# Future-proofing infrastructure often means going back to basics

In the effort to tackle the backlog of infrastructure maintenance in the United States, five steps can help prioritize projects to not only meet the greatest needs but also build resilience.


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It is a reality many of us know all too well—balancing competing infrastructure needs and immense maintenance backlogs while the world changes beneath our feet.

The American Society of Civil Engineers (ASCE) gave US infrastructure an overall grade of D+ in the *2017 Infrastructure Report Card* for good reason.[1] Our infrastructure is aging, deteriorating, and holding our communities back; we are relying on infrastructure built more than a century ago to meet the needs of a completely changed world. In older regions in the Northeast, wooden water pipes still run beneath city streets. The backlog of infrastructure projects related to drinking water manifests itself in broken water mains—an average of one every two minutes.[2] We depend on a network of roads and bridges that were designed in the Eisenhower era or before. Our roads claim the lives of an estimated 40,000 people a year, in part because of outdated designs that fail to meet our current mobility needs.[3] Large river barges sit for hours, even days, on the Mississippi River while aging locks are patched and fixed.

While these problems seem insurmountable, areas of thoughtful progress offer models for improvement. In our experience, five steps in particular can have an outsize impact: building a foundation of data, evaluating the full life cycle of a project, considering a variety of disaster scenarios, looking to land use and context-sensitive solutions, and supporting research and development that can be applied to the infrastructure sector.

## The current state of US infrastructure

The United States has coasted along on the investments of our grandparents and deferred major maintenance, spending a meager 2.5 percent of GDP annually to maintain and modernize our infrastructure assets.[4] Despite rising needs, the federal government's contribution to water projects has fallen over the past 30 years, from 63 percent of the sector's total capital spending in 1977 to 9 percent in 2014.[5] This deferred maintenance is costly to the economy and hits us all in the pocketbook. If the problem is not addressed, the average American household will lose $3,400 in disposable income every year from 2016 to 2025 because of inadequate, unreliable infrastructure.[6]

With earthquakes, wildfires, volcanic eruptions, rising sea levels, and hurricanes dominating the headlines, it is crystal clear that our system of aging infrastructure needs to be made resilient. As engineers, we are working to rebuild and upgrade infrastructure to better withstand these challenges, operating under the assumption that hazard events will continue with increasing regularity and severity. But that's only one element of what it means to future-proof our infrastructure.

In addition to anticipating what hazards and conditions our roads, bridges, drinking-water pipes, wastewater-treatment plants, airports, and power lines must withstand, engineers are also thinking about the impact of new technologies, population shifts, and other trends on communities' needs.

Infrastructure that is designed to meet future needs and withstand future hazards often incurs a higher initial cost. However, it is a worthwhile investment that pays for itself in the long run; the National Institute of Building Sciences estimates that every dollar spent on making infrastructure more resilient saves $6—an improvement over 2005, when the ratio was 1 to 4.[7]

## Five steps to reduce the backlog and build community resilience

The backlog of projects on our collective plates is daunting, but it also presents an opportunity.

As we make plans to repair and upgrade our infrastructure with an eye to the future, the following steps will have an outsize impact:

1. **Build a foundation of data on assets and use it effectively.** In this era of big data, infrastructure owners can monitor a wide variety of asset metrics and address problems in real time.

   When the city of Syracuse, New York, analyzed data on water-main breaks, administrators realized that breaks occurred most frequently downtown, particularly in the central business district—a great inconvenience for restaurants in the neighborhood. With the support of a grant from the Rockefeller Foundation, the city partnered with graduate students to use data to predict at-risk water mains, increasing accuracy sixfold over random choices and preventing more breaks.

   Infrastructure ownership in the United States is highly fragmented, making it difficult to get a big-picture view of community resilience. To this end, the state of Michigan has embarked on an ambitious statewide infrastructure plan; in their initial scan, officials found that more than 3,300 agencies deal with some sort of infrastructure in the state. Enabling these agencies to share data and tackle cross-jurisdictional projects is a Herculean task—but a critical one if we are to sufficiently evaluate community resilience.

   While the Michigan effort is the first undertaking of its scale in the United States, engineers and infrastructure owners across the country are embracing comprehensive asset-management strategies on a smaller scale. Agencies of all sizes are routinely using data and electronic records to keep a more accurate inventory of infrastructure conditions and to better prioritize capital projects. This improved record-keeping process has enabled many infrastructure owners to shift their focus from fixing the worst problems first to preventing catastrophic failures down the line, considering the highest risk and cost to the community in the event of failure.

2. **Evaluate the full cost of a project, not just the initial capital costs.** A renewed focus on life-cycle cost analysis (LCCA) is allowing engineers and planners to assess not just the up-front cost of a project but also the operation and maintenance cost, as well as the cost of retiring an asset. We tend to plan extensively for a ribbon cutting but give less thought to the condition of our assets 20 years from now. Evaluating the total cost of project ownership in the early stages of planning has an impact on design decisions and increases resilience. For example, the Port Authority of New York and New Jersey uses a standardized form of LCCA across all of its major projects to determine project selection and design, saving an estimated $37 million in 2014, the program's pilot year.

   Research commissioned by ASCE found that while nearly all government entities agree that LCCA should be part of the decision-making process, fewer than 60 percent of public-sector transportation projects include this step, and fewer than 50 percent include an operations plan as part of the planning process.[8] Those percentages must increase if we are going to future-proof our infrastructure assets, resulting in more strategic use of limited funds and projects that are designed with an eye toward anticipating and meeting future needs.

3. **Consider a variety of disaster scenarios.** As we face increasing risks and a changing climate, we need to reevaluate our assumptions and use comprehensive scenario planning to drive better-informed decisions.

   Of course, the scenarios vary by location; projects in Miami, Florida, need to anticipate a higher sea level, while the city of Tucson, Arizona, must manage water now with an eye toward dwindling supply in the future. Indeed, Tucson city leaders recently decided they could no longer rely on historical water trends and availability; instead, they had to envision a future in which they may not be able to depend on underground aquifers. They developed a robust set of solutions that includes both water storage and reclaimed water to ensure a reliable water supply for the region under a number of different scenarios.

4. **Look to land use and context-sensitive solutions.** Preparing for the future often means improving land-use planning and considering how the natural environment can serve an individual location's unique infrastructure goals. Sometimes, a resilient design is remarkably low tech, such as placing control rooms for utilities above ground so they don't flood during a major storm event.

   Following the disastrous Hurricane Katrina in 2005, New Orleans, Louisiana, has reinvented itself and is embracing green infrastructure as a way to manage frequent flood cycles and reduce stormwater flows. For example, the city is integrating new methods of storing and filtering stormwater with the system that has been pumping stormwater out into Lake Pontchartrain and other bodies of water for more than a century. Similarly, Hurricane Harvey—the most expensive natural disaster in the history of Texas—affected more than 40 of the state's 254 counties in 2017. In Harvey's wake, communities in the Lone Star State are evaluating a watershed approach to flood-risk management, investing in green infrastructure such as permeable pavements, and considering new development standards to reduce risks and strengthen community resilience.

5. **Support research and development, including on-the-ground assessments.** Scientific research in a variety of fields is sparking development of technologies and processes that can be used to extend the life of infrastructure, expedite repairs and replacements, and increase cost savings. Public R&D budgets are often the first to be reduced in a budget cutback, because research lacks guaranteed outcomes, but explorations often yield great results if researchers have the funding and time to innovate. For example, researchers looking for methods to strengthen concrete are currently developing self-healing concrete. The use of such concrete in roadway infrastructure would reduce the need for repaving and make roads less susceptible to the potholes that form when a crack takes in water and then expands during a freeze.[9]

   Furthermore, one of the best ways to learn how to future-proof infrastructure is to assess the site of a major disaster to gather evidence on to see what worked and what didn't. Both ASCE and the National Institute of Standards and Technology routinely send teams to global disaster sites to study building and infrastructure performance. These findings are critical for reducing future loss of life and property, as well as enhancing the resilience of our infrastructure assets.

The backlog of infrastructure maintenance in the United States presents an opportunity to go beyond the status quo. Optimizing our infrastructure investments will require civil engineers and community leaders to rethink and reinvent every stage of project delivery and embrace the challenge to innovate and to transform our practice. We can learn from past successes and failures and design our infrastructure to be resilient—built for today and ready for tomorrow.

[1] "America's grades," *2017 Infrastructure report card*, American Society of Civil Engineers, 2017, infrastructurereportcard.org.

[2] Dan Bobkoff, "In the US, a water main breaks every two minutes," *Marketplace*, May 12, 2014, marketplace.org.

[3] Ranjitha Shivaram and Adie Tomer, "Do our infrastructure systems put people at risk?" Brookings Institution, May 10, 2018, brookings.edu.

[4] Drew Greenblatt, "Five keys to infrastructure investment & why it's critical for US manufacturing," *Inc.*, March 9, 2017, inc.com.

[5] *The economic benefits of investing in water infrastructure*, Value of Water Campaign, 2017, thevalueofwater.org.

[6] *Failure to act*, American Society of Civil Engineers and the Economic Development Research Group, 2016, infrastructurereportcard.org.

[7] *Natural hazard mitigation saves: 2017 interim report*, National Institute of Building Sciences, December 2017, wbdg.org.

[8] *Maximizing the value of investments using life cycle cost analysis*, American Society of Civil Engineers and Eno Center for Transportation, 2014, p. 6, enotrans.org.

[9] Congrui Jin, "Fungi can help concrete heal its own cracks," *The Conversation*, January 19, 2018, theconversation.com.

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