Rebuilding for resilience

Fortifying infrastructure to withstand disaster

pwc

In the wake of a disaster, entire communities—public officials, business leaders, local residents—have united to "build back better."

In the face of sometimes insurmountable odds, they have found ways to rebuild smarter, stronger, and safer. They are successful because before the disaster struck, they had already laid the groundwork by fortifying their physical, digital, and societal infrastructure in an effort to better mitigate and manage disaster risk.

Cover photo: © City of Sendai

Executive summary

In March 2011, a 9.0-magnitude earthquake struck off northeastern Japan's Tōhoku region, shifting the Earth's axis. The ensuing tsunami, with wave heights reaching over 130 feet, devastated the nearby coastal region: 15,800 people died, 6,100 were injured, 2,600 are missing, and the landscape was permanently altered. Recovery costs are estimated at ¥17 trillion (approximately US $170 billion.)

Photo: © City of Sendai

The tsunami also triggered a series of events, culminating in the shutdown of the Fukushima nuclear reactor. Lacking both a steady power supply and functioning transportation infrastructure, industrial facilities throughout the country shut down and ceased exports, causing major disruptions in the global supply chain.

The occurrence of high-impact disasters is becoming increasingly familiar: Earthquakes in New Zealand, Turkey, and China; floods in Thailand and Australia; and hurricanes and tornadoes in the US are just a few high-profile examples. As crippling damage to the world's built infrastructure becomes more commonplace, the private and public sectors are looking for solutions to bolster the strength of their businesses and continuity of their communities—before and after disaster strikes.

Since 2011, PwC has been working closely with the United Nations Office for Disaster Risk Reduction (UNISDR) to analyze data from past disasters and uncover common themes in how business and government prepare for disaster while providing a framework for long-term public-private sector collaboration in disaster preparedness and response. *(For more, see "UNISDR and PwC chart a new global framework for disaster risk reduction" on page D)*

This report extends the focus of the UNISDR-PwC initiative, looking specifically at the long-term opportunity for public-private sector collaboration in building or rebuilding risk-resilient infrastructure.

Extensive conversations with public- and private-sector leaders worldwide in disaster management, recovery, and resilient rebuilding—in both developed and developing economies—provide the foundation of this report. They told us of their successes and setbacks, of rallying communities and local business to a common purpose, and shared their plans to build back stronger and smarter.

They were all in agreement that in the aftermath of a disaster, local communities, national governments, and business are all motivated to rebuild infrastructure that can withstand future disasters. This report describes why building disaster-resilient infrastructure is critical for a region's competitiveness, both nationally and globally. It also illustrates how the private sector can offer innovative solutions to help communities build or rebuild disaster-resilient infrastructure.

PwC recommendations

Drawing on our discussions and synthesizing our contributors' hard-earned lessons, we have distilled six key recommendations, explored in depth throughout the report:

1. *Focus on preparedness, prevention, and mitigation now.* Research from multiple sources (see page 7) proves early investment in disaster preparedness, prevention, and risk mitigation is cost effective; resilient infrastructure can prevent both human and economic loss.

2. *Foster collaboration across public and private sectors.* The earlier that business and government start to build relationships, the more effective they will be when disaster strikes.

3. *Motivate communitywide engagement.* Local participation from the entire community is pivotal to the entire cycle of disaster prevention, preparedness, response, and recovery—including rebuilding resilient infrastructure for a vibrant economy.

4. *Coordinate across regional boundaries.* Disasters don't recognize jurisdictional borders; resilient infrastructure often needs to cross regional boundaries to be effective.

5. *Encourage resilient recovery with optimal incentives.* The right combination of regulation and customized incentives can stimulate a resilient recovery.

6. *Build back stronger and smarter.* A long-term plan encompassing resilient physical and digital infrastructure—while leveraging technology for innovation—can infuse the local economy with renewed vitality.

The disaster risk management framework on page H captures PwC's findings and recommendations through the lens of infrastructure. The framework seeks to improve the capacity of physical and human systems to respond to and recover from extreme events. By analyzing their risk profile, business and government alike can chart a course to resilience.

The findings in this report are relevant for cities, regions, and businesses the world over as they prepare to face the growing risks of natural disaster, compounded by the mounting challenges of the 21st century—as well as for those currently rebuilding in the aftermath of a disaster.

Disasters worldwide have increased in intensity and frequency over the past decade

Sources: Munich Re, National Hazards Center at Kansas State University.

UNISDR and PwC chart a new global framework for disaster risk reduction

Global interdependencies—in which a disaster in one part of the world brings economic activity to a grinding halt in another because of the increased vulnerability of distant facilities—are prompting radical change in disaster preparedness and response from both the public and private sectors.

Each brings its own specialized expertise. With business continuity planning, the private sector has successfully embedded systemic resilience into its overall strategy. However, few organizations have coordinated their efforts industrywide, even though they could share leading practices.

Meanwhile, the public sector's knowledge of and experience with disaster risk is comprehensive. Working in isolation is not an effective approach; together, the public and private sectors can collaborate to reduce redundancies while building more comprehensive risk resilience across economies and societies.

While pockets of informal collaboration have always existed, no common platform currently links public and private sectors across industry sectors, national and local governments, large and small businesses, and in developed and emerging economies. Nor does any current forum provide clear focus on concrete action and practical guidelines.

A new framework for collaboration

Over the past 10 years, the United Nations Office for Disaster Risk Reduction (known as UNISDR because it was originally titled the International Strategy for Disaster Reduction) has raised global awareness of natural hazards and risk resilience. Over the next decade, UNISDR will help create and leverage private-sector disaster management solutions on a global scale in collaboration with public- and private-sector participants.

The framework for these solutions, created jointly with PwC, will serve as a foundation from which to build a global public-private collaborative platform for disaster resilience—with the goal of creating risk-resilient societies worldwide. Both the public and private sectors should play an active role in addressing the challenges that currently hinder collaboration.

Fourteen global companies, which have already developed leading approaches to disaster-risk preparedness and response, will participate in this initiative (see chart). They represent a variety of industries from consumer goods to energy.

Global private-sector participants in the UNISDR-PwC initiative

Company	*Country*	*Industry*
ABB	Switzerland	Automation and power technologies
ARUP	UK	Design and consultant engineers
BG Group	UK	Energy resources
Citigroup	USA	Financial products and services
General Electric	USA	Energy, health and home, transportation, and finance
HCC Group	India	Engineering and construction
HIRCO Group	India	Real estate
Hitachi Group	Japan	Social infrastructure and systems
Intercontinental Hotels Group	UK	Hotelier
Nestlé	Switzerland	Nutrition, health, and wellness
NTT East Corporation	Japan	Telecommunications
Roche	Switzerland	Health care
Shapoorji Pallonji & Co. Ltd (SPCL)	India	Construction
Walmart	USA	Retail

Source: *UNISDR and PwC: Working Together to Reduce Disaster Risk,* 2013.

The UNISDR initiative analyzed what makes organizations resilient—able to recognize and take risk while rapidly and effectively adapting to change. The analysis revealed these leading practices:

- Seek professional advice to understand risk exposure in the event of a disaster.
- Work with local personnel in far-flung locations to identify risk.
- Pinpoint risks in the various countries where they operate.
- Chart companywide global compliance with internal risk standards.

In the event of a disaster, leading practices included:

- Provide remote access to employees.
- Transfer work to alternative company locations.
- Set up a round-the-clock "control tower" to relay information between headquarters and all other locations.
- Rely on the expertise of staff with public-sector crisis-management experience.

Cutting through red tape

Several US companies have begun to hire staff with public-sector crisis-management expertise. One such company is Wal-Mart Stores, Inc., whose senior director of Global Emergency Management, Mark Cooper, has more than 20 years of public-sector experience. Says Cooper, "I had a lot of experience with Walmart while heading up emergency management for the state of Louisiana. We partnered with them on a number of initiatives, including preparedness campaigns. Based on that experience, I became a big supporter of collaboration between the public and private sectors."

Today, Walmart works closely with state emergency managers to build relationships ahead of a disaster so company officials know whom to contact when disaster strikes. "One of our main concerns is to get generators from point A to point B to get our stores reopened," says Cooper. "But many states have regulations that prohibit certain weight limits going across their highways. Having that relationship helped us to work through the red tape. And the sooner we reopen our stores, the sooner local communities can recover, allowing them to rely less on government."[1] *(For more, see interview with Cooper.)*

To prepare for disasters over the long term, companies use scenario planning to simulate various disaster risks. They also create their own safety standards in regions where local standards might be lax. And they coordinate with peers and suppliers to protect the various links in their supply chain, for example, by sharing resources in various parts of the world where their competitors might also have suppliers.

The UNISDR initiative uncovered several examples of public-private sector collaboration, as follows:

- An international shipping company instructed UN officials on how to prepare an airport in the Middle East for natural disasters, the only commercial airport in that particular country to which annual US exports tally more than $1 billion.
- In Florida, Miami-Dade County partnered with local businesses and universities to shore up their buildings for hurricane protection, should local residents need shelter. That meant meeting all building-code regulations, including protective glass or shutters on windows as well as obtaining backup generators.
- Education and awareness are integral to preparing for disasters in Japan. The government taught survival skills to children as young as elementary-school age, which saved lives during the 2011 tsunami.
- An easy-to-access mobile banking system generated $10 million in transactions during 2012's Hurricane Sandy, which affected a large swath of the eastern United States.[2]

The ultimate goal of the UNISDR initiative is to provide a forum for leadership on disaster risk reduction in which both public and private sectors can participate. Long-term commitment to the initiative is essential from both business and government.

Adapted from:

UNISDR and PwC, Working Together to Reduce Disaster Risk, 2013.

"A New Framework for Disaster Reduction," by Carlos Castillo, Lauren Cook, and Oz Ozturk, Resilience (a PwC journal), February 2013.

1 Mark Cooper, Senior Director, Global Emergency Management, Wal-Mart Stores, Inc., telephone interview, February 8, 2013.
2 A New Framework for Disaster Reduction," by Carlos Castillo, Lauren Cook, and Oz Ozturk, *Resilience* (a PwC journal), February 2013.

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Leading practices for rebuilding resilient infrastructure:

- Formulate long-term vision, guided by community and regional growth strategies.
- Prioritize projects based on strategic importance, potential value, and available resources.
- Assess land-use impacts and construction regulations.
- Incorporate economic, sustainability, and livability goals.
- Evaluate financing alternatives; capitalize on private-sector financing and experience.
- Provide transparency and close control over funds and capital projects.
- Establish centralized capital project management and risk oversight.

See this page for more information

Photo: © City of Sendai

Disaster
Global reverberations from a local event

A world more vulnerable to natural disaster

Over the past three decades, the world's population has almost doubled, topping 7 billion.

Today, more people than ever before are living in flood-prone river basins and cyclone-exposed coastlines. And in more than half the world's mega-cities—with populations exceeding 2 million—residents live in areas at high risk of earthquakes.[1]

Fueled by climate change, urban migration, population growth, and the increased scarcity of resources, natural disasters continue to increase in frequency and intensity.

While first responders have become increasingly adept at saving lives, the people whose lives are saved are often left with little or nothing. Their homes are destroyed and sometimes even their livelihoods, as local businesses struggle to recover. The aftermath of a disaster lingers for months and even years, creating new challenges for the region and its economy.

1 United Nations, *Building Resilience to Disasters Through Partnerships*, January 2013.

Economic losses escalate

Adding to the devastation, economic losses from disasters continue to escalate, as evidenced by the most devastating natural disaster to date: the 2011 earthquake and tsunami in Japan's Tōhoku region, which tallied more than $200 billion in recovery costs. Estimates from the resulting Fukushima nuclear accident—triggered by power and equipment failure caused by the tsunami—place total economic losses at $360 billion.[2]

The costs of disaster recovery far exceed the costs of preparedness; however, the immediacy of a disaster—with its images of crushing loss—is sometimes the only catalyst for change. It is certainly the most compelling.

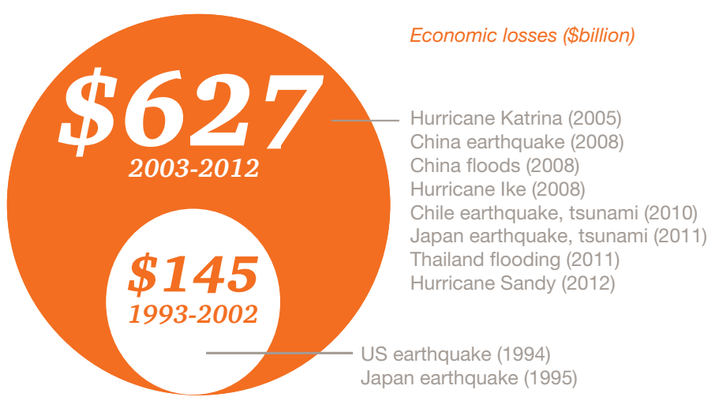
Measuring risk

Understanding the risks and impacts of natural disasters is an important first step in building fortified infrastructure. Yet measuring risk is not an easy task, and the chances to measure impacts aren't available until disaster actually strikes, and research methods can go awry.

Dr. Juan Pablo Sarmiento, a medical doctor and research professor at the Stempel College of Public Health at Florida International University, says, "We still have a long way to go in terms of measuring exposure, susceptibility, and resilience to disasters."

Sarmiento says much of the information on disasters reflects scientific language that needs to be translated so that decision makers in various communities can better understand the risks they face—not just in the immediate aftermath of a disaster, but also over the long term. *(For more, see interview with Sarmiento.)*

The most expensive disasters of the past three decades have occurred in recent years



Source: Aon Benfield Analytics

2 Elizabeth Ferris and Mireya Solis, "Earthquake, Tsunami, Meltdown: The Triple Disaster's Impact on Japan, Impact on the World," Up Front (Brookings Institution), March 11, 2013.

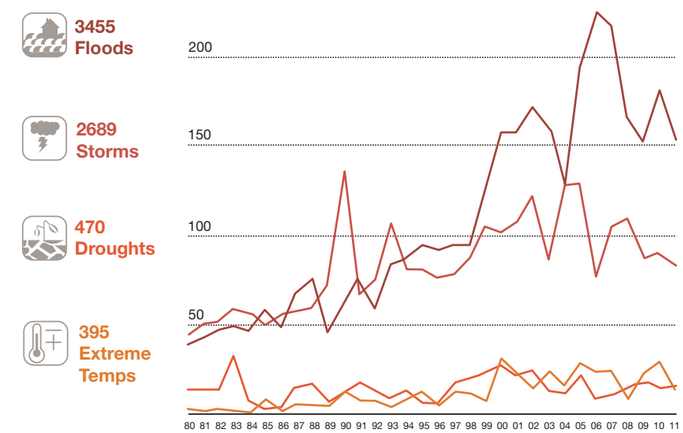
Rapidly escalating disaster risk

Long-term disaster recovery, including the rebuilding of resilient infrastructure, is compounded by the speed at which risk develops today, propelled by rapidly urbanizing societies, according to Margareta Wahlström, Special Representative of the Secretary-General for Disaster Risk Reduction at the UN and head of UNISDR (see adjacent chart).

In fact, this economic growth is driving accumulation of risk faster than it is being addressed both in the public and private sectors, she says. She is referring to the already strained resources in newly urban environments where people and infrastructure crowd a city or region with little forethought, often faster than city planners can keep up with. *(For more, see interview with Wahlström.)*

Every year, 65 million new people join the world's urban population, the annual equivalent of adding five cities the size of London.[3] Often, these migrants are replacing one risk with another: In Asia, more than 30 million people were displaced by environmental and weather-related disasters in 2010 alone.[4] *(For more, see "Asia's vulnerabilities" on the following page.)*

Number of climate-related disasters worldwide (1980-2011)



Source: UNISDR

As natural disasters continue to decimate entire cities and regions, municipalities are under increasing pressure to build resilient infrastructure—infrastructure that not only saves lives but also protects the economic future of residents and communities. But they cannot do it alone. More than ever, city leaders are recognizing that they need to collaborate—with their own residents, with the national government, and with business.

3 National Intelligence Council, *Global Trends 2030: Alternative Worlds*, 2012.
4 Fiona Harvey, "More than 30 Million Climate Migrants in Asia in 2010, Report Finds," *The Guardian*, September 19, 2011.

Asia's vulnerabilities

Disasters rack up $53.8 billion every year in the Asia-Pacific region according to the Asian Development Bank (see Figure 1).[1]

However, the true impact of a disaster extends far beyond the human and physical tolls reported in its immediate aftermath. In Asia, which is particularly disaster-prone, thanks to a confluence of geography, urbanization, and resource scarcity, the wider economic and social losses of a disaster linger for several years.

Figure 1: Disasters are particularly devastating in Asia

1970–2010:

1.7 million hazard-related deaths in the Asia-Pacific region

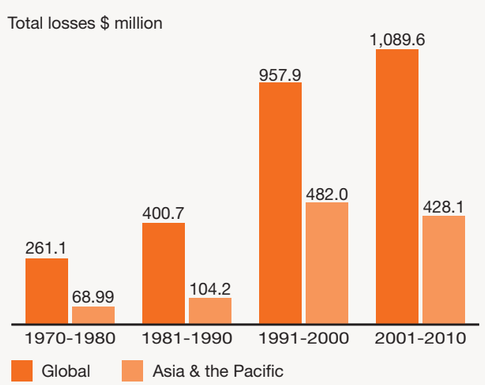
51% of global total

Annual cost of disasters: **$53.8 billion**

Source: Asian Development Bank

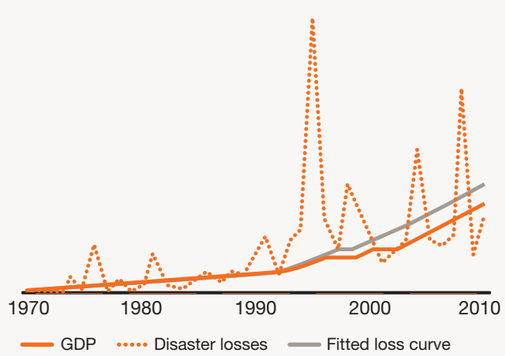
Figure 2: On an upward trend, losses in Asia are inching above GDP

Direct physical losses from disasters are following a gradual upward trend



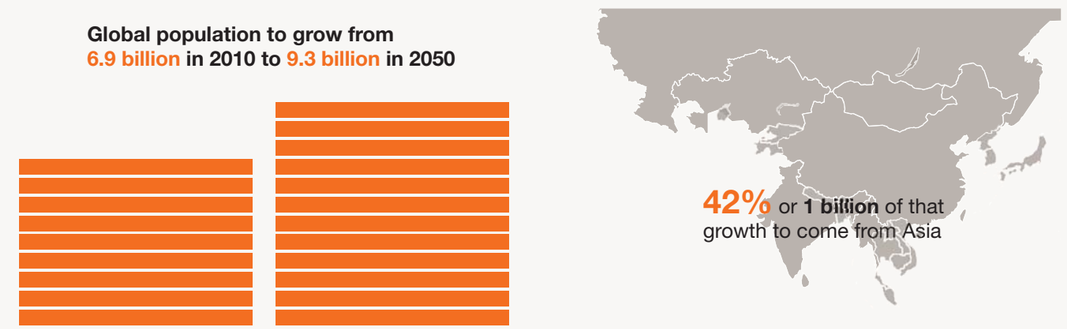
Source: Asian Development Bank

Growth in direct physical losses is outpacing regional GDP growth



Source: Asian Development Bank

Figure 3: Asia accounts for almost half of global population growth to 2050



Source: United Nations Department of Economic and Social Affairs, Population Division

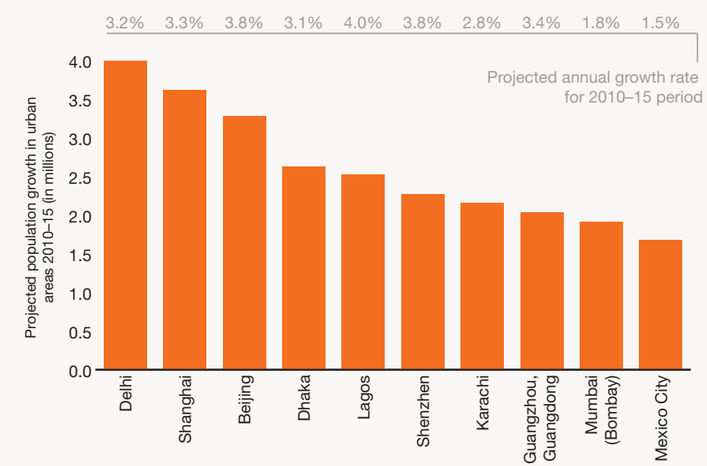
In emerging Asia, reduced output, higher production costs, supply chain disruptions, and job losses affect GDP growth rates, income and gender inequality, poverty, health, and education for the foreseeable future. In Thailand, for example, flooding in 2011 caused a 9 percent drop in Q4 GDP, slashing overall growth in 2011 to a scant 0.1 percent.[2] Overall, the loss from disasters is starting to outpace regional GDP growth in Asia (see Figure 2).[3]

Meanwhile, 42 percent of global population growth will occur in Asia between 2010 and 2050, according to estimates from the United Nations (see Figure 3).[4]

In fact, eight of the top ten fastest growing cities between 2010 and 2015 are Asian (see Figure 4).[5]

The toll on public finance for the reconstruction of infrastructure is particularly grim in the aftermath of a disaster as governments already struggling with the demands of explosive population growth encounter lost revenues concurrent with higher demands on spending.

Figure 4: Asian cities top the list of the world's fastest growing



Source: United Nations Department of Economic and Social Affairs, Population Division, *World Urbanization Prospects (2011 revision)*, and PwC analysis

Private financing, including public-private partnerships (PPPs), can lead the way in bridging the gap in public financing. The Asian Development Bank estimates that its member countries will need more than $8 trillion to build and rebuild resilient infrastructure in energy, transportation, telecommunications, water, and sanitation between 2010 and 2020.[6]

The initiative toward preparedness for disaster risk dates back several decades. What's new, however, is the recognition that development—the development of a community and its residents—is pivotal to enhancing the resilience of infrastructure, of business, of the very economy itself.[7]

Resilience in action: The role of engineering and construction firms

Engineering and construction firms have formed the Disaster Resource Partnership to collaborate with the public sector in rebuilding resilient infrastructure.[8] Their work in Asia, as detailed in a World Economic Forum report, includes the following initiatives:

- After the 2001 earthquake in Gujarat, India, Arup worked with local teams to ensure repair and reconstruction work met seismic-resistance building codes.
- Following the 2004 Indian Ocean tsunami, CH2M Hill was part of a team that assessed coastal developments and harbor plans in tsunami-prone areas with the goal of gaining local support for the long-term to rebuild resilient infrastructure.
- After the 2005 earthquake in South Asia, Arup sponsored a research project in earthquake-resistant construction. Those research findings allowed the local population to build back better and reduce vulnerability to future earthquakes.
- Following 2007's Cyclone Sidr in Bangladesh, Arup collaborated with an international NGO on prototype housing and construction methods, establishing performance criteria for cyclone resistance.
- In 2008, after the Sichuan earthquake in China, Arup collaborated on a master plan for resilient reconstruction that integrated land-use planning, economic and social recovery, sustainable development, and hazard-resilient planning.

In keeping with the UN's call to action for full participation in disaster recovery, engineering and construction firms have stepped up their role in sharing expertise and capacity by rebuilding resilient infrastructure.[9]

1 Asian Development Bank, *Investing in Resilience: Ensuring a Disaster-Resistant Future*, 2013.
2 Oxford Economics, *Country Economic Forecast: Thailand*, June 2012.
3 Asian Development Bank, *Investing in Resilience: Ensuring a Disaster-Resistant Future*, 2013.
4 United Nations Department of Economic and Social Affairs, Population Division, *World Population Prospects: The 2010 Revision*, May 2011.
5 PwC, *Global Economy Watch*, January 2013.
6 Asian Development Bank, *Investing in Resilience: Ensuring a Disaster-Resistant Future*, 2013.
7 Ibid.
8 World Economic Forum, *Engineering & Construction Disaster Resource Partnership*, November 2010.
9 Ibid.

Preparedness
Preventing human and economic loss

The imperative for preparedness

The evidence clearly bears out the imperative for preparedness: For example, a 10-year study of US Federal Emergency Management Association (FEMA) grants by the National Institute of Building Sciences found that, on average, $1 spent on disaster-risk mitigation and preparedness saves an average of $4 in future losses.[5] When the parameters of the research were broadened beyond FEMA—to include other agencies involved in disaster risk-mitigation activities such as the US Department of Justice and the US Department of Homeland Security—researchers found that, on average, $1 spent on preparedness can save as much as $15 in future losses.[6]

"Ultimately, it gets down to a mentality of 'You can pay me now or you can pay me later.' And if you pay me later, it will cost you a lot more than if you invest prudently now," says David Miller, FEMA's Associate Administrator for the Federal Insurance and Mitigation Administration. *(For more, see interview with Miller.)*

5 Multihazard Mitigation Council, *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*, 2005.
6 Andrew Healy and Neil Malhotra, "Myopic Voters and Natural Disaster Policy," *American Political Science Review*, August 2009.

Tom Prendergast, chairman and CEO of the Metropolitan Transportation Authority in New York, the largest transportation network in North America, supports this approach. "We have a State of Good Repair program to renew infrastructure and keep it within its useful life," he says. "The cost difference between using traditional design standards versus new standards that include resilience is truly an incremental step. It's not a billion-dollar cost."

Prendergast considers the cycle of urgency that surrounds natural disasters. In the current post-Sandy rebuilding process, he hasn't seen any waning of focus, but notes, "We cannot lose sight of the fact that there will be another hurricane and we do have to prepare for it. If we were to be fortunate enough not to have a hurricane for four or five years, some of that focus would go away. And we just can't afford to let that happen." *(For more, see interview with Prendergast.)*

Emiko Okuyama, Mayor of Sendai in Japan's Tōhoku region, agrees. Over the years, the city had fortified its key infrastructure after repeated earthquakes; it was considered one of Japan's most well-designed and resilient. However, Sendai's coastline infrastructure, including its sewage treatment facility, was severely damaged by the 2011 tsunami, a low-probability, high-impact event. Mayor Okuyama contends that a 15-foot-high wall would have protected the facility from the waves, and regrets that the minor additional expense wasn't added to the already significant cost of the ¥100 billion plant. *(For more, see adjacent interview with Mayor Okuyama.)*

7 PwC, *Cities of Opportunity*, 2012.

Interview with Emiko Okuyama, Mayor Sendai, Japan

In March 2011, a 9.0-magnitude earthquake struck northeastern Japan's Tōhoku region, causing a tsunami within the hour—a low-probability, high-impact event that is predicted to occur once every 1,000 years. Waves higher than 100 feet engulfed an area more than 30 square miles, including portions of Sendai, the closest major city to the earthquake's epicenter.

The city's coastal areas—including its seaport—were badly damaged, as was its airport. More than 600 Sendai residents died as a result of the disaster; some 200 were reported missing. Close to 7,000 homes were completely destroyed. Despite Japan's long-term reputation for attention to disaster preparedness, the economic losses amounted to the equivalent of 4 percent of GDP.

By March 2012, however, Sendai's post-disaster reconstruction had led to an economic upswing. The construction industry was booming, but so were the auto industry, retail sales, and hospitality, thanks to an influx of recovery workers. In October 2012, UNISDR recognized Sendai as a role model for its focus on resilient recovery. Okuyama was hailed for her political leadership in rebuilding for resilience.

Sendai has been lauded for its efforts in swift disaster recovery management. To what factors would you attribute this swift recovery?

After the 1978 earthquake, we learned some valuable lessons, especially that disaster management does not come cheap. You only get out of it what you put in. We had already begun replacing our old pipes for natural gas and water with highly elastic new ones. We were almost 80 percent done with this project. When hit by an earthquake, these new pipes don't break. Instead, they bend but stay intact.

And when we replaced our natural gas pipes, we segmented them so that we could shut off and repair only the damaged portions, thus maintaining uninterrupted supply. One of our above-ground sewage facilities was hit by the tsunami and lost electric power so we had to let the waste flow into the ocean. That wasn't our preference of course, but it was better than letting it build up.

We had also duplicated our sources as necessary so, for example, when natural gas supply ships couldn't reach Sendai because our port was completely destroyed, we were able to process our own supply of natural gas and distribute it to residents. This type of redundancy in sewage, gas, and water infrastructure—where the goal is to maintain a constant flow—is essential to overall disaster risk resilience.

What role did the local government play in the recovery?

In Sendai, we manage almost all our major roads and national highways at the local level. Same with water, gas, and sewage. We continually monitor our infrastructure to assess maintenance needs and establish immediate priorities. If the national government were involved, people unfamiliar with our local needs would be in charge and that would compound the disaster, substantially slowing the pace of recovery.

What plans do you have for resilient infrastructure going forward?

Following the disaster, we invested in elevated roads and added special tsunami evacuation roadways and facilities. We also imposed additional restrictions on the location of housing. And we are installing solar-powered generators so citizens will have an emergency supply of energy during a disaster.

In the past, we always focused on roads, sewage, water, and fuel following a disaster. They made up the lifelines of the city. A new component is telecommunications; without information technology, we can't respond to disasters. And none of that infrastructure is publicly owned. After the 2011 disaster, we had serious problems resulting from poor telecommunications. The lesson we learned there is that the government and private sector need to share information completely.

A city is only adequately prepared for disasters when infrastructure is functioning at the optimal level, whether it's operated by the public sector or the private sector. I am convinced that we must collaborate, rather than take separate approaches.

How can the government incentivize the private sector to implement resilience measures?

I think grants and subsidies will allow the private sector to implement innovative technologies that will ultimately lessen the burden on city government. We also need tighter regulations, as necessary. As we know, it was our strict building code that saved lives during the earthquake.

What role do private citizens play in disaster preparedness?

Private citizens, together with the public and private sectors, bear responsibility to increase their level of awareness for disaster preparedness. We work with the private sector, non-profit organizations, and local residents to conduct preparedness exercises every year—including informational sessions on disaster prevention at our schools. Those exercises prepared us to take action during a crisis. As a result, we were able to respond to the disaster faster in Sendai than neighboring municipalities did. This is what makes a city tenacious—the willingness of the entire community to shoulder a share of the responsibility.

How did you collaborate with the national government?

In the aftermath of a large-scale disaster, national funding is essential. But the overriding principle of the national government is that no action can be taken until a system is in place—with budget approval. Even to process the rubble, several months elapsed before we were able to settle on a unit price. But we needed to expedite our recovery, so before that unit price was determined, we went ahead with processing the rubble.

We need more flexibility during times of disaster to ensure we can start making initial payments. If the national government delegated some of its authority, local governments could take more immediate action—action that's desperately needed in the aftermath of a disaster.

During the reconstruction of infrastructure that spans various municipalities, how best can neighboring local governments work together?

We need a more formal mechanism in place that would allow us to do this faster, for example, building an embankment along a sea coast. Different local governments might settle on different heights for the embankment, thus delaying reconstruction.

How are you raising awareness of disaster preparedness among your residents?

As our population continues to age, we have to ensure that everyone is prepared at all times. We ask our condo residents to maintain a week's reserve of food, water, and medications. We will offer a certification to those condo buildings where teams of residents are prepared to help the older and less healthy among them. Eventually, we want all the condo buildings in Sendai to be certified in this way.

What kinds of cost-benefit analyses are you undertaking in the aftermath of the disaster?

We must take a long-term view of disaster risk management. We used to a take a 200-year perspective. Then we got blindsided by the tsunami which has a probability of occurring once every 1,000 years. So we need to appreciate the earth's ultra-long lifespan.

Another factor is rapidly evolving technology, which often allows us to build new infrastructure at lower cost. The tsunami completely washed away one of our sewage treatment plants, a ¥110 billion facility. In retrospect, a 16-foot wall—requiring a very small additional investment—would have protected the plant. But thanks to new technology, we were able to replace the ¥110 billion facility with one that is more compact and sophisticated for only ¥68 billion.

These types of public-policy decisions are essential to disaster risk mitigation: The ongoing repercussions from the 2011 Tōhoku earthquake and subsequent tsunami illustrate that—while nature may not be amenable to human control—its most tragic consequences can, in fact, be mitigated by public policy, according to PwC's *Cities of Opportunity*. In recognition of the role of public policy in disaster risk mitigation—especially as it relates to resilient infrastructure—PwC's survey of global cities has begun to account for the risk of, and preparedness for, natural disaster.[7]

Innovative business solutions, ready for rollout

Building resilient structures for the long-term is one of the objectives of the UNISDR's Private Sector Advisory Group, headed by Aris Papadopoulos, CEO of Titan America, the US subsidiary of Greece's Titan Cement Group. Papadopoulos says that today's building codes do not account for resilience in the built environment. He advocates reforming the system, similar to the initiative to improve driver safety in automobiles a few decades ago. As a result of that initiative, safer roads and more resilient automobiles are a reality today.

Papadopoulos says while rescue efforts to save human lives in the wake of disasters have improved considerably, those who are rescued are often left with nothing. "The whole approach to disaster risk reduction in the last 10 or 20 years has been, 'How do we get people out? We can always rebuild the structure later.' But we cannot afford that anymore," says Papadopoulos, "on a national or global scale, given the world's constrained resources."

While Hurricane Andrew in 1992 caused wholesale changes to building codes in Florida, waiting for disasters in order to change public policy "is a bad formula," says Papadopoulos. Instead, he recommends a certification process for resilient buildings, similar to the Leadership in Energy and Environmental Design (LEED) certification provided by the US Green Building Council.

Led by the insurance industry, the Institute for Business and Home Safety in the US is working on such a certification with the objective of securing tax credits for those who comply voluntarily with predetermined standards, similar to the LEED program. Unlike LEED certification, however, regional standards for resilient infrastructure will vary by likelihood and type of disaster.

As awareness of resilience certification increases, Papadopoulos hopes it will become the norm, just as with safety features in automobiles. "Today, even if you had the option to buy a car without air bags and anti-lock brakes, you wouldn't do it. I'm hoping the UN's efforts help to raise awareness so that we create a voluntary trend in this direction."

Papadopoulos continues, "In the next 20 or 30 years, we are going to spend more money on urbanization worldwide than we have spent in our entire history. If our investment isn't resilient the first time around, we're going to have to do it over." *(For more, see interview with Papadopoulos.)*

The UN's Wahlström concurs, saying it will be a lot more expensive to rebuild infrastructure in 20 years because someone made the cheaper choice today.

But that kind of long-term focus takes leadership, she adds. "It's having the courage to look at a slightly longer timeframe than two years or even one year in this rapidly evolving environment." Longer time frames allow public and private sector officials to weigh all the costs and benefits as they build or rebuild resilient infrastructure.

Bob Prieto, senior vice president of the industrial and infrastructure business group at Fluor Corp., assesses this challenge in the US. "We 're trying to have an informed debate around assets that have lifetimes of 35 to 100 years in what is effectively a two-year political cycle," he says. "We seem to learn only in failure. And that's an expensive way to learn." *(For more, see interview with Prieto.)*

Establishing trust

For effective collaboration between the public and private sectors in the aftermath of a disaster and its accompanying chaos, both sectors must establish a level of trust ahead of time—well before a disaster actually occurs, says Wahlström.

FEMA's Miller agrees that partnership between the public and private sectors is essential, especially in light of the ownership of critical infrastructure in the US: the private sector owns and operates approximately 85 percent of it.

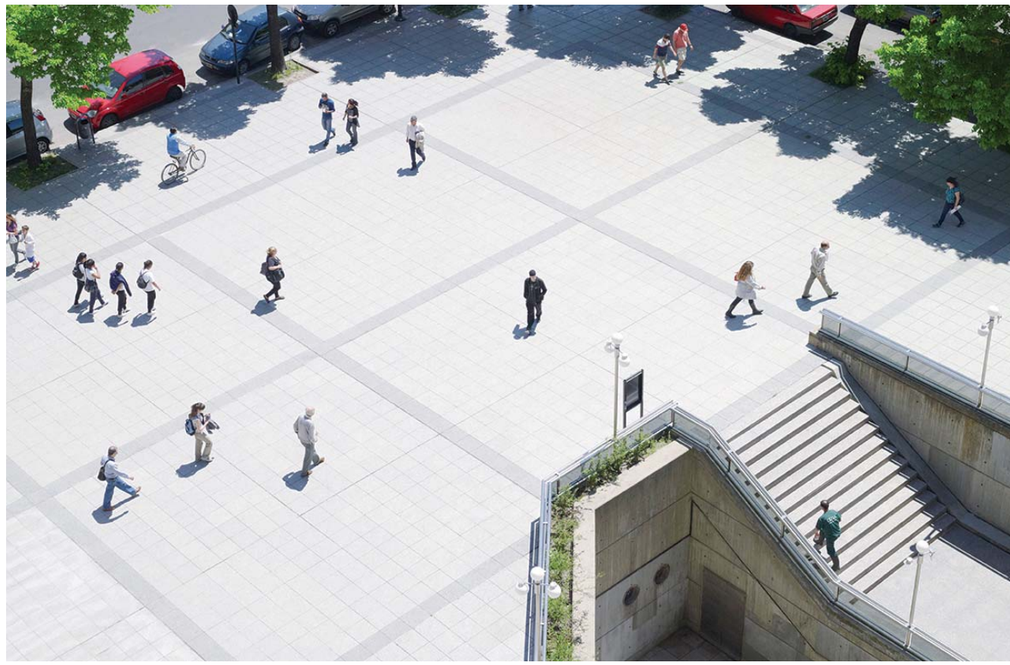
Okuyama is convinced business and government must work in concert. For example, in today's world of instant mobile communications, private sector telecommunications companies play a crucial role in the aftermath of a disaster.

After the 2011 earthquake and tsunami, Sendai experienced serious problems resulting from limited accessibility to telecommunications. "The lesson we learned," says Okuyama, "is that the government and private sector need to share information completely."

The UN's Wahlström says the conversations between business and government "are not yet concretized enough," even though they're critically important. "It's happening a bit here and there, but it's not widespread," she says.

One way to establish that level of trust is via collaborative efforts between the public and private sectors, sometimes referred to as co-design, discussed in more detail below. Disaster preparedness planning for a community that's been jointly designed by the public and private sectors not only builds trust, it also allows each sector to bring their strengths to the process.

Further, collaborative planning provides a solid foundation for working through the disaster risk management life cycle, moving the whole community into recovery and reconstruction with a focus on building resilient infrastructure following a catastrophic event.



"Waiting for disasters in order to change public policy "is a bad formula."
— Aris Papadopoulos, CEO of Titan America

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Recovery
Lessons from around the world

Public-private partnerships

In February 2011, Christchurch, New Zealand's third largest city, was struck by a 6.3-magnitude earthquake that killed 185 people, injured several thousand, and caused millions of dollars of damage. It was the most devastating of a series of year-long earthquakes and aftershocks in the Canterbury region, where Christchurch is located.

Bob Parker, the mayor of Christchurch, reports that in the course of its rebuilding efforts, the city implemented transparent contracts—negotiated by government agencies and the private construction companies involved—that provide incentives for productivity and efficiency measured by rigorous predetermined standards. *(For more, see interview with Parker.)*

Incentives for the private sector can lead to alternative sources of public financing for cash-strapped municipalities, as illustrated by the increased use of public-private partnerships (PPPs) worldwide over the past few decades.

Interview with Akihiro Ohta
Minister of Land, Infrastructure, Transport and Tourism, Japan

In March 2011, a 9.0-magnitude earthquake struck northeastern Japan's Tōhoku region, causing a tsunami within the hour—a low-probability, high-risk event that is predicted to occur once every 1,000 years. While Japan's long-term investment in resilient infrastructure minimized loss of life from the earthquake, the unforeseen tsunami did result in a death toll of some 15,800.

Meanwhile, the economic loss from the earthquake tallied more than $200 billion, one of the world's most expensive disasters to date. By early 2013, Japan's MLIT had implemented policy changes in land use, disaster risk mitigation, and infrastructure resilience that offer lessons to other disaster-prone regions of the world.

To what extent can you attribute the pace of recovery and reconstruction to Japan's legendary reputation for investing in disaster-resilient infrastructure?

After the widespread structural damage from the Great Hanshin earthquake of 1995, we initiated a national effort to make our buildings more earthquake-resistant. In my view, our progress on that count helped limit the damage from the Great East Japan earthquake of 2011. Our bridges held up. So did our reinforced shoreline breakwater and seawall facilities, which also acted as a barrier against the intensity and speed of the tsunami.

What role did pre-disaster training play in the recovery effort?

A very significant role, actually. A coordinated effort by trained personnel from The Japan Self-Defense Forces, the US armed forces, local and national firefighting units in Japan, and MLIT teams—together with residents from local communities who had been trained in disaster mitigation and recovery techniques—proved extremely effective in accelerating the pace of recovery and reconstruction. For example, MLIT teams, together with The Japan Self-Defense Forces, quickly and effectively executed "Operation Comb"—so-called because the transport route resembled a comb—which paved the way for emergency transport routes from inland to the devastated coastal areas (see following page for an illustration of Operation Comb). Continuous training and simulation were among the vital factors in the successful execution of this operation.

Our ongoing disaster-prevention education and training—with simulated drills—contributed substantially to our recovery effort. We have to continue to prepare for the reality of natural disasters with exhaustive, large-scale training programs.

In retrospect, were there areas in which you might have done better?

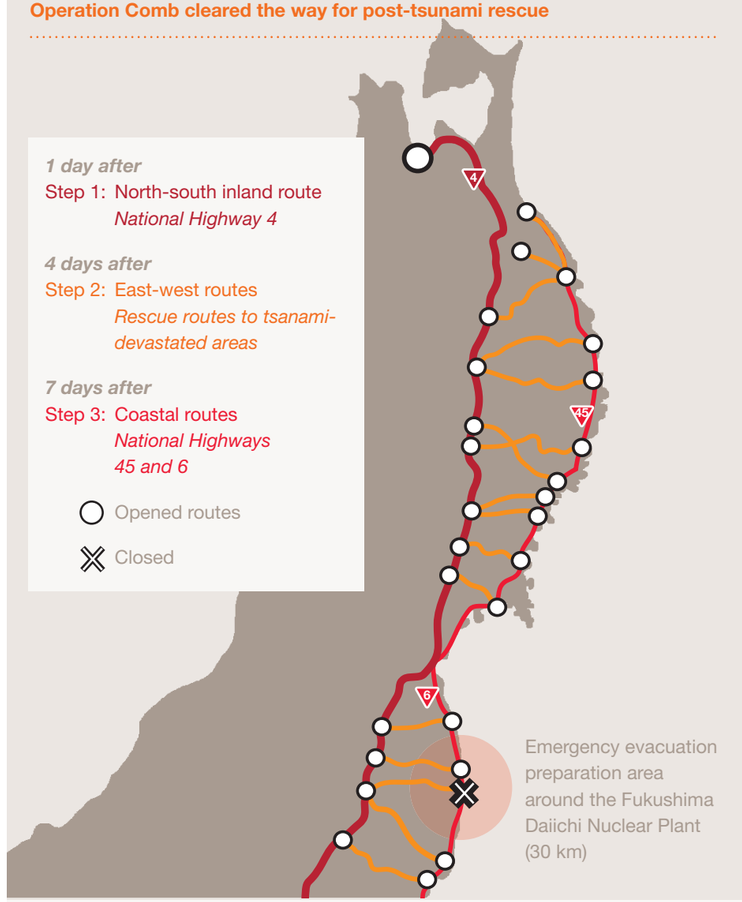
Certainly. For example, in preparation for the tsunami, we evacuated residents to nearby sites simply because that's what our scenario-planning called for. But we hadn't considered any scenarios involving monster tsunamis because they are forecast to occur every 1,000 years.

Our fundamental challenge is to maintain constant preparedness for an event of the scale of the tsunami. We cannot continue to assume they are unlikely to occur. We must ensure all residents are informed in time when an earthquake or tsunami or blizzard strikes. For that to happen, we must improve modes of communication for all first responders. These measures will require changes in regulations, which we are seeking. Besides, we must retrofit our buildings as necessary; therefore, MLIT worked on revising the law.

What fundamental policy changes have occurred since the Great East Japan earthquake?

Our fundamental views on infrastructure development continue to evolve. Some residents have historically viewed public works projects in Japan as wasteful. However, in the aftermath of the earthquake, the fields of disaster prevention, mitigation, and maintenance are now considered part of the mainstream in public works

Operation Comb cleared the way for post-tsunami rescue



Source: Ministry of Land, Infrastructure, Transport and Tourism, Japan

projects—and we must launch comprehensive initiatives to build disaster-resistant infrastructure.

We must also undertake projects that improve a building's structural resistance to earthquakes and implement countermeasures against aging and obsolescence in our infrastructure. Given our falling birth rates, aging society, and energy needs, the solution isn't to pave over our country with concrete or build higher breakwaters. We need flexible, environmentally sound, community-based development. I was a member of my sumo wrestling club at university so I would liken the infrastructure we need to Ichiro Suzuki of the New York Yankees: muscular, yet lithe and speedy.

Development projects in Japan have typically proliferated in rural areas to accommodate population growth; we need a policy shift that supports the creation of compact cities in urban areas, where residents don't have to rely on automobiles for their daily lives. We must focus on smart homes with roof-mounted solar panels and insulation that helps them stay cool in the summer and warm in the winter to conserve energy. Concentrated neighborhoods of smart homes within these compact cities is one of our goals of community development.

What role can the private sector play in post-disaster rebuilding of infrastructure?

The earthquake halted all forms of transit completely, causing train stations to overflow with commuters who had no way to get home in the Tokyo metropolitan area. We must do more to address and solve this problem with joint public-private sector collaboration, especially at key hubs such as Shinjuku, Ikebukuro, Yokohama, and Tokyo stations. In Ikebukuro, one of the largest districts in Tokyo, department stores and other businesses are participating in disaster preparedness training.

The private sector is critical to infrastructure rebuilding. The government should devise tax incentives—for example for private companies that set up emergency storage facilities for use in a disaster. However, not everything requires tax money. It's very important to pursue cooperative tie-ups between the public and private sectors, including public-private partnerships and private finance initiatives (PFIs)—in which both sectors have an incentive to participate.

What is the role of local government in the wake of a disaster?

In the case of a natural disaster, everything is local. Unlike, for example, a national missile defense system, which depends on centralized information management systems. In both cases, the national government plays a role. However, disaster countermeasures are practical business; the action is all local. So we need to arm strong local institutions with frameworks for independent action. That will allow municipal governments, town assemblies, and neighborhood groups to respond effectively in the wake of a disaster. We must develop capacity within these conventional community structures.

How do you balance costs and benefits when building disaster-resistant infrastructure?

After a disaster, the local construction industry plays a pivotal role in building disaster-resistant infrastructure. Residents who work for the local construction industry, for example, are not only employees of the local construction company but also residents of the community affected by the disaster.

They are willing to defend their community and collaborate with local government on a daily basis. Though it would be hard to quantify this collaboration as an economic benefit, this approach does lay the groundwork for healthy construction-related industries with strong roots at the community level.

The construction industry, in particular, has traditionally played an instrumental role in Japanese society as a key source of employment. In that respect, the industry plays an important role in disaster management and reconstruction—just as a doctor would in the neighborhood medical clinic.

How do you address the challenges of maintaining existing infrastructure?

In the 1970s, we built some 10,000 bridges in Japan every year. Now the average is about 1,000 or so new bridges a year. In effect, the trend has reversed sharply and we're now approaching zero. The challenge we face now is a steep uptrend in the need for infrastructure maintenance.

We have to extend the useful service life of our amassed mountain of infrastructure. The typical useful service life of 30 to 50 years is not adequate anymore. The field of maintenance engineering as a formal academic discipline will take on new importance.

Research into technologies for the seismic isolation of buildings is currently underway. Countermeasures against ground liquefaction and technologies for fire-resistant wood-frame housing are also being studied. We must find ways to make our existing infrastructure more resilient while holding down the associated costs.

Public-private partnerships require infrastructure to be managed on a life-cycle basis, which means future disaster risks must be taken into account when building or rebuilding infrastructure. Please address how this should be done.

Japan has accumulated decades and more of experience and expertise in erecting buildings of quality that last a very long time. Take the example of the Horyuji Temple, which was built in the seventh century. One of Japan's oldest temples, it is also the world's oldest surviving wooden structure. Over the years, we've reinforced the temple with extensive maintenance measures, including the addition of diagonal crossbeams.

I also found out recently that a particular five-storied pagoda has a thick central pillar that oscillates like a pendulum in sync with the shock waves of an earthquake, thus making the entire structure earthquake-resistant.

Given Japan's accumulation of knowledge in building disaster-resistant infrastructure throughout history, we now have to focus that knowledge on maintaining the useful life of our infrastructure over the long term. We can do that via collaborative public-private partnership arrangements. In my view, we must implement measures that prepare us for future earthquakes in susceptible areas of the country—such as the Tōkai and Tōnankai regions as well as the Nankai Trough.

Ultimately, we must look beyond pure countermeasures. With advances in technological development, we must build communities that lead the world in their flexibility and livability and attract people from other parts of the world.

What lessons do Japan's experience with the Great East Japan earthquake offer the global community?

I look forward to providing a systematic overview of Japan's globally heralded disaster-risk preparedness, mitigation, response, and recovery techniques to people all over the world.

I believe Japanese industry derives its collective strength from all the people on site, working silently through the long, hot days of summer and the cold snows and rains of winter. It's not only their fortitude that is remarkable but also their diligence as they work quietly to advance the recovery effort.

As a society, we value not only the technology required for advancement but also the individuals who support that technology. I hope we can share with the international community the importance of ordinary people in building a resilient community.

A more formal collaboration is what Akihiro Ohta, Japan's minister of Land, Infrastructure, Transport and Tourism, proposes. He says, "We think it's very important to pursue cooperative tie-ups between the public and private sectors, including public-private partnerships and private finance initiatives (PFIs)."

PFIs became popular in the 1990s in the UK and Australia, and were adopted shortly after in Japan. They represent a particular method of financing that allows the public sector to retain ownership of an infrastructure asset that is designed, built, financed, operated, maintained—or any combination thereof—by the private sector. Public-private partnership is a term used more generically to describe these types of partnerships that encompass flexible financing arrangements for infrastructure assets. PFI and PPP projects are very similar; both include a private-sector component.

Today, PPPs represent a form of infrastructure procurement that offers alternative financing options, specialized expertise, and risk transfer to the private sector. PPPs are most likely to succeed when deals are structured to be mutually beneficial to both the public and private partners—because each partner then becomes an active stakeholder.

Depending on the particular deal or type of infrastructure investment, private partners sometimes become long-term stakeholders. Cash-strapped cities are beginning to incorporate more private-sector participation into the planning and execution of infrastructure projects, which might not get off the ground without that private-sector participation.

However, very little consistency currently exists in the financing of critical infrastructure worldwide. "I think one of the tensions is, 'How do you use public money that benefits private companies?'" says FEMA's Miller. "And my answer is to turn that question on its head so it becomes, 'How do I invest in private industry in order to provide for the public good?' And that is a discussion that we have to have. We've got to make the case to business that it's in your interest to make this investment."

Co-designing recovery

Bob Dixson, the mayor of Greensburg, Kansas, agrees. Dixson led Greensburg's long-term rebuilding effort after a Level 5 tornado—with 205 mile-per-hour winds—destroyed 95 percent of the city in May 2007.[8] In the aftermath of a disaster, he says, "there's a tendency for all of us to want to get back to some sense of normalcy as quickly as we can." Dixson cautions however, against making life-changing decisions while the community is still coping with "a whole variety of emotional issues."

Dixson stressed the importance of community engagement and co-designed solutions for resilient infrastructure in the aftermath of a disaster. "We had the whole community—city, county, schools, hospitals—all collaborating together. So we had the opportunity to really pull together and plan our long-term recovery effort along with FEMA and other agencies. It wasn't just a boiler-plate plan from Washington, DC."

In describing the role of the private sector in Greensburg's recovery, Dixson says, "Partnerships with the private sector are highly critical in disaster recovery because it's not just about the buildings. You still have to have a community that is sustainable, that is resilient, that will be able to endure and continue. You can build back the buildings but you've got to have the people to inhabit the buildings. You've got to have a vibrant economy so we need to make sure that we involve private enterprise in the process." *(For more, see interview with Dixson.)*

Yutaka Saito, President & CEO of Information & Telecommunication Systems Company for Hitachi, sees a symbiotic relationship as being effective. He says, "The public and private sectors should have a collective vision for reconstruction. Their roles are complementary, with the public sector representing the consensus needs of citizens, and the private sector providing resources and skills for realizing the vision."

The recognition for collaboration acknowledged by public-sector officials is mirrored by the private sector: 74 percent of CEOs of infrastructure companies in *PwC's 16th Annual Global CEO Survey* said they are changing their policies to strengthen their engagement with regulators and the government.

"In the aftermath of a disaster there's a tendency for all of us to want to get back to some sense of normalcy as quickly as we can."
—Bob Dixson, Mayor, Greensburg, Kansas

8 Stan Finger, "Five Years Later, Greensburg Tornado Has Few, If Any, Peers," *The Wichita Eagle*, May 4, 2012.

Meanwhile, 72 percent are focused on boosting their engagement with the local communities in which they operate.[9]

Impelling community engagement

Christchurch's Parker takes responsibility to ensure local engagement that fosters a vibrant economy. "My job is to ensure that my city has a future," he says, adding that over the past few decades, Christchurch has made allowances in infrastructure planning for "the very real seismicity we face," given that New Zealand is "essentially the product of the collision of two of the great tectonic plates."

Says Parker, "We should be looking to rebuild a sustainable city. Not because it's the cool thing to do but because it's the smart thing to do. We have a chance to build a city that's prepared to embrace new technologies and new ways of thinking, a city that young people want. They have to be involved in shaping it."

Human resilience

Investment in resilient infrastructure is vital to protect cities from future natural disaster. But investment in "soft" infrastructure—social, cultural, and educational competencies—is also vitally important.

This "human resilience" can be nurtured with continuing education and training. Japan's Ohta says, "Our ongoing disaster-prevention education and training—with simulated drills—contributed substantially to our recovery effort. We have to continue to prepare for the reality of natural disasters with exhaustive, large-scale training programs."

Christchurch's Parker agrees. He describes human resilience as the willingness of the community to participate in the region's preparedness and recovery. "It's no good having good infrastructure if you don't have any businesses left after a disaster," he says. Today, the question Parker faces is, "How do we create a mechanism that will allow us to scale up the capacity of local businesses—without being overrun by large, wealthy organizations from out of town?"

In Sendai, a condo certification program, introduced after the earthquake, rewards human resilience. Condo operators are asked to keep a week's supply of food, water, and medications on hand, and "teams of residents are prepared to help the older and less healthy among them," says Mayor Okuyama. The goal is to certify all condos in Sendai.

Local business, local recovery

Japan's Ohta points out that—given their deep level of involvement—local businesses are well positioned to deliver major economic benefits to the community. As such, they can collaborate with the public sector to co-design the recovery, including rebuilding resilient infrastructure.

After the Tōhoku disaster, some community residents worked for the local construction industry, thus making a two-fold contribution—because infrastructure rebuilding without an accompanying economic recovery is not sustainable. Ohta says of the residents, "They are willing to defend their community and collaborate with local government on a daily basis." He added, "In that respect, the industry plays an important role in disaster management and reconstruction."

"It's no good having good infrastructure if you don't have any businesses left after a disaster."

—Bob Parker, Mayor Christchurch, New Zealand

9 PwC, *16th Annual Global CEO Survey*, 2013.

Robust business continuity planning is essential to disaster recovery

In today's increasingly interconnected world, disasters can have a ripple effect that reverberates throughout the supply chain. When a disaster destroys a manufacturing plant on another continent, for example, a supplier is unable to meet production goals. Similarly, a distributor may be unable to deliver product on time when faced with broken links in the transportation system due to wiped out roads or bridges.

Employees and customers of automakers in Detroit—on seeing initial news accounts of the 2011 earthquake and tsunami in Japan—didn't realize at first how directly that disaster would affect them. They soon found out. Several automakers source their parts from manufacturers who use microchip controllers from a Japanese company. This company, Renesas, produces those microchips in a plant north of Tokyo, which had been heavily damaged by the earthquake. With no alternative to those crucial microchips, auto production temporarily shut down.[1]

More than a decade earlier, a 1999 earthquake in Taiwan disrupted the supply of semiconductors, which temporarily halted mobile phone manufacturing worldwide. And a 2007 earthquake immobilized auto production throughout Japan when it interrupted the supply of engine piston rings.[2]

Sometimes, a disaster imposes a far greater economic loss outside the actual region where it occurs. As in the case of the 2010 volcanic eruption in Eyjafjallajökull, Iceland, which did little local damage. However, the resulting ash cloud paralyzed international air travel in Europe for more than two weeks.[3] In just the first week after the volcano, the ripple effect lopped the equivalent of $4.7 billion off global GDP.[4]

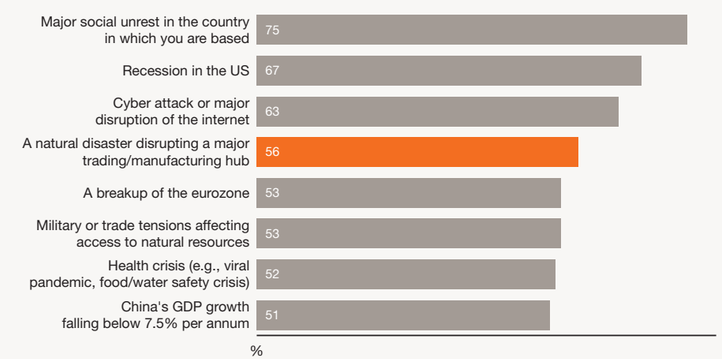
The consequences of natural disasters

Corporate leaders recognize the far-reaching implications of natural disasters. In PwC's *16th Annual Global CEO Survey* of 1,330 CEOs in a variety of industries worldwide, a natural disaster disrupting a major trading or manufacturing hub ranked fourth among threats that concerned corporate leaders—after social unrest, recession, and cyber-attacks (see chart below).[5]

While recognizing the threat, however, not all companies are prepared for the consequences. In the aftermath of 2012's Hurricane Sandy in the eastern US, even companies that had backed up their critical technology files away from primary data centers were affected because the off-site locations fell within the storm's impact zone.[6]

Natural disasters are among the top threats of concern to CEOs

Q: How well would your organization be able to cope with the following scenarios, if they happened within the next 12 months? (respondents who answered 'negative impact')



Base: All respondents (1,330)
Source: *PwC 16th Annual Global CEO Survey*

While one approach to being prepared cannot foresee all outcomes, common preparedness techniques do exist: companywide communication, accountability for various roles and responsibilities, testing of infrastructure, and training. These common techniques can work under any circumstance.[7] A holistic business continuity management plan includes scenario planning—which is essential to

disaster preparedness because it makes a company more resilient. As a result, the company's approach is flexible enough to respond to a variety of scenarios, depending on which one occurs.

What makes an organization resilient?

A resilient organization responds quickly and comprehensively to a disaster, after which it adapts to its new environment. During the recovery process, it implements new ways to protect from future disasters, recognizing that they are inevitable but that the organization controls how it responds to them.

Well-documented research from Oxford University finds that companies affected by catastrophes fall into two groups: those that recover and those that don't. Companies that recover experience a small initial decline in market value—less than 10 percent—after the crisis. Less than two months later, however, they rebound to their pre-catastrophe levels or higher. In contrast, the companies that don't recover suffer a sharp initial decline in market value—as much as 35 percent—and their market value remains 15 percent below what it was before the catastrophe for up to a year following the shock. In one instance, a company in this category ended up merging with a competitor and changing its name. [8,9]

Management's ability to deal with the aftermath of a disaster is pivotal to a company's recovery. Paul Beim, who directs business continuity management at RBS Global Banking and Markets in New York City, says company leaders at RBS expect a robust, complex, detailed program to test various scenarios. He says, "They want to see our contingency testing program increase in maturity and complexity. They want to get us where we can truly simulate the loss of a day and continue that day's processing. As we expand beyond that, we dive into more 'what-if' scenarios."[10]

Planning for eventualities

Resilient companies have the foresight to plan ahead for a variety of eventualities. They:

- Align risk management with strategy, implementing the appropriate leadership structure and collaborating with partners and customers.
- Quantify their appetite and tolerance for internal and external risks.
- Incorporate lessons learned from past business disruptions.
- Conduct ongoing reviews and testing.[11]

As Lawson did. Following the 1995 earthquake, the Japanese convenience store empowered a network of its employees to coordinate recovery in the aftermath of a disaster. Each branch office assesses emerging risks and creates response plans three times a year.

Bicycles in Lawson's branch offices serve as emergency transportation, should they become necessary. A mandatory stock of emergency goods is in place at every branch. And distribution hubs are geographically positioned to cater to disaster-struck evacuees.

Despite suffering devastating losses from the 2011 tsunami, Lawson resumed 80 percent of operations within four days.[12]

1 World Economic Forum, *Global Risks 2012*, 2012.
2 Ibid.
3 The World Bank and the Global Facility for Disaster Reduction and Recovery, *The Sendai Report*, 2012.
4 Oxford Economics, *The Economic Impacts of Air Travel Restrictions Due to Volcanic Ash*, 2012.
5 PwC, *16th Annual Global CEO Survey*, 2013.
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7 Carlos Castillo, Lauren Cook, and Oz Ozturk, "A New Framework for Disaster Reduction," *Resilience* (a PwC journal), February 2013.
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10 PwC webcast, *Beyond the First 48 Hours: From Crisis Response to Long-Term Business Continuity Management*, http://www.pwc.com/us/en/cfodirect/events/webcasts/beyond-the-first-48-hours-from-crisis-response-to-long-term-management-webcast-jan-11-2013.jhtml?display=/us/en/cfodirect/events/webcasts, accessed February 15, 2013.
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12 World Economic Forum, *Global Risks 2012*, 2012.

Rebuilding
The role of resilient infrastructure

Interdependent critical infrastructure

Building resilient infrastructure requires planning for a variety of scenarios. "I don't know what the next disaster is going to be," says Pat Foye, executive director of the Port Authority of New York and New Jersey. "There's a saying among military historians that at the beginning of a new war, the generals are always fighting the last one — oblivious to the fact that the world around them has changed."

Foye, who managed the recovery of Port Authority infrastructure after Superstorm Sandy, says, "The next challenge this region faces will be different from Superstorm Sandy; we can't fall into the military trap of fighting the last war, or in our case, the previous storm. The challenge will be different, the consequences will be different, and the way we respond to it will be different. We have to be prepared for any eventuality." *(For more, see interview with Foye.)*

The starting point is a systematic understanding of the critical infrastructure. Says Christchurch's Parker, "We identified links in our infrastructure system with potential weaknesses. Bridges, for example, over which a number of main water lines, waste-water lines, and sometimes electrical infrastructure ran. Then we brought together all the city organizations responsible and upgraded the bridges." Parker says that project, started more than a decade ago, "paid dividends for us in the aftermath of the earthquake." He also stressed, "90 percent of what we do is preparedness; prepare, prepare, prepare."

Dr. Frederick Krimgold, who heads the Disaster Risk Reduction Program of the Advanced Research Institute at Virginia Tech, agrees. "The most important factor in rapid and competent recovery is pre-disaster planning," he says. Krimgold has served as co-director of the World Institute for Disaster Risk Management and as a consultant to the Global Facility for Disaster Reduction and Recovery of the World Bank. "It is the existence of mitigation plans and pre-event relationships and planning that make response and recovery effective," he says.

Those relationships include the various interdependencies within the entire regional infrastructure. In Florida, says Krimgold, after a series of hurricanes in 2004, a comprehensive analysis revealed up to six or seven levels of inter-system dependency—each with serious consequences for regional service delivery.

Krimgold stresses the importance of mapping the various infrastructure interdependencies within a community—and bolstering the resilience at each weak link—for improved disaster preparedness. An essential water pump, for example, is dependent on upstream electric power and must, in turn, serve downstream dependent systems such as fire-suppression, cooling, and sanitation systems.

Says Krimgold, "Alternate inputs upstream can alleviate cascading failures across urban infrastructure systems when the normal power source is interrupted." He adds, "Resilience may not be as expensive as some imagine. It is largely dependent on understanding urban infrastructure as a series of interdependent systems." Krimgold advocates designing flexible urban infrastructure with independent, autonomous strategies for service delivery. *(For more, see interview with Krimgold.)*

Think global, build local

Hitachi's Saito points out the importance of tailoring disaster risk management to local specifications. "In building resilient infrastructure to withstand natural disasters, each city has different needs or specific priorities. You need to design the system and build a framework that matches the individual needs of cities."

Fluor's Prieto advocates lifecycle-based standards for infrastructure design and funding. "We do not invest sufficiently in sustaining our current infrastructure, especially throughout its entire life cycle," he says. "We always talk about having a lifecycle focus, but we're going to have to reflect that in our codes and standards. We need to design, build, operate, and maintain infrastructure more holistically."

Dr. Mustafa Erdik, Director of Kandilli Observatory and Earthquake Research Institute at Istanbul's Bogazici University in Turkey, emphasizes that regulations cannot exist on paper only; they must be implemented and enforced.

In August 1999, a 7.4-magnitude earthquake struck the industrial heartland of Turkey; the death toll exceeded 17,000. Meanwhile, 300,000 people were left homeless, and 23,000 buildings were condemned. The city of Izmit suffered disproportionate structural loss compared with earthquakes of a similar magnitude outside Turkey, which Erdik attributes to the rate of urbanization. He says, "The sheer number of housing units being built was beyond the capability of municipalities to regulate and supervise."

Recognizing disincentives

Disincentives for oversight compounded the situation. In addition to red tape and limited accountability in enforcement, Erdik says that "the government's (then) legal obligation to replace or repair damaged housing after an earthquake provided discouragement for insurance and implicit rewards for housing with poor earthquake performance."[10]

Thus, in developing economies, bureaucracy and government inertia can stymie infrastructure development in post-disaster recovery. Haiti offers another example. "Recovery in Haiti

10 Mustafa Erdik, *Rehabilitation After 1999 Kocaeli and Düzce (Turkey) Earthquakes*, Department of Earthquake Engineering, Bogazici University, Istanbul, Turkey (available from http://www.koeri.boun.edu.tr/earthqk.html.)

The way forward for infrastructure design in Japan

The archipelago that forms the modern nation of Japan sits at the nexus of four tectonic plates. The seismic activity these plates generate is a constant presence in daily Japanese life; more than 1,500 seismic events occur each year, including two of 5.0 magnitude or higher.[1, 2]

It comes as no surprise then that Japan leads the world in early warning systems to protect its population from disaster. Nor that the Japanese have a well-earned reputation for earthquake mitigation. Despite this preparedness, the 9.0-magnitude earthquake that struck off the northeast province of Tōhoku in March 2011 tested the resiliency of the nation in unprecedented ways.

A massive tsunami swept across the coastline within 30 minutes of the quake, changing entire landscapes and washing away villages and infrastructure. A 45-foot wave disabled the power supply and cooling at the Fukushima nuclear reactor, causing a meltdown in three cores and the release of radioactive materials. The Japanese government ordered the evacuation of more than 100,000 people from the surrounding area.[3]

The human costs were high:
- **15,800** people died;
- **6,100** were injured;
- **2,600** are missing; and
- recovery costs are estimated at **¥17 trillion**.

However, the damage to the nation's infrastructure was remarkably low compared with what similar events have caused in other regions of the world. Mechanisms implemented long before 2011 to strengthen infrastructure against earthquakes, tsunami, and fire saved millions of lives while also mitigating economic losses. The infrastructure showed remarkable resiliency, attributable to the forethought of its flexible design.

Lessons from Japan

The farsighted decision to enforce some of the strictest quake-resistant standards in the developed world paid off, as very few building collapses occurred in areas unaffected by the tsunami. Meanwhile, reinforced shoreline breakwaters mitigated tsunami damage. Japan's bullet trains were programmed to automatically decelerate even before the earthquake hit, thus avoiding derailment—and providing an important object lesson in the vital role of infrastructure in disaster mitigation. The 2011 disaster also illustrated how preparedness contributes to protecting the social and economic fabric of a community.

Robust catastrophic planning has also contributed to social resilience. Early warning and alert systems, continuous national earthquake drills, and well-understood evacuation plans effectively limited the loss of life. The spirit of mutual assistance was widely on display. Groups of young people helped with the evacuation of the elderly from disaster-stricken houses and more than a million volunteers helped staff supply lifelines and assist in disaster relief.

Close cooperation between the public and private sectors was an indispensable part of the rescue, recovery, and reconstruction process. In several cases, local authorities had pre-established agreements with private companies to provide basic necessities to evacuees.

Building back stronger and smarter

While Japan's first response has been hailed as a model for other disaster-struck regions to emulate, the challenge now is long-term infrastructure rebuilding. Rather than repairing or replacing the damage, cities and towns are using the reconstruction effort to introduce innovative state-of-the-art technologies. They are building smarter, more efficient infrastructure to ensure a vibrant future.

A number of ground-breaking initiatives now underway in the Tōhoku area focus on leveraging new technologies to develop safe, sustainable, energy-efficient communities. Lessons from the 2011 earthquake are being incorporated into "Smart Community" and "Future City" designs to revitalize the region's economy and support the redevelopment of communities affected by the disaster.

Yutaka Saito, President & CEO of Information & Telecommunication Systems Company for Hitachi, says public-sector officials are making the effort to build a smart city—or city of the future—by applying innovative IT that combines safety and comfort. The private sector is playing an essential role in the development of the future city and its infrastructure, contributing innovative ideas, solutions, and technologies in a collaborative process with the public sector.

Mayor Emiko Okuyama of Sendai notes that the success of these future-oriented initiatives can serve as an example to other cities striving to address the complex challenges of demographic, climate, and economic change. Forged from the chaos of devastation, Japan's ground-breaking solutions ensure a more sustainable future in response to the global challenges of the 21st century.

1 Central Intelligence Agency, *The World Factbook 2013-14*, 2013.
2 Department of the Interior, US Geological Survey, "Japan Earthquake Density Map," November 1, 2012.
3 World Nuclear Association, *Fukushima Accident 2011*, 2013.

following the earthquake slowed because uncertain land tenure made long-term investment for recovery problematic," says Virginia Tech's Krimgold, "and outside agencies, in an effort to respect local laws, were unwilling to make commitments in areas with contested ownership."

Infrastructure critical in security

Christchurch's Parker compares the aftermath of a disaster to a war zone, saying no matter how much advance planning occurs, "those plans actually won't pan out the way that you had rehearsed for them. But what really sticks is the structures that you've put in place to respond."

On another continent, in a former war zone—the Democratic Republic of Congo (DRC)—a £7 million infrastructure program is under way as part of a £60 million Security Sector Accountability and Police Reform program funded by the UK's Department for International Development. After two recent wars in the 1990s, the DRC now has a democratically elected president and is gradually rebuilding its infrastructure.

The DRC lacks the infrastructure necessary to deliver basic services to its citizens: Only a small minority of the country's population receives electricity while waste collection and sewage treatment are sporadic, at best. Neither do the skills exist to build the infrastructure. So any rebuilding effort begins with training workers, taking them through the entire process, and monitoring their progress along the way.

Rebuilding security infrastructure—such as police stations, garages, and communications centers—reflects a larger effort to revamp the police force. After the 40 or so planned facilities have been built, the police will be able to patrol areas of the country they weren't able to reach before, thus changing the very fabric of each neighborhood.[11]

Co-investing for resilience

In the Mexican state of Oaxaca, which has experienced earthquakes, floods, and hurricanes, PPPs and other forms of collaboration with the private sector are helping develop resilient infrastructure for water, sanitation, health care, transportation, and public safety, according to Governor Gabino Cué.

The state provides access to financing and training for small businesses, which dominate Oaxaca: According to the Mexican government's National Institute of Statistics and Geography, 93.8 percent of businesses in Oaxaca employ less than five workers.

"Government activity should provide an environment that simplifies the creation, development, expansion, and consolidation of business," says Cué. "The government of Oaxaca works to develop the necessary conditions and infrastructure to increase Oaxaca's competitiveness."[12]

Francesco Paolo Schiavo, General Director, Ministry of Economy and Finance in Italy, agrees. "Infrastructure is an enabling factor of critical importance to the provision of public services. Consequently, it helps increase productivity. It allows improvement in citizens' quality of life, thus playing a vital role in the development of modern market economies."[13]

Says FEMA's Miller of business and government collaboration: "You have to walk down that road together to say, 'What are the trade-offs? What's the return on investment? How can we co-invest for the resilience of our community and still meet the business model requirements of the companies building the infrastructure?' "

Cross-border collaboration

Natural disasters are not limited to the administrative borders of city, state, or county—which can be a challenge in preparedness and reconstruction. Coordinating across regional boundaries is essential in rebuilding resilient infrastructure, whether that infrastructure is a sea wall crossing regional lines in Japan or a port in one state whose activity affects the economy of the surrounding region, as with the Port of Seattle, which is essential to Alaska's economy.

Collaboration proved effective in Japan during the post-tsunami rescue operation. A team composed of members of the Ministry of Land, Infrastructure, Transport and Tourism, Japan Self-Defense-Forces, local governments, and local construction companies effectively executed "Operation Comb"—so-called because the transport route resembled a comb. Operation Comb swiftly cleared the way for emergency transport routes from the inland to the affected coastal areas (see map on page 14).

11 Hugo Warner, telephone interview, February 8, 2013.
12 PwC, *A New Contract Between Business and the State: Government and the 16th Annual Global CEO Survey*, 2013.
13 Ibid.

Photo: © City of Sendai

"How can we co-invest for the resilience of our community and still meet the business model requirements of the companies building the infrastructure?"
—David Miller, Associate Administrator, Federal Insurance and Mitigation Administration, FEMA

Continuous training and disaster simulation for all stakeholders were vital factors in the successful execution of this operation.

Leverage technology

In the aftermath of a disaster, replacing pre-existing infrastructure with technologically advanced options can offer better value for money while building risk resilience.

In New York, the MTA is securing transit system openings such as stairways, entrances, and ventilation gratings with lightweight, stainless-steel enclosures that can be put in place quickly, according to Prendergast. And in rebuilding the infrastructure damaged by Superstorm Sandy, the MTA will replace 95-year-old duct banks containing conventional cables with technologically advanced submarine cables that are impervious to water damage. "Because we have reason to believe that tunnel is going to be flooded in the next 100 years," says Prendergast. "At least once, if not a number of times."

In Sendai, meanwhile, the destroyed wastewater facility was restored using up-to-the-minute technology for ¥68 billion, ¥42 billion less than the original cost, for a plant that is more compact and sophisticated than the previous one. For Mayor Okuyama, embracing advances in technology to build the new facility "provides benefits for society as a whole while lowering costs for government."

Advances in technology are now front and center in Japan's renewed effort to build smart cities—with a focus on energy security—in the wake of its triple disaster. Cities such as Yokohama, Fujisawa, Fukushima, and Kitakyushu, are participating in a variety of initiatives—co-designed by the public and private sectors—that monitor energy use with smart meters, promote heat and energy reuse, and replace traditional energy sources for cleaner, more efficient energy generation.[14]

In overseeing the challenge of rebuilding Tōhoku, Hitachi's Saito has observed a change in community expectations. "We are very much aware of the importance of resilient social systems. We are now trying to build 'smart cities,' by applying new technology that contributes to sustainable and environmentally friendly cities, but is also efficient and comfortable for people themselves." Saito believes a consortium of public and private sector supporters is essential to oversee the introduction of the new, specialized infrastructure and ensure Tōhoku emerges as an archetype of rebuilding for resilience.

PwC recommendations

The frequency and intensity of disasters today typically means that every day, somewhere in the world, a city or region is rebuilding. Somewhere in the world, a business is collaborating with state emergency management. Somewhere in the world, a community is assessing its infrastructure for vulnerabilities.

The imperative to rebuild for resilience cannot be overstated. While it may be impossible to anticipate the unexpected, it is possible—imperative, in fact—to incorporate resilience into physical, digital, and societal infrastructure.

The public- and private-sector contributors to this report were candid in describing their experiences with disaster risk mitigation and recovery. Despite the wide differences in geographic base and type of risk encountered, common themes emerged in our discussions.

After evaluating the outcomes of the actions these public- and private-sector leaders took to mitigate risk and recover from disaster—and considering the ideas and insights that they offered—we highlight six key recommendations.

Our hope is that these recommendations will resonate with civic and business leaders the world over as they prepare to meet the growing risks of natural disaster, compounded by the mounting challenges of the 21st century.

1. *Focus on preparedness, prevention, and mitigation now.*
   Prudent early investment in risk mitigation, including resilient infrastructure, has proven cost-effective as research from FEMA and other organizations has shown. Low-probability, high-impact events such as the tsunami in Japan—previously predicted to occur once every 1,000 years—are becoming more frequent, thanks to changing climate patterns. And their effect is compounded by the convergence of urban migration, population growth, and the increased scarcity of resources. Resilient infrastructure can prevent both human and economic loss.

2. *Foster collaboration across public and private sectors.*
   As our experts and survey respondents made clear, business (across and within sectors) and government (across administrative boundaries within a given region) should begin collaborating well ahead of any actual disaster. By the time a disaster strikes, both sides will then have built up the trust they need to act promptly during its aftermath. The UNISDR effort on a global scale provides a framework for national and local replication.

3. *Motivate communitywide engagement to rebuild a vibrant economy.*
   From disaster recovery areas such as Greensburg, Kansas, Christchurch, New Zealand, and Sendai, Japan, to war-torn DRC, local participation—sometimes referred to as co-design—is pivotal to rebuilding resilient infrastructure for a vibrant economy. Christchurch's Parker says local voices matter, even though large military and national government organizations would rather just come in and take over because they have the knowledge and experience. Building local capacity is key to long-term resilience.

4. *Ensure participation across state and regional boundaries.*
   Disasters pay no heed to city, state, or even national boundaries—which can be a challenge in preparedness and reconstruction. Coordinating across regional boundaries is essential in rebuilding resilient infrastructure, whether that infrastructure is a sea wall that crosses regional lines in Japan or a port in one state whose activity affects the economy of the surrounding region, as with the Port of Seattle, which is essential to Alaska's economy.

5. *Encourage resilient recovery with optimal incentives.*
   The optimal combination of regulation and incentives (both financial and non-financial) can stimulate a resilient recovery. Effective government incentives can be localized depending on the particular characteristics of each region's infrastructure and private-sector capacity.

6. *Build back stronger and smarter.*
   Sendai, Japan, illustrates the opportunity to build back stronger, leveraging technology for innovation. In October 2012, UNISDR recognized Sendai as a role model for its focus on resilient recovery and Okuyama was hailed for her political leadership in rebuilding for resilience. On a macro-level, this takes collaboration between the public and private sectors; closer to home, it takes engaged community participation. Ultimately, a long-term plan encompassing resilient physical and digital infrastructure can revitalize the local economy.

14 Sarah Murray, "Smart Cities: Tsunami Brings Rethink on Sustainability," *Financial Times*, December 3, 2012.

For a deeper discussion on rebuilding for resilience

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