"Focusing solely on physical infrastructure runs the risk of overlooking another critical component of resilience: social infrastructure."

The Right Way to Build Resilience to Climate Change

DANIEL P. ALDRICH

For 400 years, residents in the Inupiaq Eskimo town of Shishmaref, Alaska—population around 600—built and lived in homes on a narrow island of sand just three miles long, protected from the frigid waters of the Chukchi Sea by layers of ice. Their subsistence lifestyle of hunting, fishing, and gathering remained largely unchanged. But in recent years, warming seas and rising air temperatures have melted permafrost and ice, allowing the water to come right up to homes on the shore. Some previously inhabited structures have collapsed. The sea has swallowed up 100 feet of coastline over 20 years. Physical infrastructure built to keep the town safe—such as rock seawalls—has only slowed the sea's inexorable conquest or deflected currents to eat away at the sand and rocks up or down the beach.

Changing with the Climate

Fourth in a series

Fourteen homes have already been towed from the town's more vulnerable side. Locals speak of how their great-grandparents built homes on sand that has since turned treacherously unstable. Warmer seas have also resulted in thinner ice. Some villagers have fallen through and drowned in areas where the ice used to be solid year round.

Recognizing the danger of warmer, encroaching waters, the village has voted several times to relocate. Only a few people have actually moved. The Army Corps of Engineers projects that relocation costs will run close to $180 million. Beyond the costs, many questions remain about where the people of Shishmaref might go. The town is one of about thirty in the region that experts believe are in imminent danger of destruction.

DANIEL P. ALDRICH *is a professor of political science and public policy at Northeastern University.*

For years, it was possible to assume that climate change would create problems only for future generations. No longer. Societies around the world now face the effects of climate change on a daily basis. Millions of people from developing countries flee every year from slowly unfolding climate-related crises like drought and famine. These crises in turn may be fueling political violence and civil wars over access to water, fertile land, and other critical resources. Studies from the Center for Climate and Security, among others, have identified climate-driven violent incidents around the world, such as bloody riots in the summer of 2017 by farmers facing ruin because of drought in India's southern state of Tamil Nadu.

It is not only parts of the developing world that have seen impacts from global warming. Citizens of advanced, industrialized countries have begun moving from long-occupied areas that are now threatened by rising sea levels, soil subsidence, and the erosion of barrier islands. These coastal areas, such as Shishmaref, have been inhabited for hundreds if not thousands of years. But in the Anthropocene Era (the formal name for the present geological time period in which human beings have begun to alter the earth's atmosphere and environment), time is runing out for such low-lying communities.

Of course, nations with limited resources have fewer options. With only two or three meters of land above sea level, Palau, the Cook Islands, Kiribati, and other small island developing states face grim futures and the need for mass relocation. One man's attempt to be recognized by New Zealand as a climate-change refugee due to the slow submersion of his native island of Kiribati failed; the petitioner, Ioane Teitiota, was deported in 2015 after losing a legal appeal. But many

other Pacific islanders have sought long-term solutions, including assistance from developed nations to help with adaptation measures. Group out-migration seems like one of the surest ways to save lives, but it will remove people from lands and cultures that have defined them for their entire history and create social pressures and financial burdens for their new host communities. Teitiota's case suggests that larger, more developed nations may be reluctant to accept substantial numbers of climate migrants.

Warmer ocean temperatures have made extreme weather events more common in recent decades, as data from organizations such as the Center for Research on the Epidemiology of Disasters confirm. Climate scientists have warned that a 2-degree Celsius increase in average temperatures—which is happening in our lifetimes—will likely increase wind speeds of tropical cyclones by around 10 miles per hour. Experts including Judith Curry at the Georgia Institute of Technology have found that the number of the most severe hurricanes—category 4 and 5 storms—has doubled over the past 40 years. To drive home this point, 2017 brought a series of powerful storms in the Caribbean, including Harvey, Irma, Jose, and Maria, which cut off most of Puerto Rico's 3.4 million residents from telecommunications and electricity and disrupted access to food and water for weeks, while devastating other Caribbean islands.

Collective action works best when communities have deeper ties and trust.

With consequences like these, which could become much worse, climate change belongs in the category of "wicked problems"—a social science term for problems that are extremely difficult if not impossible to solve and require knowledge and action from a variety of fields and disciplines. Engineering solutions alone will not fix the problem, and it is unlikely that politicians will force corporations to radically change their ways. Slowing and ultimately stopping climate change will require a commitment by individuals, businesses, and nations to work together to end the use of technologies that emit carbon dioxide, change lifestyles to curb demand for electricity, and move toward a carbon-neutral approach to everything from supply-chain management to architecture. But however much progress is made in that direction, societies will need to adapt to become more resilient to the inevitable effects of climate change.

Costs and Benefits

In the face of such challenges, societies have a range of potential responses to choose from. These include four general approaches: business as usual, incrementalism, adaptation, and transformation. Few options will be cheap. Some expert groups, such as the Intergovernmental Panel on Climate Change, have estimated that African nations will need to spend up to 10 percent of their gross domestic product to reduce the effects of climate change over the next few years. But the costs of inaction will certainly be much greater.

Under the business-as-usual approach, which seeks to preserve the status quo, decision makers and ordinary citizens facing the effects of climate change would double down and continue to act in ways that in the long term will damage or destroy their homes and societies. This would include continued subsidies for fossil fuels, car-centered city planning, and tax-free carbon generation. It would also mean continued coastal development entailing the elimination of wetlands and mangrove marshes that serve as natural shock absorbers for floods and tidal surges. Farmers in the North African Sahel and other arid regions of the world would continue to plant water-intensive crops while locals would keep cutting down trees for fuel, accelerating desertification. Jared Diamond and other authors have shown how past societies that continued to engage in destructive practices in the face of environmental crises ultimately collapsed. Nevertheless, in the absence of political will, and given strong business pressures for unchecked development, many may prefer this approach. The current US administration is a prime example of such tendencies.

Incrementalism describes a strategy designed to reduce the damage from future crises and shocks without requiring major institutional changes. That approach might include putting up seawalls around coastal towns and building levees, dikes, and dams to keep encroaching waters out of developed areas. On a piecemeal basis, societies might install solar panels, wind turbines, and other renewable-energy systems in houses and larger buildings, and experiment with energy-efficient smart grids for power transmission. Farmers might switch from water-intensive crops to those that require less water. These small changes would reduce some of the societal and economic

damage from warming oceans and melting ice but would do little else.

Adaptation, in contrast, would involve retreating on a large scale from areas that are most vulnerable to the effects of climate change and allowing nature to reclaim those spaces. Many in Japan have argued that as the population ages and as people continue to move from rural areas to the cities, these peripheral, often underdeveloped places should be left to nature. Likewise with climate change, as rising sea levels threaten inhabited areas, some may be willing to simply withdraw. Adaptation involves more intensive changes than incrementalism but still leaves many institutions in place. Rather than pushing car users toward public transportation, bicycles, or walking, governments would encourage them to purchase electric vehicles—some countries already subsidize these models. Nonetheless, cities would still in many ways be built for cars, not people.

The most challenging and therefore least likely response to climate change is transformation, which would require paradigm shifts in the ways we live our everyday lives. Cities would ban cars from downtown districts, impose taxes on fossil fuel–burning vehicles entering certain metropolitan zones, and curtail sprawl—policies that some cities have already begun to implement. Educational systems would also play a part in transformational strategies to ensure that graduates understand the consequences of vehicle ownership and urban sprawl. The World Bank and other international agencies would stop supporting environmentally destructive megaprojects.

Adaptation would involve retreating on a large scale from areas that are most vulnerable to the effects of climate change.

Changes would also need to occur at the village level. Laura Kuhl of Northeastern University has pointed out a variety of options in her study of rural communities in Ethiopia: setting up credit associations and microinsurance for crops, developing livestock breeds that require less water, diversifying livelihoods. Some Ethiopian communities have undertaken these practices, but none have done so simultaneously in a holistic approach.

SOCIAL INFRASTRUCTURE

Standard approaches to extreme storms, flooding, and other weather crises have revolved around physical infrastructure. Japan's central government, for example, has long favored the construction of concrete seawalls, a policy that has continued since the disastrous 2011 earthquake and tsunami despite the fact that seawalls failed to prevent the loss of more than 20,000 lives. The Netherlands has addressed perennial flooding of low-lying areas with a combination of green space, dikes, coastal beach replenishment, river widening, and managed retreat from the most vulnerable areas. These policies are clearly visible, easy to measure, and provide additional benefits including construction jobs.

However, focusing solely on physical infrastructure runs the risk of overlooking another critical component of resilience: social infrastructure. Scholars and practitioners alike have begun to recognize the powerful role it plays. No physical structure can protect against every threat. Seawalls meant to keep water out may in fact trap it inside. Walls built to stop coastal erosion merely push its destructive effects farther down the coast. Yet the connections that we have to each other—which are known as social capital—can mitigate the effects of crises and disasters and also unite us to tackle large-scale problems like climate change.

Our links to other people can assist us before, during, and after crises in several ways. First, we know from research around the world that communities with deeper ties, more trust, and more interaction suffer lower mortality during extreme weather events and other natural disasters. Neighbors in Kobe, Japan, following the 1995 earthquake, were first on the scene to dig through rubble and save their neighbors' lives. After the earthquake off the coast of Japan in 2011, friends and caregivers carried the infirm and elderly to higher ground in the 40 minutes before the tsunami arrived. Areas with deeper reservoirs of social capital had lower mortality than those with shallower ties.

When the 911 emergency assistance system failed and first responders were unreachable during Hurricane Harvey in Texas in August 2017, volunteers from nearby communities and others from farther away, including Louisiana, using their own boats and calling themselves the Cajun Navy, arrived on the scene to save people who were stranded on rooftops.

When natural disasters strike, strong social ties also provide informal insurance and facilitate other forms of mutual aid. Informal insurance is based

not on money but on investments of time and trust. In neighborhoods where people have worked together on environmental projects, zoning boards, and other civic activities before weather events damage homes, those ties activate during a crisis to let people share information, resources, and psychosocial support. In neighborhoods in New Orleans after Hurricane Katrina in 2005, people borrowed bleach, masks, and hammers from friends so that they could pull out rotting drywall. In Miami after Hurricane Irma, homeowners shared information about how to apply for assistance from the Federal Emergency Management Agency (FEMA) and make it through the labyrinth of insurance claims. Farmers in Ethiopia can learn of drip irrigation techniques and new crop varieties through connections with colleagues in other communities.

Many of the problems linked to climate change call for collective action. Coordinating societal and market choices, and responding to disasters, require people to work together in a systematic and focused way. No family working alone in Haiti's capital, Port-au-Prince, could keep looters and thieves away from homes that collapsed after the 2011 earthquake. Yet in neighborhoods where people had worked together before the disaster and trusted each other, families volunteered for an hour at a time to create an effective community patrol. These kinds of collective action work best when communities and societies have deeper ties and trust. A number of communities, including Boulder, Colorado; San Francisco, California; and Lyttleton, New Zealand, have worked to develop social cohesion so that they are better prepared for extreme events.

Lessons from Rotterdam

The Netherlands, half of which lies beneath sea level, has faced the challenges of encroaching seas and regular flooding since its emergence as a nation. Archaeologists have found evidence of dams and levees dating back to the late thirteenth century. Under the guidance of the Dutch Ministry of Transport, Public Works, and Water Management, the country upgraded flood control systems that served it well for much of the twentieth century. It has protected important areas called polders (reclaimed, low-lying land that has been shielded against flooding with levees, berms, dams, and dikes) and set up pumps and canals to channel out unwanted water.

As evidence of global warming accumulated in the 1970s and 1980s, and a series of studies predicted more precipitation, rising sea levels, milder winters, and hotter summers, Dutch politicians and civil society moved to cut back carbon dioxide emissions and joined in the chorus of voices calling for international action on the issue. When it became clear that international treaties and existing policies were insufficient given the Netherlands' acute vulnerability, decision makers decided to take transformational action.

In 2007 the Netherlands released its National Adaptation Strategy, and it has adhered closely to the plan since then. The framework has guided actions on a range of policies, including urban planning, architecture, design, and transportation. It pushes transformation and change in three areas: climate, governance, and society.

First, decision makers wanted to secure broad agreement that the nation would be at increased risk from flooding in coming decades. Politicians at all levels promoted this message. Next, planners, city managers, and politicians wanted to ensure that society itself would transform to address the problems of climate change. Community activists and nongovernmental organizations helped by promoting bottom-up networking and participation instead of top-down governance.

Finally, the national and regional governments urged all citizens to learn what they could do to help keep their cities resilient in the face of likely flooding threats. Citizens were encouraged to participate in building homes, proposing new housing developments, and educating children on the principles of resilient design. Rather than viewing climate change policies as controlled from above, individuals, NGOs, and academic institutions saw themselves as having a voice in the process. Cities such as Rotterdam, a major port in the delta of the Rhine and Meuse rivers, the lowest parts of which are more than 20 feet below sea level, developed their own climate change adaptation strategies as early as 2008.

Sand dunes along the coast, dikes along the rivers, and a network of levees and berms are all part of the system for managing water across the country. Critical facilities such as power plants have been located in flood-proof areas. Rather than relying solely on physical infrastructure, however, Rotterdam and other cities across the Netherlands have come up with creative ways to transform themselves. The nation has used a "build back better" approach to rebuilding in flooded areas. For example, engineers converted one flood-prone

shunting yard into a levee that is used for a public park and artists' shops.

Developers have built underground facilities under public spaces such as Museum Park and Zuiderpark in Rotterdam to manage and store water. Some of them allow residents to experience floodwaters as a backdrop for play and socializing. Cities have planted more flowers, bushes, and trees to leave less impermeable pavement. Community gardens also improve water absorption. Moving beyond green roofs that are planted with vegetation and serve as heat sinks for urban environments, some buildings in the Netherlands feature blue roofs with water parks and pools, and some architects have begun designing floating homes. These are not houseboats, but rather resemble conventional homes that are tethered to poles which will float in the event of a serious flood.

To achieve this transformation of urban life, the Netherlands has moved beyond an approach that relied solely on physical infrastructure to manage the effects of climate change. The new approach encourages broad-based cooperation and shared commitment to new norms. Despite memories of massive floods like those of 1953 that killed more than 1,800 people, decision makers and ordinary citizens alike have come to recognize that water cannot be managed away and that flooding in parts of the country is inevitable. Citizens' acceptance of the need for long-term investment in natural and built systems (and a high tax rate to pay for it) have created a society whose cities are more resilient to climate change.

Rotterdam and other cities across the Netherlands have come up with creative ways to transform themselves.

HOUSTON'S MISTAKES

Houston, Texas, makes for a striking contrast to Rotterdam. Houston grew tremendously in the late twentieth and early twenty-first centuries to become one of the largest cities in North America. But unfettered development, a booming oil and gas industry, a lack of systematic zoning throughout the city, and a desire to build large and fast have created a vulnerable low-lying metropolitan area that sprawls across more than 600 square miles near the Gulf of Mexico, with a population of more than 6 million.

Many areas of Houston—where zoning is done neighborhood by neighborhood, if at all—require only that buildings be raised a foot above the ground to avoid 100-year floods. Communities have ignored warnings about the increasing frequency of such extreme flooding. Homes and businesses in the neighborhood of Westlake Forest, for example, were built in an area that FEMA identified as a floodplain.

A planning mechanism known as a Municipal Utility District, or MUD, has allowed the Houston suburbs to expand at breakneck speed. Developers have organized ballot initiatives to create around 1,000 such districts that give them authority to issue bonds to finance electricity, water, and sewer infrastructure. The developers then build and sell single-family homes and serve as the water providers. These districts are designated as areas under extraterritorial jurisdiction, meaning that even if local government wanted to enforce building codes in the new developments, it would be unable to. While some MUDs initially followed green-building policies, most abandoned them to cut costs by installing minimal stormwater drainage systems. MUDs also typically encourage car-based planning rather than public transportation options.

While Houston's downtown population has remained constant in recent years, people continue to stream out to the suburbs, putting pressure on critical infrastructure systems and placing homes and neighborhoods in areas likely to flood again and again. Some 100,000 people moved to Houston in 2016 alone. Free space, greenbelts, and smaller patches of vegetation have disappeared as concrete and brick spreads.

Houston's past development and zoning choices have set it up for consequences that are now being felt. In healthy ecosystems, a variety of natural mechanisms help absorb rain and floodwater, creating equilibrium. These include wetlands and green space planted with grass and trees. Houston, like many other cities, has replaced these permeable surfaces with driveways, parking lots, and roads. While artificial water management systems of culverts, drains, and sewers can absorb ordinary amounts of water, excessive rainfall overloads the system.

In August 2017, Hurricane Harvey brought nearly five feet of rain to the region, turning roads into rivers and backyards into lakes. The storm caused an estimated $180 billion in damage and

left over 80 people dead. Insurance is likely to cover little of the loss; by some estimates, only 1 in 8 homes in flooded areas of Houston had flood insurance. As with past disasters, taxpayers across the country may ultimately end up funding much of the recovery effort and bailing out a federal flood-insurance program that encourages rebuilding in vulnerable areas.

Some argue that Houston's development choices and the environmental consequences are the result of a conservative political culture and Republican dominance of state government. Yet Texas was one of the earliest states to develop wind energy in a big way. When George W. Bush served as governor from 1995 to 2000, he encouraged businesses to become first adopters, creating a "wind boom" that boosted Texas into the top rank of renewable energy–producing states. Houston's planning decisions reflect local, not regional, choices.

With little agreement about the realities of climate change, and no obvious political will to set a new course for residents or developers, Texas leaders nonetheless in October 2017 called for a major package of flood-control measures, including infrastructure rebuilding and property buyouts. Its prospects are uncertain. In the meantime, while Houston's drive for growth has created vulnerable physical infrastructure, emergent civic groups like the Cajun Navy and the strong local volunteer response showed how its social infrastructure may have to serve as a substitute for strong zoning and environmentally focused growth strategies.

LOCAL EFFORTS

Around the world, local communities are living with tangible reminders that we have set our climate on what may be an irreversible course. Coastal homes in places like Alaska are slowly sinking into the sea, potable water has become scarcer in regions such as western Africa, island nations are seeking resettlement, and extreme weather events have become more frequent and costly. Some cities and countries have accepted scientific arguments about the causes of these shifts and moved both civil society and industry into new adaptive configurations. Others have not. President Donald Trump has pulled out of the Paris Agreement on climate change, leaving the United States as the world's sole holdout from the pact to curb carbon emissions and fund adaptation measures.

Many communities have recognized the important roles of both social and physical infrastructure in building resilience to extreme weather and climate change. The Houma-Thibodaux metropolitan area in southern Louisiana, for example, moved beyond waiting for large-scale change by agencies like the Army Corps of Engineers (typically responsible for coastal waterways and floodplains) to protect its population of over 200,000 from future floods. Through a combination of adaptation measures—restoring marshes, elevating homes on stilts, buying out areas that are likely to flood, and raising community awareness—the Houma region has sought to improve its chances for survival. The money for many of these changes has come from a self-imposed sales tax rather than outside agencies or donors.

Similarly, residents of Boulder, Colorado, moved to organize bottom-up responses to floods and wildfires, building social infrastructure through education and community development programs. Instead of assuming that strengthening resilience must be the exclusive responsibility of federal or state authorities, residents formed an organization known as BoCo Strong to create shared norms about the role of social ties in disasters, helped high school students develop their own plans for mitigating risk, and built a network of community-based activists.

Societies around the world have a variety of options at their disposal to prepare for a changing climate. Some, like Houston, have adopted approaches bordering on business as usual and perhaps extending to incrementalism. Others, like Rotterdam, have engaged in systematic adaptation and transformed their design, building, and planning processes to engage citizens and alter the urban environment. As societies face the consequences of massive flooding, extreme storms, and rising seas, they must begin building resilience through social as well as physical infrastructure before it is too late. ■