing interests; and (c) community resources for coping with threats and disruptions. The problem is that it is very difficult to find measures of these kinds of community dimensions in sets of social indicators that have developed for all or most communities. A few pioneering efforts have been made, such as RAND, 2011, and Norris, 2008; but there is no consensus on a workable approach that would not require new data development for US communities.

As indicated earlier, perhaps the most fundamental issue for metrics, standards, or certification approaches for evaluating the resilience of communities is that comparisons across communities imply that "one size fits all" for community resilience, which only makes sense for certain specific purposes. Two issues are often worth considering in developing metrics: (1) What is the metric for? Who would use it and for what? Is the proposed metric and the information to support it credible to the user (e.g., an insurer of public infrastructure in a community)? (2) Even where a single metric for the resilience of many communities is not achievable, can metrics be developed for selected determinants of community resilience as an indicator of status, progress, and needs for at least those driving forces?

IV. Perspectives on Infrastructure Resilience

Many of the participants in the symposium expected that developing standards for infrastructure resilience would be far easier than for communities – tending to reflect engineering judgments about sensitivities of built structures to risks of disruptions rather than the social complexities of communities. In fact, however, the discussion was far more nuanced than this, connecting with a wider variety of knowledge and experience.

The starting point was a strong consensus on three issues, that:

(1) infrastructure resilience to particular risks and threats is related to overall infrastructure health, and we have too limited a capacity to assess infrastructure health;

(2) actions to increase infrastructure resilience should start by identifying the desired outcome – more clearly than "increased resilience." What are the performance goals? Metrics can be of a number of different types. For example, an NAS/NRC report on the appropriate use of metrics for the Climate Change Science Program (*Thinking Strategically*, 2005) listed five types:

- process metrics (measuring a course of action)
- input metrics (measuring tangible quantities inserted in a process to achieve a goal)
- output metrics (measuring products or services delivered)
- outcome metrics (measuring results)
- impact metrics (measuring longer-term consequences)

(3) the resilience of particular infrastructures in particular places is powerfully linked to interconnections between infrastructures, places, and systems: e.g., engineered vs. operational vs. policy; and between different kinds of infrastructures, such as energy, communication, and transportation; and between urban areas and the regions around them – when responsibilities for infrastructure resilience are typically very fragmented.

Avenues for progress begin with building on existing "mainstreamed" processes and practices. Examples include normal infrastructure replacement and revitalization cycles (although they are proving to be very slow for public sector infrastructures in this country) and existing codes and standards for buildings and other built infrastructures. Incorporating resilience/adaptation/sustainability in normal infrastructure planning can reduce its incremental cost and simplify decision processes; and codes and standards can often be updated by the engineering community to reflect new knowledge, as the American Society for Civil Engineering (ASCE) is currently doing for climate change adaptation. One danger that has been noted in the research literature is a "levee effect," where awareness of a risk to society and/or infrastructure managers is addressed by a specific action (e.g., building a levee to protect against river flooding), after which stakeholders stop worrying about the risk because it has been taken care of – when other factors shaping the risk continue to be threats.

But symposium participants also made the point that codes and standards do not change behavior and deliver resilience unless they are understood and supported by a broad range of stakeholders. Engineering actions are determined by people, implemented by institutions, and sustained by social consensus. If significant improvements in the resilience of US infrastructures are to be made, there is a need for far better – and far more broadly communicated – information about the current status and vulnerabilities of infrastructures, especially in the public sector and in private-sector infrastructures whose reliability affects public sector infrastructure. Specifically, this includes changes in current and future conditions and driving forces compared with familiar history, in order to generate support for practices that build resilience. There are almost certainly potentials to make better use of available data sets in this regard (as the 2014 National Climate Assessment has done) and to increase emphasis on the co-production of data and information, top-down and bottom-up, by interested parties at a variety of scales and roles in society.

At the same time, there are potentials to apply science and technology to make the job easier. For example, if metrics can be developed for at least selected aspects of resilience – if not for resilience as a whole – then sensors and control systems can be developed for monitoring infrastructure performance and responding to emerging threats. Moreover, there are many other possible opportunities for S&T innovation, such as innovative construction approaches that might lead to structures that are more adaptable to changing conditions. Attention to such S&T potentials is not an alternative to attention to social contexts; the two components of long-term infrastructure resilience can in fact work together and reinforce each other.

V. Perspectives on Mechanisms for Improving Resilience

One of the stated objectives of the symposium was to illuminate the challenge of encouraging incentives for investment of financial resources in community and infrastructure resilience. Again, the message from the symposium was that this is more multi-dimensional than simply assessing resilience as a strategy for risk reduction and then using those assessments to catalyze financial investment. The broader issue is mechanisms for improving resilience, which can include other approaches than catalyzing financial investments alone.

Two realities cut across any discussion of such mechanisms. One is that many infrastructures and communities are already stressed by a multitude of driving forces and changes for which no immediate coping mechanism appears to exist. Resilience can be seen as just one more requirement added to a very large pile, or resilience can help to draw attention to actions that help to reduce vulnerabilities to a number of concerns. The second is that responsibilities for improving resilience to such stresses are so fragmented – in terms of knowledge development, strategy development, and action implementation – that resilience is nobody's job. Is anybody responsible for the big picture, with all of its interconnections?

In many ways, the issue is how to combine public sector and private sector mechanisms – and to use them to complement and reinforce each other. On the public sector side, the reality is that many critical infrastructures are the responsibility of local and other governments, while infrastructure replacement or revitalization is often very expensive in an era when local and state governments are expected to keep budgets balanced and, above all, avoid tax increases. Resilience may be something that we support in principle, but a local or state elected official who raises taxes to assure it is unlikely to stay in office. The challenge is finding innovative ways to overcome this very significant obstacle for progress by the public sector (see Philadelphia's "Green City, Clean Waters" program as a conspicuous example).

On the private sector side, the issues are the value proposition and business continuity. What is the bottom-line payoff from investments in this aspect of risk management, when it is only one of a number of risks? In this regard, resilience as a priority is shaped by policy environments, societal values, and co-benefits, related to normal elements of risk management – such as normal cycles of infrastructure replacement and revitalization, where new risk factors can be introduced relatively easily. Insurance costs and conditions for risk-averse financing are an important part of this process, but they are seldom the dominant part of it. Related to but not quite the same as valuing payoffs from private sector investment in resilience, i.e., in profit margins or market shares, is assuring business continuity – reducing the risks of interruptions in sales and services due to disruptive surprises, a strong motivation indeed.

The challenge is to determine how to put the two sets of responsibilities and mechanisms into an integrated pattern of response that meets national, regional, and local needs. One step is to distinguish which responsibilities belong in which sector – for instance, federal and state agency program activities the responsibility of the public sector, while operating strategies of individual private sector firms are the responsibility of the private sector. A second step is to determine which functions a sector performs best – working in partnership, with each partner avoiding trying to do everything. For instance, the public sector is well-suited to be responsible for providing open-access data, while the private sector is well-suited for assuring economic efficiency. A third step is to take a careful look at linkages, such as contracting activities or grant programs of agencies. As is being done by some federal agencies for climate change adaptation (e.g., EPA), incorporating resilience in a proposed activity could be made a condition for a grant to a community. Another possibility could be to reward resilience by increasing regulatory flexibility for an infrastructure or community.

In either case, unless leadership is unusually effective in making new things happen, the best starting point is often to graft changes in incentives onto existing processes and practices, emphasizing three aspects of revised practices or standards: *non-stationarity* – revising current practices to reflect recent changes in driving forces; *flexibility* – providing incentives to establish frameworks for resource allocation and action that encourage and enable appropriate and creative adaptations to a wide variety of possible circumstances; and *a focus on performance rather than prescriptive compliance*, a different criterion for evaluating compliance with standards.

Several useful ideas have been suggested: (1) focus more attention on the costs of a lack of infrastructure resilience – and who suffers as a result; (2) phasing in improved codes, standards, and other practices that have community support – and then monitoring results so that fine-tuning can be considered, with future fine-tuning a part of the "social contract"; (3) seeking to identify promising innovations arising from bottom-up problem-solving, especially innovative approaches for overcoming a lack of public sector funding for infrastructure improvement (e.g., from structures such as the White House Local, State, and Tribal Leaders Task Force); and (4) developing ideas about desirable changes in policies and practice that can be proposed in a future post-disaster response.

VI. Thoughts About a Way Forward

Where do we go now? A number of contributors to the symposium, from Steve Flynn to [name redacted], offered useful suggestions as place to start. The issues are (1) what do we need to try to do? And (2) how do we move in those directions?

a. The first issue is focusing on a limited number of objectives. Ideas worth considering seriously include:

Raise awareness of risks and interdependencies.

Obviously, this is often easier said than done, but leadership can be supported by signals from the insurance industry to make it difficult to ignore the importance of integrated risk management. In addition, the potential for social media to support informal communications should not be ignored – which might call for reaching out to a younger age cohort for assistance (!).

Encourage a sense of shared responsibility.

This is also easier said than done, but leadership can be supported by institutions whose potential roles are often overlooked. Examples include educational institutions from universities to local schools at all scales, including adult education and vocational training but also potentials for knowledge and viewpoints of students to enrich family decisions and increase societal support for resilience in the longer run. In addition, roles of environmental and social non-governmental organizations (NGOs) could contribute, related to the value of resilience for sustainability, as well as the support of faith-based organizations.

Emphasize enhancements of currently mainstreamed processes and practices.

As mentioned above, it is usually easier to tweak an existing process than to create a new one; and many aspects of strategic planning by communities and infrastructures, along with operational rules and guidelines, can be revisited by responsible leaders and stakeholders to see if changes can be introduced that would be broadly acceptable and perhaps even offer benefits beyond increased resilience alone.

Align resilience with efforts concerned with sustainability and climate change adaptation.

Climate change preparedness and adaptation are increasingly recognized as essential, now that climate change impacts have been shown to be real; and sustainability is a growing concern on the part of a host of institutions and leaders concerned about interactions between society and nature. These movements have some momentum, active proponents, and supportive institutional structures; and in nearly every case their agendas have strong overlaps with resilience as an objective. Increasing the capacity to bundle these naturally aligned forces in support of effective policies and action that have multiple benefits could add to the prospects of them all.

b. The second issue is how to make progress toward achieving these objectives. Possibilities include:

Mechanisms for raising awareness and encouraging a sense of responsibility:

Broad-based contingency planning and exercises.

Participative contingency planning is a powerful tool for encouraging a variety of stakeholders and parties at interest to consider implications of possible futures that are not normally on their personal radar screens. Probabilities matter less than possibilities, and impacts and actions can be considered and discussed without necessarily calling for immediate action. Bodies of practice and knowledge exist for aspects of this approach from participatory scenario development to consideration of "shock" disruptions. Meanwhile, such communities as emergency preparedness and national defense frequently conduct exercises that include role playing in responding to hypothetical threats. This is a familiar mechanism for "converting the unimaginable into the imaginable" in encouraging responsibilities for resilience.

*Using focal events as opportunitie*s.

We all know that focal events such as terrorist events, extreme weather events, and pandemics "open policy windows" for actions that would be difficult to catalyze and implement in normal times. Having good ideas, fully vetted and supported, ready to go in the unfortunate event that a disruptive focal event occurs can move resilience along in ways that offer wide-ranging benefits in the longer run.

Public recognition of resilience achievements.

One of the most powerful mechanisms for encouraging resilience, and one of the easiest and least expensive to implement, is to offer widely-publicized high-level awards to individuals who show notable leadership and to community and infrastructure activities that have led to notable achievements in resilience improvement. Presidential awards announced each year?

Visualization as a key to awareness.

An item that may sound rather mundane is the underestimated power of visualization as a way to promote resilience awareness. Such possibilities as short videos showing changes in maps or communities under different threats and possible futures can support contingency planning, resilience education, and outreach through the media in publicizing risks and rewards from risk reduction; and introducing resilience as a theme in certain kinds of computer games can reach additional audiences. How about a "resilience visualization laboratory," analogous to the Decision Theater at the Arizona State University, developed with support from NSF's program on decision-making under uncertainty?

<u>Immediately accessible mechanisms for making progress while awareness is being raised</u>:

Attention to normal processes of infrastructure revitalization and community planning, including attention to revisions in existing codes and standards.

Described above.

Developing taxonomies of <u>determinants</u> of resilience and focusing on those niches a few at a time.

Even if developing metrics for community or infrastructure resilience as a single variable is not generally possible at the present time, it is possible to imagine developing taxonomies or matrices of the major determinants of resilience and to start to populate the taxonomy with metrics for several of the determinants at a time, moving toward comprehensive coverage of major pieces of the resilience puzzle in the longer run.

Government as a consumer in the resilience marketplace.

Finally, government does not have to wait until it raises awareness and catalyzes investments across all of society in order to make progress. As has been done with issues from environmental protection, equipment energy efficiency, and climate change adaptation, government can start by establishing standards and practices for itself. Significant improvements can result, awareness can be raised, and markets for resilience products, services, and expertise can be created. In many cases, this can be carried out by Presidential Directive without requiring Congressional action. It can be a very real place to start.

VII. Conclusion

In some ways, the International Resilience Symposium might be considered a failure. It did not succeed in developing standards for community and/or infrastructure resilience, and it did not succeed in developing incentives for catalyzing financial investments in resilience. But its ambitious agenda led to a discourse that will be more sustainable in the longer term, because it recognizes and identifies the main challenges in moving toward a feasible agenda for resilience action. Rather than providing answers for now, it points toward some very realistic steps that can be taken now – significantly improving prospects for resilience over the next several decades.

C.4: *Resilience to natural disasters: the role of standards,* Tim Davies, Department of Geological Sciences, University of Canterbury, New Zealand

Resilience to natural disasters: the role of standards

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Abstract

The role of standards in societal and infrastructure resilience was the subject of a 2-day meeting at NIST in Gaithersburg, USA in September 2014. The discussions at that meeting were exceptionally wide-ranging, and the breadth of perspectives present indicated a need for a rational conceptual basis for the broad concept of resilience. This paper attempts to provide such a basis by suggesting that the strict usage of the term 'resilience' be focused on approaches to reducing the impacts on society from unknown, unexpected and/or unquantified events, while known, expected and adequately quantified events are dealt with by risk management. While risk management can legitimately be considered to be a component of resilience, it is useful from an operational point of view to separate them. Study of the probabilistic basis of risk management emphasizes the limits of its reliable application, which are to frequent minor events only. Reducing the impacts of less frequent and larger events requires a different approach, related to the degree to which these events are inadequately quantified or unexpected. Complex dynamic system behaviour is suggested as a useful descriptor of the processes, in both natural and human systems, that give rise to disasters, and it is hypothesised that the behavioural characteristics of complex dynamic systems may indicate societal behaviours that are intrinsically resilient. Recognising the increasing divergence of societal behaviour from complex dynamic system behaviour suggests ways in which society may be able to increase its intrinsic resilience, e.g. by increasing decentralisation, diversity and redundancy. The use of disaster scenarios to complement or replace probabilistic data can be effective in informing a community about ways in which it can become resilient.

Introduction

The potential for natural events such as earthquakes, floods and tornadoes to detrimentally affect society leads to their identification as hazards. The occurrence of these hazard events results from the behaviour of the natural systems that generate them; earthquakes result from plate tectonic motions, floods from the way in which rainfall affects river flows, and tornadoes from the complex fluid dynamics of atmospheric convection. These natural systems are known to behave as a 'complex dynamic systems', and in fact this behaviour is also recognised in the societal systems impacted by the natural events (Sornette, 2002). Thus the occurrence of natural disasters – the impacts of major natural events on society – can be described as the interaction of two sets of complex dynamic systems. A great deal is known about complex system behaviour (e.g. De Toni and Cornella, 2011), and we show later that this knowledge may have the potential to form a sound conceptual basis for better understanding natural disasters, and for devising ways to reduce their effects.

Traditionally, disaster reduction has been approached by attempting to understand and quantify the natural behaviour that causes the event. When engineers ruled the world this resulted in attempts to alter the natural system behaviour so that society was less affected – for example, altering river behaviour by building levees to prevent the river from re-occupying a part of its bed that was now occupied instead by societal developments. Such efforts still continue, but are increasingly realised to be at best short-term and very expensive ways of delaying and exacerbating future disasters (Davies and McSaveney, 2005; Criss and Shock, 2001). A less confrontational approach has developed more recently as Risk Management, in which the quantified event data are used to develop event magnitude-frequency curves; these then form the basis of cost-benefit analyses which allow optimal solutions to be found among a range of mitigation strategies (which still include event modification). Risk management is the dominant current paradigm for disaster reduction, and forms the basis of the ongoing global push for Disaster Risk Reduction ("DRR"; UNISDR, 2005, 2015). As shown herein, however, this approach is intrinsically unreliable when planning for disaster reduction in a planning time-frame that is reasonable by human standards, because probabilistic predictions are then being made about very small numbers of events.

Another concept for reducing the effects of future disasters is that of 'resilience'. Though variously defined and widely criticised, this has the value of being conceptually useful, in that a family, community or society that is resilient is commonly seen to be able to deal better with a future disaster than one which is not. Resilience is often assumed to be inclusive of, and able to be developed from, risk management; however the latter assumption has been sharply criticised by Park et al (2013), on the basis that many of the hazards that threaten society are poorly-quantified or even unknown, and thus are not amenable to risk management analyses.

In this context it is useful to think of the threats to society as being at three levels: those encountered as a matter of routine (e.g. daily afternoon thunderstorms, car tyre punctures), those that are non- routine but expected (e.g. minor car accidents, 5-year floods), and those that are extreme and thus unexpected (e.g. the Tohoku earthquake and tsunami, the current California drought). Events in the first two of these categories are apparently amenable to risk management procedures, being expected and quantifiable, but as will be seen later only the routine events occur sufficiently frequently in a realistic planning time-frame to be reliably predicted by probability in a specific location or for a specific community. The third category evidently cannot be approached by risk management, being poorly- or unquantified, or even unknown.

The basis of the present discussion is to associate the requirement for resilience with the second and third categories of threat; and it seems very likely that a community that can cope with an extreme event will much more easily cope with an expected one. Thus *the characteristics of a resilient community are those that enable the community to cope with and redevelop from unexpected shocks without catastrophic loss of functionality*. It is assumed that threats of the first ("routine") category can be dealt with by risk management procedures. In the context of standards, the first category offers no difficulties other than those of defining and enforcing a specific level of performance; the other categories, however, are less easy to visualise as standards, and we address this following further development of the resilience concept.

To set the stage for developing strategies to increase resilience, we first outline the limitations of probabilistic analysis for reducing the impacts of events that occur only a few times in a realistic planning time-frame, and proceed to illustrate how cost-benefit analyses are particularly sensitive to even minor data imprecisions. Following this is an outline of the concept of unexpectedness, and the ways in which even known events can become unexpected; this also emphasises how progress in science can reduce the range of unexpected and currently unforeseeable events. Then we take a deeper look at the behaviour of complex dynamic systems, and how that might provide some insights into behaviours that might allow society to become more resilient, before discussing how event and impact scenarios can provide crucial information for developing and increasing resilience.

Limitations of probabilistic risk management

Even if we assume the availability of perfect data to define the statistics of past events, and with perfect confidence that future probabilities will be identical to past statistics, using these probabilities to design strategies for managing future catastrophic events remains fundamentally problematic. This is because any risk management process, and therefore any probability, is in reality applied only to a specific future time-frame defined by human interests, and, in the context of hazard events, this time- frame is inevitably such that *the expected number of hazard events in a given locality is small*.[1] Even with perfect statistics the probabilities of small samples are intrinsically unreliable, insofar as the very small number of events that occur in a given location in the planning time-frame almost certainly differs significantly from the probability distribution. Thus probability-based management of low- probability risks is liable to unavoidable unreliability (Davies, 1993).

As an example of the small sample problem, consider flood prediction in a river; we are tasked with predicting the number of times a flow of say 1000 m^3/sec will occur in this river over the next 100 years, in order to optimise flood management strategies. Assume we have 10,000 years of precise data on this river, and that we are confident that the next 100 years is part of the same statistical distribution. Examining the past 10,000 years of data we find that 1000 m^3/sec is exceeded 162 times; we can be pretty confident that in the next 10,000 years the number of exceedences of 1000 m^3/sec will be very close to 162 – or at least, sufficiently close that our optimisation will be realised. So we can plan satisfactorily for the next 10,000 years. When we focus on the next 100 years, however, we find that the most likely number of exceedences is 1.62, which obviously cannot be realised in reality

– exceedences either occur or they do not, and 0.62 of an occurrence cannot happen. In reality the number of exceedences will be an integer – probably 0, or 1, or 2, or 3. Obviously, which of these occurs is extremely important to the success of our optimisation strategy, and the apparent precision available from the precise statistics is an illusion.

The errors intrinsic to predicting into samples of various sizes are illustrated more generally in Fig. 1. This shows the error (± %) in calculating the largest average of sets of ten various-sized random samples of integers from the range 0-99; the average of all the integers in this range is exactly 50. With a sample size of 100 (equivalent to predicting a 1-year recurrence-interval event over 100 years) the largest average error is ± 10%; but with a sample of two (as in predicting a 50-year event in a 100-year period), the error is ± 95%. This trend is shown in terms of event prediction in Fig. 2. Risk analysis can only be a reliable basis for risk management when the expected number of events in the management time-frame is sufficiently large that their occurrence can be sufficiently similar to their probability; i.e. for well-quantified, frequent, low-intensity events. Larger and less frequent hazard events, *even if adequately quantified*, cannot be reliably mitigated in a realistic time-frame using probabilistically- based risk management processes.

However, probabilistic analyses are certainly of value for insurance purposes, because that industry can and does spread its risk widely so that the event numbers into which probabilities are projected are large enough to ensure that probabilities match outcomes, even for locally infrequent events; but they cannot be reliably used for local risks over realistic planning time-frames.

1 This is in fact the definition of a hazard; something that occurs sufficiently rarely that society does not automatically avoid its effects. For example, people do not try to live below high tide level, because they know the area will be frequently covered with water.

The large error in low-frequency occurrences renders optimisation routines such as cost-benefit analyses highly questionable. This is because such routines involve calculating differences between costs and benefits, both of which are large and imprecise numbers; the resulting net benefit is inevitably a much smaller number with an inevitably and much higher imprecision. To give a numerical example:

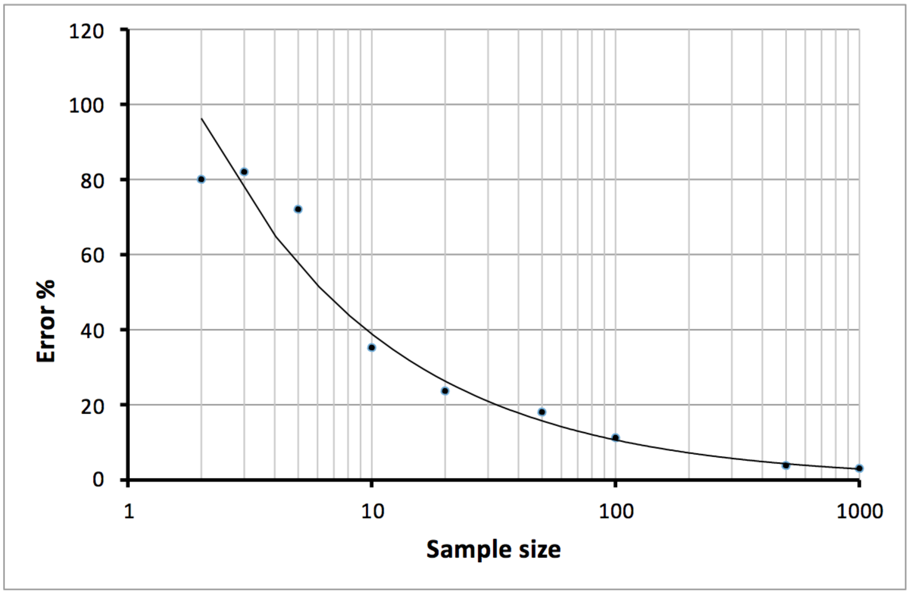

Fig. 1 Prediction error varying with sample size. The graph shows the largest error in the averages of ten sets of samples (of various sizes from 1 to 1000) of random integers between 0 and 99.

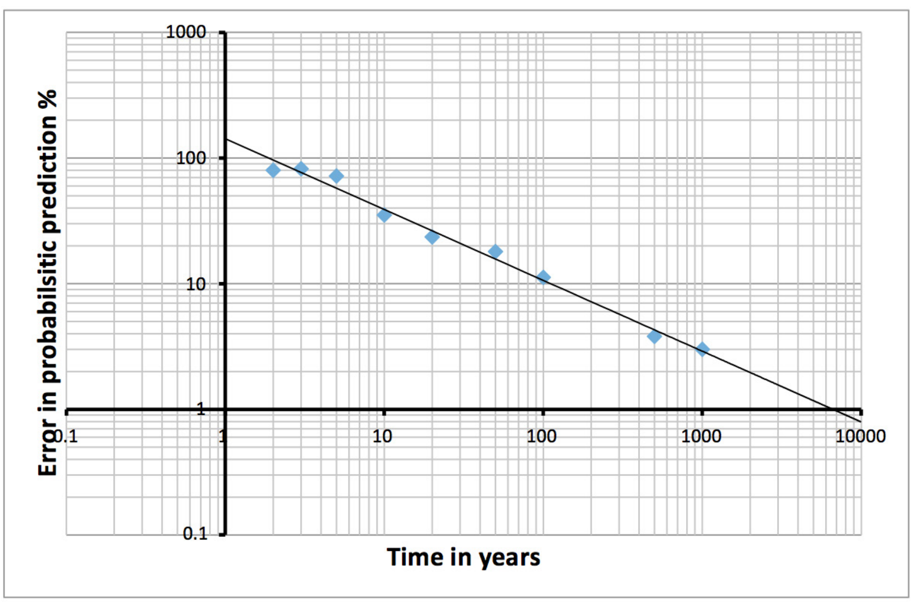

Fig. 2 Error in probabilistic prediction of occurrence of a 1-year event in a range of time periods, derived from Fig. 1

Assume we have calculated average annual flood damage at a site in the absence of mitigation as

$1,000,000; flood damage with mitigation in place is reduced to $400,000 per year; and the cost of mitigation is $400,000 per year. This yields a net annual benefit of $200,000 per year, or a 20% per annum return.

In reality these figures have errors associated with them; let's assume this is ±10% on average annual costs so the unmitigated cost is really $1,000,000 ±10% or $900,000 – $1,100,000. Likewise, the average annual flood damage with a mitigation strategy in place ($400,000 ±10%) is $450,000 - $550,000, so the total benefit is $650,000 – $350,000 (or $500,000 ± 30%). To get the net benefit we must subtract the annual cost of the mitigation strategy, which is $400,000

± say 5% or $420,000 - $380,000; this gives an annual net benefit in the range $270,000 to -

$50,000 (or $110,000 ± 145%). This gives quite a different impression of the situation.

Two further difficulties are associated with the probabilistic characterisation of hazards. One is that assigning a future catastrophic event a low probability means that when it occurs, society is probably unprepared for it, because its probability is known to be low and preparation for it is therefore always seen to be of lower priority than more immediate and pressing issues.

Finally, generations of hydrologists and managers have found extreme difficulty in communicating concepts of probabilistic flood risk management to the lay public. This constitutes yet another fundamental problem with probabilistic procedures; if the communities affected are to play a role in decision-making for their future safety, as ethics and evolving practice (e.g. Lane et al, 2011) demand, then they need to be able to understand how the "experts" are thinking, and where probabilities are concerned this is a serious challenge.

For these reasons, risk management procedures based on probabilistic data are intrinsically and unavoidably unreliable as a methodology for reducing the effects of any but routine threats on society. This realisation leaves a gaping void in our portfolio of disaster reduction tools, and it is this void that resilience needs to be able to address. This we now attempt, starting again with the concept that both the natural systems that generate hazard events, and (to a perhaps lesser extent) the societal systems that they impact, behave as complex dynamic systems.

The nature of disasters

A disaster can be defined in general as an event (in the present context, an event that is part of the behavioural spectrum of Earth's natural systems) that causes substantial damage to society. Refinements of this definition may include the criterion that the damage cannot be managed and rectified locally, so that outside resources are required; or that a certain number of deaths occurs, and damage exceeds a certain value; but these are not necessarily crucial. In reality, a family tragedy is a disaster to those involved, as the Indian Ocean tsunami of 2004 was a global disaster. In principle, disasters are independent of scale.

A requirement for an event to cause a major disaster to society is that the event is *unexpected by society*. The reason for this is obvious – if it was expected[2], people would have prepared for it, and it would have done manageable damage. At the family level, the expected death of an aged relative is sad, but the sudden death of a child is a disaster, because the latter is unexpected; while at the national level, a hurricane whose

2 Note here that genuine expectation means that not only an event's possibility is recognised, bu t that its occurrence is a real part of the consciously anticipated future of society.

track and intensity are accurately forecast several days ahead should not cause a disaster because adequate preparations can be made (unless the preparation and response are unexpectedly ineffective – and that is not an *event-triggered* disaster, it is a societally- triggered disaster). Unexpectedness also implies that the event triggering the disaster occurs infrequently, because if it occurred sufficiently frequently people would remember its previous occurrence(s) and effects, and would expect recurrences in the future.

A natural event at a given location can be unexpected for a number of reasons: (i)

the *type* of event that occurred was unexpected,

(ii) the event *magnitude* that occurred exceeded current estimates of a maximum credible event, or

(iii) the event was anticipated but assigned a low probability that reduced its priority and no preparations were undertaken. Finally, with the best arrangements and organisation in the world,

(iv) people make mistakes.

The first of these is the result of incomplete knowledge of Earth's processes, which is understandable and a challenge for science. It is exemplified by, for example, the many sediment deposits until recently thought to be glacial moraines (which represent no hazard until glacial advance again creates an ice-front in that location) now shown to be deposits of large rock avalanches (which can potentially indicate a present hazard); see e.g. Barth, 2013; McColl and Davies, 2013; Tovar et al., 2008; Hewitt, 1999. In terms of the second cause of unexpectedness, exceedence of a scientifically-determined maximum credible event has been remarkably common in recent years; for example, considering only earthquakes, the 2004 M9.1 Andaman, 2010 M8.8 Maule and 2011 M9.0 Tohoku earthquakes all substantially exceeded their scientifically-determined maximum credible magnitudes.

Event frequency or probability is a topic rife with actual and potential misunderstanding. In particular, the concept of a recurrence interval is misleading and often poorly expressed as the interval between event recurrences – when in reality it is the *mean* time interval between recurrences *averaged over a large number of recurrences*. Thus quoting long recurrence intervals for potentially disastrous events does not provide information that makes them expected, in fact the contrary is true, and lay people especially are likely to not expect recurrence of an event that happens rarely. Quoting a long return period or a low probability for an event can in fact cause it to be unexpected. This is well illustrated by the earthquakes that hit Christchurch, New Zealand in 2010-2011; the probabilistic seismic hazard map of Canterbury (Stirling et al., 2008: Fig. 3) showed that a peak ground acceleration (pga) of 0.4g was expected in Christchurch every 1000 years, and that a pga of 1.0 in Christchurch was correspondingly less frequent – perhaps of the order of once every 10,000 to 100,000 years (on average). In 2010-2011 Christchurch experienced one event (Feb 22 2011) with a pga of 2.2g, and two others (September 4 2010 and June 23, 2011) with pgas of 1.0 or greater. This extreme event sequence was not necessarily incompatible with the probabilistic seismic hazard information, and therefore could have been expected; but the available information on its likelihood did not encourage the people or authorities in Christchurch to expect the event to occur in the foreseeable future, or to prepare for it, and the earthquake was therefore unexpected – and disastrous - when it occurred.

The reality is that *any event can occur at any time*. On this basis, reliable prevention of disasters requires that all events must be expected, but this is clearly never going to be the case simply because knowledge of Earth's systems will always be incomplete. It follows that disasters can never be completely prevented, and will inevitably occur in the future, so the objective herein is to reduce their impacts rather than to prevent them.

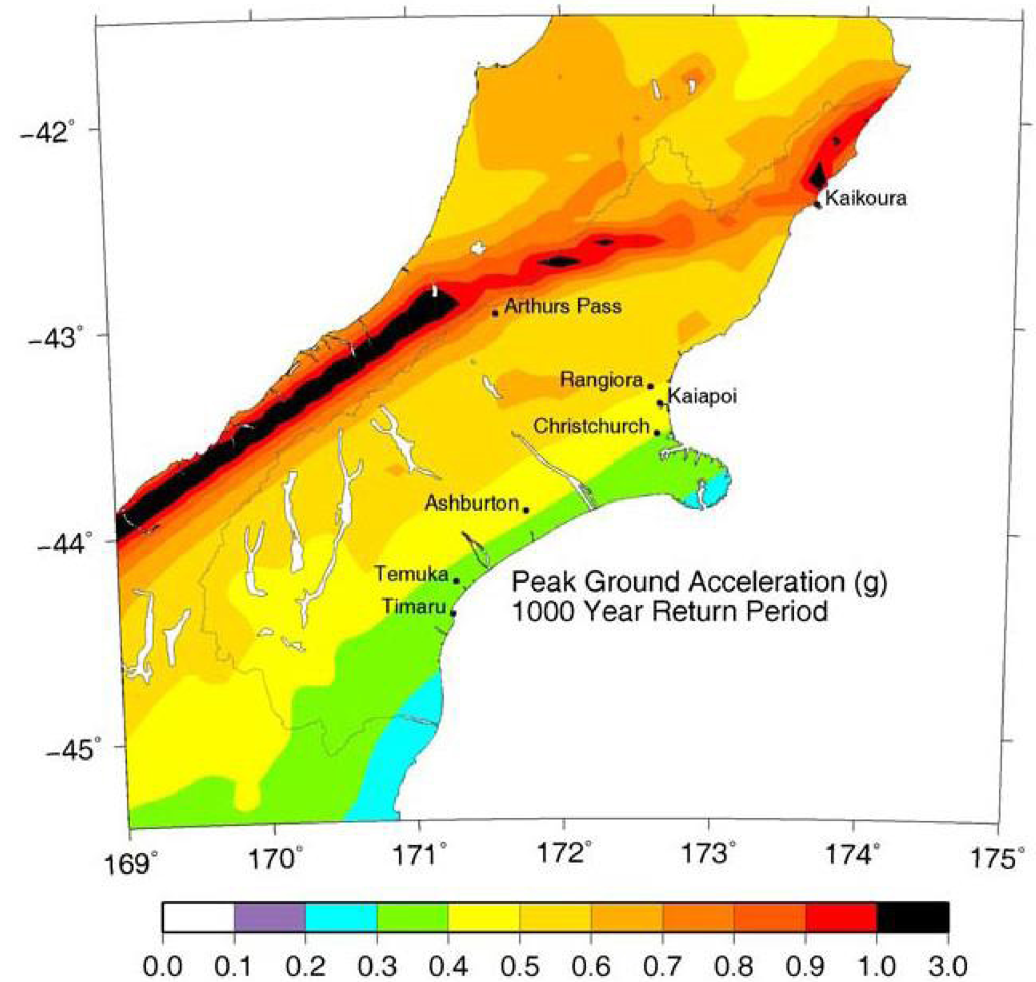

Fig. 3 Probabilistic seismic hazard map of Canterbury (Stirling et al., 2008)

It may appear that the degree to which an event is expected should be associated with its probability, because something that is more probable is by definition more likely to have occurred in any given past time-frame and is therefore more likely to be expected in the future. The counter to this argument is that the most important disaster in a given locality is always the next one, and the next event may not be the most probable one. In fact, unless the most probable event has an individual statistical probability ≥ 50%, *it is more likely that some other event will occur next*. Thus, every event that has been identified as possible should have the same expectability, irrespective of its probability, because *any possible event can be the next that occurs*. This is consistent with the concept that expectedness is in reality a binary property – something is either expected or unexpected, and for present purposes there is really no such thing as partial expectability.

Finally, human error can never be ruled out and but often causes unexpected outcomes; given its inevitability, there is a strong case to be made for including resilience to human error in as a factor in designing and operating systems.

Natural and human system behaviours

In talking about systems we need to define the boundaries of the system under consideration, and in this context Earth is a single, large natural system, isolated except insofar as it receives energy from the Sun and some matter (meteorites) from space, and radiates energy into space. This single system comprises a set of subsystems (e.g. oceans, atmosphere, land surface, internal processes) that all interact and exchange energy and matter with each other, and these in turn host innumerable living and non-living systems that interact in the same way. The systems picture of Earth is thus of an immensely complicated set of systems of all sizes and types, all interacting with each other at a huge range of time- and spatial scales. The sciences of physics, chemistry and biology describe some of these interactions at some scales, but many of them are poorly-known, and much remains unknown, due largely to the complexity of system interactions. Earth's natural systems have evolved to their present state over the ca. 4.5 billion years of its existence. For the vast majority of that time they have been uninfluenced by, and have not influenced, human behaviour. Thus we can consider the behaviour of the natural systems (but not necessarily their present states, e.g. atmospheric CO_2) to be independent of the presence of human society.

One of Earth's (natural) current subsystems is the human system (or "society"), which comprises the members of the species *Homo sapiens* and their associated artefacts (the latter including modified natural systems such as reservoirs, crops and herds). Society has evolved since the human species itself became distinguishable from its progenitors some millions of years ago. Especially in the last few thousand years, society has increased dramatically in scale and complexity. It has also increased its ability to utilise resources for generating power (in the sense of ability to affect natural systems), far beyond that of any other species. Most importantly, it has also adopted societally-determined decision-making processes. Society is today rapidly-growing, widespread, complex and intricately inter-related, with very rapid transmission of information across the system, and its behaviour is thus changing rapidly compared to that of most other natural systems. In addition, society appears to be increasingly affecting natural system behaviour by altering the composition of the atmosphere and oceans, potentially altering climates worldwide with potentially serious consequences for society.

Earth's systems have been subject to innumerable shocks throughout their existence, and it is their responses to those shocks, together with the evolution of living systems, that has led to the present system state. During this process innumerable species evolved, and most later became extinct because they were not adequately resilient to the shocks they experienced. The requirement for society to be sustainable on Earth is that it becomes sufficiently resilient to future shocks both from Earth's other systems, and from within itself. As we shall see below, development of resilience requires that systems have the ability to *adapt and evolve* in response to the shocks they experience, and this requirement means that society must recognise the realities of the environment it is embedded in, and realise the need to be adaptable.

Both natural and human systems are known to behave as "complex dynamic systems" ("cds"; Sornette, 2002). This is a class of systems that are complex (in the sense that we are unable to precisely predict their behaviour) and which change with time in response to both internal and external forcings. This means that dramatic changes can occur in natural systems both as a result of external inputs (e.g., in the context of Earth systems, bolide impacts and solar flares) and internal inputs (e.g. plate tectonic motion causing earthquakes and eruptions); similarly, human systems can change rapidly as a result of external (e.g. earthquake) and internal (e.g. global financial crisis, war) forcing.

While natural and human systems have many behavioural similarities, one critical difference is in intentionality. As far as we know, non-human systems develop over time with no internal (or, for present purposes, external,) intention to do so. In this context “intention” describes the will and the ability to choose behaviour. At least at the individual level, humans continually make choices based on conscious use of memory and intellect; as far as we know, this behaviour is not found in individuals of other species to an extent significant to the present context. Whether this human ability to make choices is also true at the larger scales of families, communities and society as a whole is less empirically obvious; for present purposes, we assume it to be the case.

Complex dynamic systems in general are characterised by behaviours such as:

- Self-organisation.
- Positive feedback, in which a disturbance causes a change of behaviour that in turn causes the disturbance to amplify.
- Non-linearity, which renders future behaviour unpredictable except by simulation.
- Emergence, in which large-scale behaviour patterns appear that cannot be anticipated from small-scale behaviour (a natural example is the development of meanders in a turbulent river flow).
- Chaos, in which a system exhibits hypersensitivity to initial conditions, so that its behaviour cannot be predicted far into the future unless initial conditions are prescribed in unrealistic detail.
- Heterogeneity, i.e. non-uniformity.
- Unsteadiness, i.e. time-varying behaviour.
- Behaviour patterns that repeat across a wide range of scales (“scale-free” of “fractal” behaviour).
- Bifurcation, in which a gradual change in an input causes the system to move suddenly to one of two available state trajectories
- Power-law probability densities (except for events that occupy much of the system space, which occur more frequently than expected – so-called “dragon-King” events; Sornette, 2009, Sornette and Ouillon, 2009).

These behaviours have been shown to describe a wide range of both natural (e.g. floods, earthquakes, landslides, avalanches, fluid turbulence) and human (e.g. heartbeats, epidemics, financial cycles, city population) systems. They can be simulated in computers, and such simulations appear to have[3] successfully reproduced such phenomena as the flocking behaviour of birds and the synchronicity of firefly flashes, as well as species extinctions due to internal system behaviour rather than external input; the behaviours of hearts and financial markets have also been reproduced using complex system simulations.

Since both natural systems and society behave as complex dynamic systems, it is rational to look at disasters as the result of the interaction between two large complex systems, one of which (society) is embedded within and intimately linked to – and thus a subsystem of - the other (nature). In other words, we should

3 I write “appear to have” because no accurate criterion exists to decide whether two particular complex patterns that look like each other are in fact characteristically similar.

expect the occurrence of disaster-triggering events to be non-linear, emergent, chaotic – i.e. *unpredictable*, in both common and technical senses of the word. This view leads to the rather negative perception that since disaster events are fundamentally unpredictable[4], then reducing their impacts by deterministic processes (i.e. processes based on understanding of how the system has behaved in the past) is unrealistic. Although not usually formulated in these terms, the obvious difficulty of deterministic disaster management has been known for many years, and has led to the current paradigm of probabilistic analysis, with the associated ongoing need for better data to better define event magnitude-probability relationships. The view presented here is that such data cannot significantly improve the situation, because of intrinsic factors associated with complex system behaviour; and also because of intrinsic factors associated with probabilities, as outlined above.

Resilience in natural systems

The natural systems of Earth have evolved over billions of years to their present state, and in that state, as emphasised above, they have developed behavioural characteristics that appear to correspond to those of complex dynamic systems. This applies to both living and non-living systems, although the living systems emerged from the non-living systems a long time after the former began operation. The initiation and evolution of living systems has been intensively studied for centuries, and in spite of considerable controversy it is generally accepted that the complexity of ecosystems and species has increased with time. In the commonly-accepted picture, long-term gradual evolution has been punctuated a number of times by sudden catastrophes (at least some of external origin) in which large proportions of all existing species became extinct, and were replaced by other species that evolved to fill the ecological space left vacant.

Species require resources and space in order to survive and multiply, and resources and space are never infinite; thus at some stage, species compete with other species for resources and/or space. This they do by evolution; members of a species that experience stress due to this competition (as well as from other types of system shock) either die or survive. Those that survive generally differ from those that die by being better able to survive the full suite of stresses, thus the characteristics of the non-survivors gradually dwindle in the overall species gene-scape, while the characteristics of the survivors increase. Thus, over time, species evolve to become increasingly resilient to the behaviour of their environments – or, since the environment also includes other species which are also evolving, groups of species co-evolve with their environments. This evolution can be viewed as a race towards ever greater resilience in an increasingly competitive and occasionally shocking environment. The characteristics of species or systems of species that have existed for a long time, then, can be expected to be those that confer resilience to the system. These appear to be the characteristics of complex dynamic systems, because a large number of natural systems behave as cds.

Human society has evolved just like all other systems on Earth, so why has it not become resilient by adopting these behaviours? In many cases early human societies unconsciously did just that, and some modern indigenous societies still do, or at least they retain the corresponding behavioural principles in their traditions. Increasingly, however, modern society has intentionally superseded these behaviours with others (designed to increase e.g. economic efficiency, or power of the ruling classes, or obedience to superhuman powers) that do not increase resilience to natural system events. Examples of these behaviours are to be found in many areas of present-day society, and a few are:

4 Recently Cavalcante et al (2013) have shown that extreme events in a complex system can be forecast in real time, and can be suppressed by applying tiny perturbations to the system. This may indicate future possibilities for averting disasters, but only if knowledge of natural and human systems is adequate.

1. "Just-in-time" supply of goods from national to local centres. This reduces local storage costs by centralising storage, but leaves a local population very vulnerable to supply interruption due to a disaster cutting transport links.
2. Centralisation, which increases vulnerability of the core functions to a direct hit, and also constrains communication.
3. Cost-savings by reducing system redundancy, so that society is critically dependent on fault- free functioning of continuously-used components.
4. The tendency to move towards homogeneity and steady-state behaviour of economies, and the disastrous effect of financial swings; a homogenous society is brittle, in mechanical terms, because a failure at one point can propagate widely through the system causing widespread failure. Greater heterogeneity (both spatial and temporal) would arrest the failure before it spread far. Heterogeneity in society is like biodiversity in nature – it increases resilience.
5. The tendency to greater simplicity, operational ease and "cost-efficiency" via top-down management and communication. This reduces the bottom-up information flow which could warn of developing crises.
6. The drive for greater efficiency, so that more gets done for less. This is always designed to operate in ideal conditions, which in fact rarely occur.
7. The increasing tendency for data-driven decision-making; the result of an increasingly technical and litigious societal environment, this devalues any information that cannot be unquestionably quantified, and again leads to lack of consideration of the future occurrence of events whose past occurrences are poorly quantified.

Society has been able to develop these behaviours by using technology to increasingly isolate itself from many of the system behaviours of the environment, e.g. by controlling rivers so that cities do not have to put up with flooding or be moved. While this is effective for a short time and against minor natural system events, it generally fails when faced with large-scale, and therefore unexpected, major system events – i.e., those that trigger disasters. In fact, there is much evidence that controlling minor natural system events increases the impacts of larger events when they inevitably occur (e.g. Davies and Hall, 1992). As a result of these behaviours, and in spite of increasing expenditure on risk management, societal resilience to disasters is not improving noticeably at present, and certainly not rapidly enough to match the increasing vulnerability of society that results from population growth, asset growth and increasing rate of commercial activity. Table 1 summarises the contrasts between complex system and societal behaviours.

Table 1 Comparison of complex system behaviour with societal behaviour[5]

Characteristics of complex systems:	Characteristics of modern societal systems:
*self-organising (bottom-up)	*externally-organised/ordered (top-down)
*adaptive	*designed
*heterogeneous/unsteady	*uniform/steady
*step changes (bifurcations)	*incremental changes
*distributed	*centralised/hierarchical
*optimise effectiveness	*optimise utility/efficiency
*rapidly responsive	*slowly responsive (political)
*linked to sub/super systems	*isolated from natural sub/super systems
*drastic losses accepted	*drastic losses unacceptable
*emergent behaviour expected	*predictable behaviour expected

If we are seeking strategies by means of which society can become more resilient to disasters, then, perhaps one such strategy may be to purposefully increase the extent to which society is structured like, and behaves like, a cds. The behaviours in question include:

- Self-organisation and adaptation
- Scale-free spatial and behavioural patterns
- Spatial and temporal heterogeneity
- Expectation of emergent phenomena
- Isotropic information transfer
- Optimisation of effectiveness rather than efficiency

5 Note that efficiency can only be defined in the context of a system whose inputs and outputs are well -defined and adequately quantified.

Some of these have previously been identified as contributing to urban resilience (e.g. Godschalk, 2003), but have not been specifically derived from complex system behaviours.

There thus appears to be an association between resilience and behaviours that characterise complex dynamic systems (e.g. Park et al., 2013). This is hypothetical at present, and is worthy of investigation. Supposing for the present that this is indeed the case, how can this information be used?

Resilient to What? Disaster Scenarios

If adopting behaviours characteristic of complex dynamic systems can engender resilience, the next question that arises is, how does any part of society know how to organise itself around these preferred behaviours? This requires at the very least some idea of what effects resilience is required to reduce. Thus, having cast out the most probable event, what does society select as the event to which it needs to become resilient?

One possibility (there may be others) is that *a specific disaster scenario* (or suite of scenarios) is selected, its full impacts predicted, and societal behaviour altered so that the detrimental effects will be reduced. This prepares society for the effects of a specific event, and provided that this event is the next that occurs (or is of the same type as, and greater than, the next event that occurs) then society will benefit by way of reduced impacts.

One objection to this idea is that the scenario selected (whatever it is) is arbitrary, and is neither more likely to occur than the most probable event nor more representative of what the next major event is likely to be, so what advantage is gained? A response is that the scenario to which resilience is needed is not the *event* scenario – that is, the natural event triggering the disaster – but the *effects* scenario, which describes the impacts of the event scenario on society. Because the range of disaster *effects* (e.g. population displacement, deaths, infrastructure damage, commercial disruption) is much smaller than the variety of disaster *events* (e.g. flood, earthquake, landslide, tornado, blizzard, tsunami) then preparation for any effects scenario will be beneficial to some extent whatever the next event is. Another response is that the event scenario is indeed less arbitrary than the most likely event, because it can be selected, by the threatened part of society (henceforth "the community", but in reality any group of people from a family to society as a whole) in consultation with its expert advisors and officials, as *the scenario to which the community wishes to become resilient*. The context of its selection makes it less arbitrary and more relevant than the most likely event. In many ways, a carefully-chosen scenario (or set of scenarios) is much more relevant to a community seeking resilience than is a set of event magnitudes and probabilities.

A scenario also has the advantage that it is easily comprehended by everyone; scientists, government officials, lifelines organisations and lay members of the public. Thus there is no segregation of understanding, and everyone involved is able to discuss the situation on an equal footing. This enables the full participation of the community in decision-making that lies at the core of successfully developing resilience (e.g. Nirupama & Maula, 2013; Gaillard and Mercer, 2012). Further, a scenario that has no probability associated with it is likely to be taken seriously as a likely representative of the next major disaster trigger that can occur, without being deprioritised relative to more likely but less disastrous events; and resilience to a large event automatically confers resilience to all smaller events of the same type. If the scenario is accepted by the community as able to occur at any time – which is in most cases literally true – the difficulties of "educating" the public about probabilities cease to be relevant. And, of course, a scenario that the community has chosen will be accepted by the community.

Scenarios have been used for many years as the basis for exercises for groups such as armed forces and emergency managers, and the values of these exercises in improving the response to conflicts and emergencies is well demonstrated (UNDHA, 1993; Ringland and Schwarz, 1998; Robinson et al., 2014). As a result, considerable literature exists on scenario development, but this has rarely (if ever) been used to inform disaster resilience.

The relatively limited range of disaster effects also suggests that a community that develops resilience to a specific disaster scenario will also be significantly more resilient to a range of different disasters; ultimately, any resilience is better than none. In addition, because (as has been noted above) resilience is first and foremost a behavioural attribute, then adopting resilient behaviours will ensure that the community (and its advisers) remain on the lookout for changes in the preferred events and effects scenarios. The former may occur as a result of climate change, for example, or (more likely) as a result of changes in the way scientists understand hazard events; the latter will always be changing as society changes due to increasing population, advancing technology and (hopefully) increased resilience.

The role of the worst-case scenario needs to be considered here. It is often possible to scientifically define a *maximum credible event* for any given process, and evidently if society can become resilient to its effects then the problem is solved for that type of event. However, recent experience suggests that maximum credible event magnitudes are unreliable: examples are the 2004 M9.1 Andaman, 2010

M7.0 Haiti, 2010 M8.8 Maule and 2011 M9.0 Tohoku earthquakes, all of which exceeded their maximum credible magnitudes by a significant margin. In addition, the maximum credible event is by definition the *least* likely to occur, and this is a disincentive for its use as a basis for developing resilience. Nevertheless, the worst-case scenario has value as (hopefully) an end member indication of what can occur, and increases a community's knowledge of natural system behaviour.

The role of standards

From the above it is clear that standards, in the conventional sense of absolute quantitative levels which specific performance indicators can be required by law to meet, are applicable only to the level of threat ("routine", in the scheme adopted herein) that can itself be adequately quantified in order that a standard can be justified. A wide range of quasi-standards already exists in this area, including building codes, fire regulations, safety regulations for automobiles and provision of lifeboats on ships, and these can presumably be transformed into standards fairly easily, and enforced of political will is sufficient.

While many of these measures are event-specific, a number are not. As an example, the provision of lifeboats on a ship does not require specification of the event that causes the ship to sink; it simply recognises that the environment of a ship is intrinsically threatening. This gives a potential lead into the possibility of generating guidelines – which may eventually be able to be codified as standards – *for increasing the intrinsic resilience of communities against non-specific threats*, by way of adapting their organisation and behaviour so that they are less intrinsically vulnerable to disruption by any event, be it externally-generated or internally-generated.

It may, for example, be feasible to take some of the key behaviours associated with complex dynamic systems outlined above and nominate them as key elements – that may evolve to become quantifiable characteristics – that indicate progress towards resilience. These might include for example

- the degree of decentralisation and redundancy of critical infrastructure;
- the degree of spatial heterogeneity in society;
- the degree of design for increased effectiveness under all circumstances, rather than for maximum efficiency under ideal circumstances;
- the degree of consideration of long-term societal and environmental evolution, which will require a degree of de-politicisation of resilience planning;
- the degree of acceptance that circumstances will change, and willingness to adapt accordingly;
- the degree of isotropic and rapid communication throughout communities.

All of these are definable and quantifiable, even if acceptable levels will always be difficult to choose. In the sense that the basic need is for increasing resilience, and in the knowledge that the next event to which resilience will be required may be many years away, then perhaps minimum decadal increases in these values might be definable by standards, and in this way these elements might lay the basis for achievable progress in the medium-term future. Whether other standards might be developed to ensure, for example, proper community involvement in decision-making around resilience (e.g. OECD, 2014) remains to be seen.

Conclusion

In order to develop standards for resilience the concept needs to be clarified, and a rational clarification is to assume that future events whose occurrence cannot be adequately quantified require intrinsic societal resilience to be increased in order to reduce the damage from the disasters these events will cause. Damage from adequately quantifiable future events can be reduced reliably by risk management procedures, but such events are minor and rather frequent and fall into the category of routine events. Standards for managing routine events can be codified now. Standards for the concept of resilience as assumed herein require quantification of societal characteristics and behaviours that increase resilience, and it is hypothesised that such characteristics correspond to complex dynamic system behaviour, so these may be able to become key elements in aspirational standards. Protocols for community engagement in scenario development may also be able to be standardised.

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C.5: *Societal Resilience,* Meir Elran, Senior Research Fellow, Institute of National Security Studies, Tel Aviv University

Resilience, as a generic term, is the capacity of any system – physical, human, social, organizational, or economic - to bounce back quickly following a major disruption, so as to ensure the earliest possible recovery, the return to its basic form and to its required operational functionality. Societal resilience is mostly an inherent trait of the human race, even though different societies and communities, in different places, manifest different levels of resilience in different disruptions. The level of societal resilience is not a given trait. It can and should be enhanced in advance, in order to ensure its full effectiveness. It has to be accomplished in a carefully preplanned manner, in accordance with the relevant threats, so as to maximize the capacities of the society to overcome a major disruption and to return quickly to normal functionality.

Several points should be emphasized and clarified:

- Resilience is meaningful only in circumstances of major disruptions, or disasters, man-made or natural. The term itself seems to be less significant. What really matters is the public subjective perception of the defining event and its consequences. From an overall political perspective, it is the public perception that counts. The actual level of damage, both human and physical, is mostly a contributing factor.

- Measuring resilience is a major challenge. In most cases, it is gauged by subjective surveys, in which people are asked to attest to their own sense of their resilience. This might be of interest, but not really sufficient. There is a need for a quantitative empirical methodology of benchmarking societal resilience. One could find several such ventures in the professional literature, but those are not really developed and are hardly acceptable as recognized tools. I suggest that we focus on this challenge of measuring societal resilience, perhaps through the juxtaposition of the severity of the disruption and the time framework of bouncing back following the disruption. The main thrust of such a methodology would be to produce clear quantitative answers to the question of how quickly a given system returns to its initial functionality.

- More specifically, we need to reach a level of accurate analysis that could differentiate between different levels of societal resilience: at least low, medium or high. From studies conducted in Israel, we have found that different sectors of the public respond in different ways to disruptions; some sectors show a consistently higher level of resilience, manifested in a swifter bouncing back, than other groups. These studies also found indicators of very high resilience, manifested not only by swift bouncing back, but also by reaching a higher level of functionality than was gauged before the disruptions occurred. This was the case in the protracted terrorist campaign of the Palestinian second intifada (2000 – 2004), when in the dire context of more than 1000 fatalities, 85% of them civilians, the overall social resilience of the Israeli public has been estimated as high and becoming more so, as time and the challenges evolved. Toward the end of the intifada and shortly afterwards, the degree of functionality was higher than the one measured throughout the period, as was measured by several benchmarks.

- We all understand that different communities react differently to similar threats. Still, it is imperative to improve our capacity to understand what the main features are that make one community more resilient than another. If we gain a clearer understanding of the roots of societal resilience, we can focus our efforts on enhancing resilience before disruption occurs.

- And lastly, what is missing is the necessary transformation of the notion of resilience from a commonly used buzzword to a structured paradigm for action. In many instances, especially in Israel, we hear a lot of resilience. Much less is being actually invested in making sure that our systems, infrastructure and communities, become more resilient. I would suggest that more professional work is needed to clarify the practical meaning of resilience, how it should best be measured, and what should specifically be done to ensure progress on the road to systemic resilience.

Israel has unfortunately been in a continuous state of external manmade threat to its security. More than half of our citizens were exposed, for fifty consecutive days, this summer, to an average of 90 daily rockets launched from Hamas-controlled Gaza. The resilience of our civilian population facing these protracted disruptions has been very high. It is manifested and can be measured by the swift return to normalcy following the stoppage of regular functioning due to sirens of incoming rocket attacks. We have also seen that civilians living in close proximity to the Gaza border, who have been constantly and intensively harassed by rockets, mortars and offensive tunnels, have left their residences, but returned, together with their families and children, immediately following the declarations of cease-fires, despite the fact that most of those did not last. This is a clear expression of high societal resilience.

This resilience has deep roots. For years, resilience-enhancement programs have been implemented in many of those communities. Many, though not all, of those projects have proved themselves successful. Still, we see differences in the conduct of different communities and social groups, even in a limited high-risk area such as the Gaza border region. Some show greater and others demonstrate comparatively less resilience. Overall, their systemic behavior can be studied as a model of a national social laboratory of resilience.

The level of resilience of the critical infrastructure in Israel has not been tested. There is room to suspect that it is not as high as needed, mostly because the scope of resilience-oriented preparedness programs has been rather limited. I would presume that we need a major disruptive event to serve as a wake-up call.

To sum up, I would like to suggest that we should work together to transfer the issue from the level of politics and communication, to the operational level by systematically promoting long range resilience community programs, that would involve all sectors that would be relevant following disruptions. The potential is there; the experience and knowhow are there. What seems to be missing is the leadership that comprehends that resilience is a worthwhile framework for action. Resilience can and should compete with the paradigm of resistance, which managed to solicit most of the resources dedicated to disaster consequence reduction. It is my repeated proposition to the decision makers in Israel, to consider diverting just 10% of the budget allocated to resistance projects to resilience enhancement ventures in the communities. This will most certainly pay off lavishly following crisis situations.

1. Resilience is a broad notion, used by different people in quite different ways. For any practical objective, there is a need to set an accepted framework for the term and its meaning. As was manifested in the NIST discussions, we are still quite far from this status. It is quite a vast challenge, as there seems to be a significant gap between the abstract concept of resilience, as a state of mind, and the practical requirements of setting standards, even in a general form of a framework for action. There is also a meaningful gap between the basically technological approach of scientists coming from the engineering world and the social sciences. Encouraging steps of integration between these two approaches have been made at the NIST conference, but more are needed to construct an acceptable definition to resilience.

2. Even the Presidential directive 21's definition of resilience[6] needs to be refined for the sake of the NIST's standards needs. I would suggest to use the notion of "recover rapidly" as the central most important practical component, and to focus on it as a basis for developing the concept associated with "bouncing

3. back" and "bouncing forward", as the ultimate goal of any resilience policy. A vital part of such an endeavor would be to construct a measuring system for benchmarking resilience in whatever field, particularly that of infrastructure. Such metrics would enable a common gauging of the resiliency of systems in the context of disruptions, to be based mostly on the time and trajectory of the bouncing back trend of the given system.

4. The component of disruption (or catastrophe, disaster etc.) should be regarded as an essential part of the theory of resilience. Without a disruption of any kind, There is no theoretical or practical meaning of resilience. Hence, the inclusion of "routine" situations in the concept of resilience is superfluous. The only place for routine within the theory of resilience is for the sake of gauging the degree of bouncing back following disruptions, as a baseline for the conduct of the examined system.

5. It has been widely discussed in the conference, and there is room to state this again: The social components of resilience are as important (some will say even more important) than the technical

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6 The term "resilience" means the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents".

aspects, even when we deal with infrastructure resilience. The role of people, networks, communities, customers, leaders, is always paramount. Hence, when one searches for means to enhance resilience, there is a major need for education and communication, to actively engage with politicians, business leaders, NGO's, and the like. Community resilience programs have proven to be effective in time of crisis. They must be perceived as important part of any whole of community efforts for the enhancement of resilience of infrastructure.

6. There is a need for further research on the many faces of resilience, and particular on the interdependencies of societal and infrastructure resilience. As of now, most of the studies on resilience are "silo based", where each discipline has its own separate communities, researchers, journals and conferences. It is time to try to integrate the field and to focus collaboratively on two major issues of resilience: Resilience enablers – the factors that make a system more resilient, and resilience measuring – methodologies (mostly quantitative) to benchmark resilience. Once we reach the needed stage of understanding these factors, it will be easier to transform the notion of resilience from a state of "buzzword" to a working agenda. For the purpose of reaching this stage, there is a need for an international cooperation, integrating the knowledge and experience of the various cultures in the globe.

C.6: Reflections on the International Resilience Symposium, Russell E. Bowman

Earlier this month, Northeastern University's Center for Resilience Studies, in partnership with The National Institute of Standards and Technology (NIST), hosted a two-day "International Resilience Symposium" at the NIST Headquarters in Gaithersburg, MD. Participants from across government, various industries, standards-focused organizations (such as the National Fire Protection Association and the Insurance Institute for Business and Home Safety), academia, and NGOs, along with representatives from 13 countries, convened to address, through panel discussions and break-out sessions, three critical issues. Specifically, the event concurrently explored mechanisms for advancing community and infrastructure resilience; developing appropriate, usable standards for each; and creating the demand (i.e., incentives) arguably necessary for these initiatives to succeed.

In opening the first plenary session, Dr. Stephen Flynn, Director of the Center for Resilience Studies, noted that while governments (at the federal, state, and local levels, as well as internationally) have increased their respective efforts to promote resilience, most continue to struggle with achieving tangible improvements on any type of regional, cross-sector scale. He suggested that four specific barriers are impeding progress in this regard. Namely, that (1) we do not recognize how unprepared we are to handle foreseeable risks and uncertainties; (2) we do not have incentives to create resilience; (3) we do not know how to measure resilience because there is not yet consensus on how to create it (i.e., we lack an integrative approach); and (4) there are organizational and governance barriers to creating resilience.

Drawing from the author's memory and notes on each presentation, this paper analyses the dialogue and specific recommendations generated through the course of the symposium. It does so in three sections. First, it documents the extent to which the contributions of the various symposium participants (whether formal presenters, panel discussants, or participants in the various breakout sessions) validated, and provided insights concerning, each of the barriers to improving resilience described by Dr. Flynn. Next, it suggests four additional themes – complexity, community, culture, and communication – that ran throughout the conversations. Finally, this paper comments on five tangible recommendations that emerged during the symposium, which, in the author's opinion, hold particular promise for advancing resilience.

While the symposium was not organized around the four aforementioned barriers to enhancing resilience, they nonetheless surfaced as recurring themes. The following section consolidates the key comments made regarding each obstacle, regardless of the particular panel or session in which the comment was made. Each barrier is discussed in turn.

We don't recognize how unprepared we are to handle foreseeable risks and uncertainties.

The first barrier to advancing national resilience incorporates four related sub-components: (1) as a society we tend to overestimate our current capabilities to deal with catastrophes and disruptions; (2) we are generally biased toward (inappropriately) discounting the risks of aging infrastructure and the leading indicators of change; (3) we design and build based on assumptions of stationarity (i.e., that a 100-year event will always remain a 100-year event); and (4) politicians are loathe to look for, or acknowledge, community or infrastructure risks to the extent doing so (without adequate resources to address them) becomes a political liability.

Interestingly, perhaps the strongest voices stressing this related set of challenges were those representing the federal government itself. [Name redacted] observed that "*there is something about human nature that makes it difficult to assess true risk and incorporate that into our decisions*." [Name redacted] used this point to stress the importance of incorporating more social science into resilience research and improvement efforts. [Name redacted] also highlighted the "high probability, high consequence challenge" of "climate change" or "global warming" (whatever term you want to use), to underscore the need for breaking assumptions of stationarity. In [pronoun redacted] words, "*a 'bouncing back' model will not work, as the old conditions will not apply… resilience has to incorporate more adapting and planning to future projections* (not just the historic past). *We are going to have to be comfortable looking at [and planning to] projections*."

[Name redacted], stated the challenge more bluntly. "*We still do not understand the inter-dependencies and cascading effects of climate change on critical infrastructure. We need to look at risk in a new way. Now things are much more multi-dimensional. Our critical infrastructure has its own interdependencies in [each sector's] silos. But there are interdependencies among these [sector] silos as well*." Regarding the political challenges to acknowledging and prioritizing resilience, [name redacted] noted how numerous threats abroad place an even greater strain on the availability of resources for such domestic initiatives. "*These days, with anything that happens overseas, you have to look at the unintended consequences on infrastructure*," [name redacted] observed.

We don't have incentives to create resilience.

Included within this second barrier are the inter-related notions that (1) there are few rewards for investing in resilience; (2) routine efficiency and optimization (e.g., eliminating redundancy and utilizing just-in-time delivery) are valued over continuity of function; (3) we are skilled at transferring risk to others (but not reducing or eliminating it); and (4) we are not sure how to measure resilience (or what it is). Symposium participant comments stressed the first, third, and last of these points in particular.

On the first point, most speakers went beyond the observation that there are few rewards (or "carrots") for investing in resilience to noting the number of actual *disincentives* for undertaking resilience improvements that exist under current policies. As [name redacted] pointed out, the Stafford Act's very design guarantees federal funds for 75% of (publicly owned) infrastructure loses. As a matter of practice, Congress routinely authorizes funds above this default cost-share percentage (often effectively providing 90-100% reimbursement rates). Moreover, [name redacted] noted, the number of presidentially declared disasters and the percentages of the total losses paid by the (federal) government for each have been steadily increasing over time.

[Name redacted] stressed the significance of the moral hazard problem created by how the Stafford Act has been implemented. "[I]*t is difficult to find anyone who is anti-resilience; but you do find people who believe that the federal government is going to bail them out. The* [organization redacted] *has identified this as one of their challenges*," [name redacted] noted.

A significant component of all discussions concerning incentives revolved around the lack of available information on infrastructure-based liabilities. [Name redacted], put it bluntly:

> *What is the exposure on the public side of infrastructure? We don't know! We can't price something in the market, absent knowing what it is. There is little incentive to find out! … One of the incentives [we develop] has to be about whether we are willing to be transparent about the exposure. Otherwise we are transferring risk, and doing so behind a curtain. Today's system says its best to not fully know what your risk issues are, and to just wait for another system [or Administration?] to come in to find out.*

[Name redacted] agreed. "*We do need to incentivize agencies to inventory.* [organization redacted] *does this because we buy insurance. Most public entities don't [and remain self-insured]. We need to get public entities to understand their assets*." [Name redacted] comments highlighted one of the few existing "rewards" for investing in resilience: lower insurance premiums.

Unfortunately, this reward is generally only applicable to those entities who either choose, or are forced, to procure private insurance.

Several commenters considered the issue of enhancing infrastructure resilience from a cost-benefit perspective. This approach prompted discussions about the need for a clearer "value proposition" and *chain* of incentives to ensure improvements are made. [Name redacted] framed this idea as follows: "*Every step of the way, all the stakeholders are going to do a benefit-cost analysis. If anywhere in that progression [from the status quo to a future, more* *resilient state] there is not a clear, beneficial next step, we get stuck (for lack of any reason to move forward). That's why incentives are going to be so important*." Similarly, [name redacted], argued the need to "*map the relevance*" for each stakeholder to get more involved in such resilience improvement efforts. In a similar vein, [name redacted] suggested that to leverage private investment, there is a need to better *show how enhancing resilience is value (if not revenue) positive*.

[Name redacted], offered an additional interesting point on incentives, which ties back to the challenge of our collective bias toward (inappropriately) discounting risks. [Pronoun redacted] observed that, in general, people are always looking at short-term pay-offs. When it comes to critical infrastructure, [pronoun redacted] argued, "*we need to develop incentives that reach long term*." This point was made all the more meaningful by [name redacted] observation that "*we only replace 1-2% of the nation's building stock each year*."

We lack an integrative approach to advancing resilience.

The third suggested barrier to enhancing national resilience arises from the current lack of any widespread agreement on what resilience is, and how best to measure it. This, in turn, results in the absence of any comprehensive, interdisciplinary, systems-based approach to tackling this challenge. As with the other barriers to resilience already discussed, the symposium participants' professional opinions and observations confirmed the presence and significance of this impediment to progress. The following representative reflections further illustrate this point.

[Name redacted] recounted his methodology for a "resilience project" that [pronoun redacted] firm recently completed for the Port of New York and New Jersey concerning buses at the Battery Park terminal. Applying a systems approach, the firm brought together, in a workshop format, a variety of city departments and stakeholders to better understand how the entire transit system functions (and interacts with other systems). [Name redacted] explained that it was simply not possible to understand everything one would need to know about that (or any given) system by simply studying a line drawing. "*Unless you look at the interdependencies [by mapping how the systems function] you can't achieve resilience*," [pronoun redacted] observed. Critically for present purposes, [name redacted] noted that this was the first civil engineering project he was aware of (anywhere) that undertook this type of integrated, function-based process.

[Name redacted], recounted a similar lack of integrative approaches in his discussion of "Resilience, Health, and Health Systems" – a study of the continuity of care and of the public health system in the wake of Superstorm Sandy. [Name redacted] work highlighted the critical interplay between infrastructure and social systems, the consequences of which had not been fully anticipated. When the greater New York Metropolitan area lost 10% of its bed capacity due to flooding and power outages, many patients were displaced from highly regulated (and monitored) hospitals to less regulated, community-based care facilities. The home healthcare workers that staff such facilities, however, had difficulty getting to work (to provide the needed continuity of care) because they were not deemed "essential" in the same way that hospital staff are. Further study and understanding of the interaction between infrastructure and social systems, [name redacted] concluded, is required to improve the continuity of health care function. [Name redacted] noted an additional challenge in conducting this work. As in other sectors, there is *no accepted (human) measure for determining how resilient a given public health system is*.

Other related observations were more brief, but equally poignant. [Name redacted], commented on how "*we don't think about the collateral effects of some of our mitigation measures*." The lack of a holistic, system-of-systems approach that incorporates interdependencies within and across sectors could have dire consequences, [name redacted] suggested. Given that flooding is often a "game of inches," [name redacted] observed "*if you plug the Holland tunnel* [as some post-Sandy improvement proposals are calling for], *the water will rise higher elsewhere*." "Who is looking at that?" [pronoun redacted] wondered.

There are organizational and governance barriers to creating resilience.

The fourth barrier to enhancing resilience arises, in part, from the fact that lifeline infrastructures (transportation, energy, communication, and water) are *regional* systems that are inherently interdependent, yet we are organized to manage them by sector, and through local, state, and federal constructs. This approach overlooks the regional nature and interdependencies among the systems. Moreover, organizationally, we tend to "fight the last battle" or, in the present context, prepare for, and act based on, the last disaster. Here again, a diverse set of participants validated this challenge through their remarks.

Perhaps the most succinct expression of this point came from [name redacted], who noted that "*disasters happen to communities, not governments. Communities work in highly complex ways. It is important to recognize that orientation*."

Addressing the structural barriers to enacting more resilient building standards, [name redacted], lamented how "*some states, through their governance structure, can't enact certain building codes. We are only in the high single digits for states that actually follow all national (model) building codes*." Efforts to develop and enact uniform codes of any type are further complicated by budgetary and federalism concerns. [Name redacted] explained that implementing uniform building standards through federal regulations is problematic (beyond any potential limits on federal authority to do so) as the Office of Management and Budget and Congressional Budget Office will require any such regulations to show how implementation costs that will be borne by the states will be offset. This, [name redacted] suggested, might be difficult to do. Relatedly, [name redacted], questioned the appropriate balance of power between the federal and state governments in this area: "*if a state didn't adopt a statewide building code, should the federal government require it to*?"

Other participants commented on related organizational impediments to securing better, inter-disciplinary resilience research. [Name redacted], observed that "*research is linked to sources of funding. In order to get a more coherent body of research on resilience, it is necessary to get a more coherent (and consistent?) source of funding. Projects are developed based on where researchers can get the resources to do them*." Accordingly, current research is largely compartmentalized around fairly discrete (not, holistic) issues that are tied to the specific interests of the myriad agencies funding resilience related projects. [Name redacted], agreed with [name redacted] point. "*Where the government decides to fund, we will go to it*."

In sum, the foregoing comments, and many others like them, confirm that the four barriers to advancing resilience proposed at the outset of the symposium are very real indeed.

The barriers to resilience, however, were not the only recurring themes that surfaced during the symposium. The following section proposes four additional concepts that, while inter-related with each of the aforementioned obstacles, are critically distinct therefrom. In the author's opinion, these core concepts were woven throughout the discussions and provide a useful alternative framework for considering the key takeaways from the event.

Complexity

All who spoke about the lessons of Hurricane Sandy stressed, in some manner, the need to better understand the *complex* interdependencies (and resultant cascading failures) within and among the lifeline infrastructure sectors that were devastated by the "predictable surprise" of that storm. A separate series of complexity-themed comments centered on how American communities are all unique. Because of this heterogeneity, many opined, there cannot be a one-size-fits-all approach to resilience. Clearly, the need to better comprehend complex issue falls under the heading of "we don't recognize how unprepared we are." A related discussion – which is perhaps better categorized under the caption of complexity itself, rather than the rubric of our bias toward discounting future risk and overestimating our current abilities – is how to best disentangle these problems.

The consensus of those present was that, to be effective at understanding complexity and enhancing resilience, we must discern and appreciate the *desired functionalities of each community.*

Additionally, a chorus of voices acknowledged the need to view advancing community resilience and critical infrastructure resilience as inter-related goals, which are best viewed through a systems (and system of systems) perspective. While these ideas are certainly not new – indeed, they were the focus of Dennis Mileti's 1999 book "Disasters by Design," – it is telling that they were repeated throughout the symposium.

Interestingly, those stressing this complexity theme were apparently preaching to the choir. Attempts to compartmentalize the symposium discussions themselves were questioned by several participants. In one set of breakout sessions, for example, one group was asked to discuss potential economic incentives for spurring investments in resilience, while another was asked to consider (broader) policy based incentives. [Name redacted], who was assigned to the policy incentive group discussion, openly questioned, "*Shouldn't we be having this conversation with the [participants in the] economic incentives discussion? Aren't they inter-related*?"

Community

Given that the NIST event was designed to prompt discussions on methods for enhancing, standards for measuring, and incentives for spurring community resilience (in addition to critical infrastructure resilience), it is not surprising that the idea of "community" came up frequently. What is perhaps surprising, especially for a dialogue that occurred in the nation's headquarters for technical standards, was the number of times and variety of contexts in which "community" was discussed. [Name redacted], noted how "community needs drive functional requirements" for infrastructure. There is much more to the importance of communities, however, than their relation to building and materials standards.

Community characteristics matter. [Name redacted], noted that [name redacted] studies of Israelis in the wake of security-oriented disruptions suggest that the ability to "bounce back" is heavily influenced by the nature of the communities affected. "*Communities that are more socially active, and philanthropic*," [pronoun redacted] noted, "*are more resilient*."

While resilience can be built at the individual, household, and community level, the numerous comments concerning "community" suggest that a critical force in enhancing *national* resilience will, and necessarily must, be communities themselves. Along that line of thinking, [name redacted] argued that what *any "resilience initiative" needs is an advocacy "community" of its own*. Specifically, [pronoun redacted] pointed to how Mothers Against Drunk Driving was able, through effective lobbying, media outreach, and other grass roots initiatives, to create a sea change in how drunk driving is viewed by the public, and treated by the government. Something similar, [pronoun redacted] suggested, will be required – but does not concurrently exist – to bring about the type of large-scale improvements in resilience that those in attendance have been advocating.

Culture

An important component of building an advocacy community is instilling a "culture of resilience" into our social fabric. As [name redacted] put it, "*we need to get to the tipping point of a culture of resilience to make the political climate more workable*." The importance of fundamentally changing our culture surfaced in a variety of comments and contexts.

[Name redacted] observed that *resilience success* (evident in the anecdotes offered by [name redacted] and others) *appears to grow out of a sense of responsibility* (a cultural characteristic). [Name redacted], recounted how [pronoun redacted] agency has been targeting this issue through a subtle shift in focus from response, to individual preparedness and prevention (including through a recently released preparedness app). [Name redacted], offered a similar prescription, suggesting that *we must focus on education and getting people "used to" the concept of resilience in order to affect needed change*. There was clearly consensus that a shift away from dependency on government (in terms of both rescue and bail out) to one of preparedness and personal responsibility is needed.

An additional aspect to both culture and community themes was the importance of building trust and connectedness within and among communities, sectors, and interests; ideally, in advance of an event. As [name redacted] observed, "it is about relationships and trust." [name redacted] agreed, "*trust and connectedness are absolutely essential* [to overcoming] *the myriad structural barriers to the goal we are aspiring to*."

Communication

A final cross-cutting theme that emerged – which can be seen in many of the comments concerning the need for cultural change – is the importance of communication (with respect to both education and transparency). [Name redacted] expressed the essence of this theme well. "*What we need is to figure out how to communicate the right information, at the right time*, *in the right form*. *We keep finding a lot of our information [and research] is lost in translation; it is not understood by people who need to make decisions*." This point, while made with respect to politicians and policymakers, should be construed to include individuals and households as well.

Indeed, [name redacted] argued, one of the major reasons there is an empirically documented high rate of community resilience in Israel is because of a culture in which everyone maintains a elevated degree of situational awareness. Critically, this is enabled by that government's efforts to disseminate information in an open and timely fashion. Such transparency "has to be promoted on a regular basis," [name redacted] suggested. "[*People] have to understand not only what the risk is, but what must be done*."

In addition to better communicating threats, many participants saw the necessity and potential power in forcing more transparency in infrastructure risks and liabilities. Because Protected Critical Infrastructure Information (PCII) information is so tightly held, often only trusted "security" personnel within a given organization have access to it. Yet, in many instances this information is even more meaningful to professional engineers or other technical experts that could provide a more holist view of the associated vulnerabilities and means for reducing them. [Name redacted] argued, "*we need a trusted atmosphere where this information is (more) available*" to enable the type of multi-disciplinary, integrative approach to resilience we have been discussing. Relatedly, some, including [name redacted] and [name redacted], saw regulatory requirements that would mandate inventories and disclosure of infrastructure risks as a potential forcing function for improvement. While required transparency might indeed create the very political liabilities that resource constrained politicians fear, mandating such disclosures (from above) would provide significant incentives for creative action (despite the pervasive lack of adequate funding at the local level).

Whether couched in terms of external threats or internal vulnerabilities, all of these comments provide a clear message: more open communication among wider audiences is needed to further enhance resilience.

This final section highlights tangible recommendations that emerged during the course of the symposium, which, in the author's personal opinion, hold particular importance or promise. It does not recapitulate all of the observations and recommended actions from each panel and breakout session. Instead, the following discussion reviews five suggestions that appear capable of overcoming the noted barriers to resilience, while concurrently addressing one or more of the core themes of complexity, community, culture, and communications.

Develop and deploy (more) policy "flight simulators."

Several presenters extolled the virtues of recent innovations in visualizing "big data." Related advancements in complex, non-linear, dynamic modeling have led to the creation of decision support tools that provide policymakers with the ability to model multiple "what-if" scenarios and to "see" the likely cross-sector consequences of various policy choices. Some efforts are already underway to apply these technologies to decision-making in the resilience realm. ([Name redacted], for example, detailed [pronoun redacted] efforts with a GIS-based environment that incorporates functionally realistic infrastructure and engineering systems). More investment is needed, however, in applying these technologies to improving national resilience on a larger scale.

The benefits of doing so are, at least, fourfold. First, such policy "flight simulators" have the potential to simplify (through visualization) the *complex* interconnected systems to which achieving resilience is linked. Second, focused efforts on developing new, or integrating existing, systems will likely spur greater research and understanding of cross-sector interdependencies. Third, widespread use and experience "playing with" such tools will make influential actors more comfortable (and thus, more inclined to consider) the concept of resilience in other contexts. Fourth, the resulting increase in resilience "fluency" will foster an environment more conducive to achieving a fundamental cultural shift.

Propagate disaster case studies (and rapid response teams in support thereof).

While developing and deploying policy flight simulators will require additional time and funding, we need not wait on such efforts to communicate our current resilience risks and opportunities. As *Dr. Flynn* remarked, "*disasters are a terrible thing to waste*." Political scientists have long studied how catastrophes and other "focusing events" open narrow "policy windows" of opportunity for enacting meaningful change. There is much to be learned from volumes of existing, readily accessible post-disaster data. The ever-growing number of disaster and resilience-focused research centers – which have historically proven instrumental in promulgating research – are poised to help *open our eyes* to the challenges, and *change our culture* by broadly *communicating* these lessons learned.

To raise the quality of the data underlying such research and education efforts (and to help foster the resilience community of practice discussed further below), funding agencies should look to supporting deployable, post-disaster research teams, similar to the quick response studies that have been used by the University of Delaware's Disaster Research Center and funded by the University of Colorado's Natural Hazards Center to further the fields of disaster sociology, crisis decision-making, and emergency management (among many others). Teams of rapidly deployable, resilience-focused researchers would leverage a proven fieldwork technique especially suited to capturing ephemeral data on critical response and recover decision-making that assuredly has implication for resilience, but has yet to be studied through that lens to any significant degree.

Explore parallels to the environmental movement and a NEPA-like approach to considering resilience in all government activities.

For several symposium participants, conversations about the need to affect a *cultural* "sea change" toward an era of resilience evoked memories of the environmental movement of the 1960s. A popular uprising ("viva la resilience!?") clearly has the potential to improve our collective recognition of risks, create political incentives for action, and spur agencies (and political jurisdictions and institutions of government) to work together in a more integrative fashion. Government funded outreach and resilience education efforts have begun, but how can we further a true uprising?

While the National Environmental Policy Act was more of a Congressional reaction to the environmental movement than a driver, a similar statute (and mindset) could create the very widespread awareness and deliberation that is needed to break down the barriers to enhancing resilience and, ultimately, change our culture on the subject. [Name redacted] suggested just such an approach, which quickly piqued the interest and attention of many in attendance. As a procedural law, NEPA does not require the government to choose the most environmentally "friendly" course of action. It does, however, force policymakers to (publicly) acknowledge the environmental impacts of a given course of action.

An analogous resilience-focused statute (or NEMA amendment?) would indeed cause a sea change. To the extent no "major" piece of infrastructure is built without some connection to federal funding, resilience would quickly need to be "baked in" to the design of all infrastructure proposals to ensure easier passage through any procedurally required resilience review. Such a regime would concurrently "feed" the education process across myriad sectors and industries – potentially making resilience a competitive endeavor – ultimately enhancing our likelihood of achieving a more integrative approach.

Alter existing regulatory schemes to better incentivize resilience investments.

By making "resilience" a specific criterion for evaluating disaster recovery improvement grants, the federal grant process has been leveraged to ensure "smarter" reconstruction and mitigation efforts are underway. During one breakout session [name redacted] opined that the best paths to embrace with respect to incentives are the ones that already have traction. Following this logic, it makes sense to explore how the Stafford Act itself might be refined to reduce or eliminate moral hazards and other *disincentives* for resilience investment. Ideally, the disaster relief fund could be leveraged to *create incentives* for better mapping and managing existing risks before the next catastrophe.

One proposal for doing so involves making disaster relief monies contingent on a jurisdiction effort's to: (1) inventory and estimate the value of its public assets (in advance of a storm or attack); (2) phase in adoption of modern model building codes (instead of grandfathering buildings to older standards); and (3) secure insurance for that portion of a jurisdiction's exposure that would not be covered by the Stafford Act's disaster relief formula (i.e., anything above 75% of the potential loss). This proposal appears to synthesize many of the points raised in the various incentives discussion and deserves further discussion.

Create a (trans-national) community of practice.

In closing the International Resilience Symposium, Dr. Flynn remarked how he could not help being invigorated by the breadth of engagement on the issue of resilience, and by the wide array of talent assembled at the event. Interestingly, the day before, [name redacted] observed that "*outside of this [assembled resilience] community, not a lot of people understand what resilience is*." This comment, along with previously highlighted remarks concerning the importance of trusted networks within and among communities, and statements concerning the need to better weave resilience throughout the cultural fabric of our lives, collectively underscore the necessity of widening the array of stakeholders and key players actively engaged in resilience research and discussions.

One important step toward doing so is better organizing the thought leaders, communities of scholars, practitioners, and other stakeholders who are already activity working on and thinking about these difficult issues. As an "emerging" field of trans-disciplinary study, greater organization and collaboration will generate even more attention, interest, and inertia. Only through such efforts will more *integrative* analyses and solution be possible.

As the many insights recounted above attest, the International Resilience Symposium was a truly impressive event for what it was able to tease out of a diverse cross section of resilience experts in such a limited amount of time. While not an expressly stated goal for the event, the assembled participants effectively validated the barriers to resilience noted at its outset. Moreover, the thoughtful presentations and rich dialogue produced several important themes – complexity, community, culture, and communication – that can be used to further inform research, standards development, and policy initiatives going forward. Finally, the event yielded a number of promising tangible recommendations for action, as noted above. The author is extremely grateful to have been a part of this symposium, and for the opportunity to offer this small contribution to it.

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