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Report

Built to Endure

A Smart Guide for US Cities To Build Resilient Infrastructure That Lasts

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Nicholas Institute for Energy, Environment & Sustainability

The Nicholas Institute for Energy, Environment & Sustainability at Duke University accelerates solutions to critical energy and environmental challenges, advancing a more resilient and sustainable world. The Nicholas Institute conducts and supports actionable research and undertakes sustained engagement with policymakers, businesses, and communities—in addition to delivering transformative educational experiences to empower future leaders. The Nicholas Institute's work is aligned with the Duke Climate Commitment, which unites the university's education, research, operations, and external engagement missions to address climate challenges.

Bentley Systems

Bentley Systems is the infrastructure engineering software company providing innovative software to advance the world's infrastructure. Bentley's software supports the full infrastructure life cycle, from planning and design to construction and operations, and is used by infrastructure professionals and asset owners across transportation, water, energy, and cities. Infrastructure Policy Advancement (IPA) is Bentley Systems' thought leadership initiative, focused on advancing digital transformation and data-driven approaches to infrastructure decision-making and delivery. IPA works with leaders across government, finance, industry, and academia to explore how best practice in technology, data, and policy can support improved infrastructure outcomes for communities and the environment.

AECOM

AECOM is the global infrastructure leader, committed to delivering a better world. As a trusted professional services firm powered by deep technical abilities, AECOM solves its clients' complex challenges in water, environment, energy, transportation and buildings. Teams partner with public- and private-sector clients to create innovative, sustainable and resilient solutions throughout the project life cycle—from advisory, planning, design and engineering to program and construction management. AECOM is a Fortune 500 firm that had revenue of $16.1 billion in fiscal year 2025.

American Society of Civil Engineers

Founded in 1852, the American Society of Civil Engineers (ASCE) represents more than 160,000 civil engineers worldwide and is America's oldest national engineering society. ASCE works to raise awareness of the need to maintain and modernize the nation's infrastructure through sustainable, resilient practices, advocates for increasing and optimizing infrastructure investment, and improve engineering knowledge and competency.

Microsoft

Microsoft's mission is to empower every person and organization on the planet to achieve more. For cities, Microsoft offers cloud and data platforms designed with security, privacy, and compliance capabilities to help protect sensitive information while connecting geospatial and operational data. Analytics and digital twins let teams explore infrastructure interdependencies and test "what-if" scenarios, supporting informed decisions, transparent planning, and effective policy execution. These capabilities can strengthen resilience planning and community engagement, while keeping local governance and expertise at the center.

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Foreword

***Kate Gallego**, Mayor, City of Phoenix, AZ*
Co-Chair, Accelerator for America Advisory Council |
Chair Emerita, US Climate Mayors

Across the United States, communities of every size are on the front lines of a rapidly changing climate, aging infrastructure, an affordability crisis, and rising expectations to deliver reliable, affordable services under increasingly growing fiscal pressures. Local leaders are being asked to do more often with limited staff, uncertain funding, and systems that were never designed for today's conditions.

As mayor of Phoenix, I see these realities every day. Extreme heat, water scarcity, population growth, and economic competitiveness are not abstract challenges. They shape every infrastructure decision we make. We must balance difficult trade-offs, frequently with incomplete information and significant uncertainty. And Phoenix is not an outlier. Cities of all sizes, particularly small and midsized communities, carry so much of the responsibility for the infrastructure that underpins public health, safety, and economic opportunity across the country.

Built to Endure responds directly to this challenge. This Smart Guide is refreshingly practical. It does not assume that cities can simply hire large consulting teams or overhaul systems overnight. Instead, it meets local decision-makers where they are, recognizing real capacity limitations, governance complexity, and the urgency of action. It focuses on three building blocks that mirror my experience: strategic resilience planning, policy and regulatory effectiveness, and community and decision-maker empowerment. Together, these form a blueprint for moving from reactive fixes toward durable, system-wide resilience.

The guide is also clear-eyed about the role of technology. Advances in data, modeling, and digital tools are expanding what cities can understand, test, and prioritize across transportation, water, and energy and interconnected systems. These tools can help local governments make smarter, more defensible decisions, especially as climate impacts intensify and as new demands, including from the rapid growth of energy and water-intensive data centers, place added strain on existing infrastructure and resources. Technology is changing what cities can understand and anticipate, but it does not replace the foundational work of planning, governance, and leadership.

This perspective aligns closely with the work of Accelerator for America, which exists to help cities access the tools, partnerships, and capacity they need to deliver transformative infrastructure projects. It also reflects the priorities of US Climate Mayors, where cities are working together to cut emissions, adapt to climate impacts, and strengthen local economies, recognizing that infrastructure decisions account for nearly 80% of global greenhouse gas emissions and shape community outcomes for generations.

I was proud to be part of the early conversations that helped launch this effort, and even prouder to see it realized in this guide. Built to Endure offers cities something they urgently need: credible examples, clear frameworks, and actionable pathways forward.

America's cities are the backbone of our nation's infrastructure system. With the right support, shared responsibility, and practical tools, they can also be the backbone of a more resilient, equitable, and prosperous future. I encourage local leaders across the country to use this guide, learn from one another, and take the next steps, together.

Travis Ezzel/Flickr

SMART GUIDE KEY TAKEAWAYS

This Smart Guide is designed for cities of all sizes, but speaks most directly to the small and midsized US communities that manage much of America's infrastructure while operating under tight funding, staffing, and governance constraints.

These eight takeaways reflect the core message of Built to Endure: resilience is achievable—even for lean municipal teams—when people, sound governance, and systems thinking are supported by increasingly accessible digital tools that help inform decisions and strengthen community outcomes.

1. **Resilience is no longer optional, and it must be system-wide.**
   The greatest risks facing today's communities do not come from isolated asset failures, but from cascading disruptions across interconnected systems such as power, water, transportation, and communications. Effective resilient infrastructure solutions require a system-wide approach, grounded in professional judgment and local context and supported—not replaced—by tools that help cities understand interdependencies and trade-offs rather than rely on one-off fixes. Accessible tools for modeling, mapping, and scenario-building can help a wider range of cities apply this integrated thinking in practice.
2. **Cities don't need large teams or advanced expertise to start.**
   Small and midsized cities often assume that resilient infrastructure solutions require a large staff, specialized expertise, or expensive technology. That assumption no longer holds true. Modern digital tools such as GIS platforms, hazard datasets, intuitive modeling tools, and AI-enabled analytics are far more affordable and user-friendly than in the past. When paired with training and institutional knowledge, these tools support municipal professionals by making complex information easier to interpret and apply in real-world decisions.
3. **Strategic planning helps limited resources go further.**
   When funding and staff time are constrained, every decision matters. Strategic resilience and adaptation planning relies on local knowledge and professional experience, supported by tools that help identify priority risks, understand asset criticality, explore future scenarios, and incorporate financial realities. This approach helps cities direct resources toward the most impactful investments, reducing costly missteps and ensuring that resilience dollars deliver lasting value for communities.
4. **Policy updates are essential to reflect today's risks, not yesterday's assumptions.**
   Plans alone are not enough. Local codes, design standards, permitting requirements, comprehensive plans, and capital investment frameworks shape what gets built and how it performs over time. Technology does not set policy, but it can inform better policy by clarifying risks, trade-offs, and long-term consequences. This information helps cities update rules in practical, defensible ways so routine decisions consistently reinforce infrastructure resilience, rather than undermine it.
5. **Fixing misaligned regulations and incentives is essential for implementation.**
   Even well-designed plans and policies can stall when the entities responsible for funding or implementing improvements do not directly benefit from the reduced risk.

Misaligned incentives across agencies, utilities, developers, and jurisdictions are a common barrier to implementation. Clear decision frameworks, updated standards, and practical financing approaches help align and institutionalize costs and benefits, enabling public and private partners to operate under the same expectations.

6. **Empowering staff and communities improves outcomes.**
Resilience is strongest when it is understood and supported within both government agencies and the community. Clear guidance, training, and intuitive tools help municipal staff integrate resilience principles into day-to-day work. Public-facing visuals, maps, and dashboards, used as communication aids rather than technical endpoints, help residents understand risks, engage in trade-offs, and develop trust by making resilience visible, concrete, and actionable.
7. **Communities can learn from others without reinventing the wheel.**
Cities do not need to start from scratch. This guide highlights a small set of case examples, practical tools, and other resources that show how peer communities have taken first steps—often by improving data sharing, prioritizing critical assets, embedding resilience into existing planning processes, and engaging communities. Starting with proven approaches allows cities to move from planning to action more quickly, even with limited time and capacity.
8. **Regional collaboration expands capacity and lowers costs.**
Small and midsized communities need not build resilience alone. Shared data platforms, regional hazard analyses, cross-jurisdictional partnerships, and pooled technical services can dramatically reduce costs, expand access to expertise, and ensure consistency across interconnected systems. Working together helps communities address system-wide risks that do not stop at municipal boundaries.

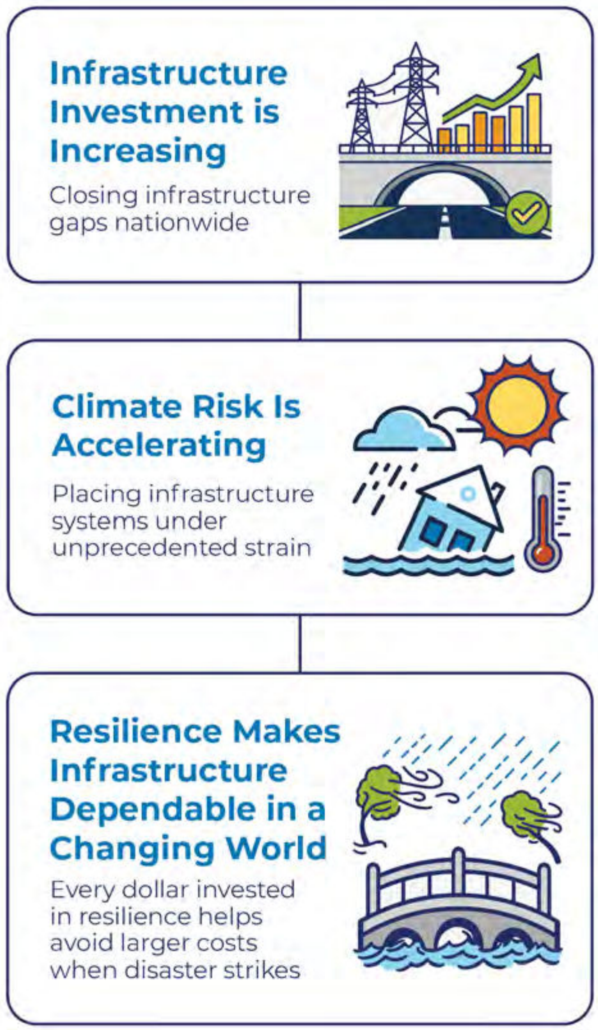
INTRODUCTION

The *2025 Report Card for America's Infrastructure* from the American Society of Civil Engineers (ASCE) shows meaningful gains in US infrastructure performance, driven in part by the historic federal investments of the 2021 Infrastructure Investment and Jobs Act. Nearly half of the 18 evaluated infrastructure sectors improved their grades, signaling measurable progress after decades of widening funding gaps.

Despite this progress, the 2025 Report Card highlights an urgent, persistent national challenge: infrastructure resilience. More frequent and costly disaster events, triggered by natural or man-made hazards and exacerbated by climate change, have exposed the fragility of interconnected infrastructure networks, resulting in cascading failures, major economic losses, and threats to public safety. According to NOAA's National Centers for Environmental Information, the United States experienced 73 distinct weather and climate disasters with impacts over $1 billion each from 2022–2024, for a total of $462 billion in damages (NOAA NCEI 2020). The total averages to $3 billion per week.

ASCE has advocated for resilient infrastructure solutions for two decades. Recently, ASCE's 2021 Report Card highlighted overall needs, while its latest edition identified specific pathways for resilient infrastructure. In the 2025 edition, prioritizing resilience is one of the top three recommendations for improving infrastructure performance over the next four years.

Investment Builds Infrastructure.
Resilience Determines Whether it Endures.



The 2025 Report Card outlines resilience challenges and opportunities in each of its infrastructure sectors. For example, the energy sector faces weather-driven outages that account for 80% of interruptions since 2000, while drinking water systems must contend with severe weather, aging infrastructure, and emerging contaminants. The Report Card also emphasizes enhancing resilience across infrastructure sectors by including nature-based or "green" infrastructure solutions, such as rain gardens, constructed wetlands, vegetative buffers, bioswales, permeable pavements, and the use of parks and restored floodplains to manage stormwater and reduce flood risks.

"ASCE applauds Congress, state and local policymakers, and the private sector for demonstrating leadership over the past several years and prioritizing our nation's infrastructure. Those investments are starting to have an impact, but our work is not yet complete. More work is needed to integrate resilience that protects against the impacts of extreme weather … and ensure infrastructure is built for the needs of the 21st century."

—ASCE 2025 Infrastructure Report Card

Evolving from Projects to Systems-of-Systems

It is increasingly clear that resilience must shift from asset-by-asset strengthening to managing system-wide interdependencies. Failure in one network can cascade across others, causing significant economic losses and, tragically, loss of life. A recent report by the Coalition for Disaster Resilient Infrastructure shows that the economic losses from service disruptions can exceed direct physical damage by a factor of seven or more (CDRI 2025). After each disaster, awareness of interdependencies has grown, yet a significant gap remains in developing holistic, system-wide approaches to these risks.

Planning for system-wide resilience requires collaboration across levels of government and between public and private sectors and the community (FEMA 2024). Strengthening flood resilience, for example, may require coordinated action between local water utilities, regional transport authorities, emergency management agencies, private energy providers, and infrastructure designers. This requires not just mandates and funding, but a culture of cooperation and trust.

Table 1. Differences Between Project-Level and System-Wide Infrastructure Resilience

	Project-Level Infrastructure Resilience	System-Wide Infrastructure Resilience
Definition	The ability of a discrete infrastructure project (e.g., bridge, data center, wind farm) to anticipate, absorb, adapt to, and recover from disruptions while maintaining or quickly restoring its intended services.	The collective capacity of an entire interconnected network or sector (e.g., urban transit network, national energy grid, regional water supply) to withstand and recover from disruptions affecting multiple components while maintaining stability and reliability of public services.
Scope	Asset-specific design, construction, operation, and maintenance (e.g., designing a bridge to a higher flood elevation specification).	System design, construction, operation, and maintenance that account for interdependencies, cascading effects, and coordinated recovery strategies across assets, operators, and governance layers (e.g., evaluating impacts of flooding on local transportation patterns to prioritize alleviating choke points).
Time horizon	Typically aligned to the asset's life cycle.	Long-term, typically spanning multiple asset life cycles.
Stakeholders	Project owner, engineers, contractors, operators, and local regulators.	Government agencies, utilities, network operators, emergency services, regulators, and community members.

Data and Technology Open Up New Opportunities

Building resilience across infrastructure systems requires an understanding of how entire networks behave under stress, how disruptions ripple across sectors, how services depend on one another, and how proposed adaptation measures perform across a range of future conditions. Until recently, this kind of system-wide insight was difficult to achieve. Today, a new generation of digital tools and data sources makes it possible for cities of all sizes to plan more strategically, act with greater transparency, and deliver better outcomes for their communities (Pritchard et al. 2023).[1] Moreover, studies such as those by CDRI (2025) indicate that, in some contexts, advanced technologies can contribute to avoided losses, more efficient maintenance, and faster recovery when applied as part of broader resilience strategies.

Small and midsized jurisdictions have outsized opportunities to integrate technology solutions at many levels:

1. **Expanded data foundations**
   With the arrival of high-resolution, continuously updated data sources, decision-makers no longer have to rely on static hazard maps or decennial surveys. Instead, a growing array of authoritative and high-resolution datasets now supports resilience planning. These include national climate and hazard datasets refreshed on frequent cycles; satellite and aerial imagery capable of submeter detail; lidar and radar that map terrain and surface change with remarkable accuracy; and distributed sensors capturing real-time conditions such as flooding, air quality, flow rates, temperature, or infrastructure load. Local governments are also increasingly producing their own operational datasets, creating "living" data layers that reflect what is happening in the community currently—not what happened years ago. This matters when cities must decide which assets are most exposed, which neighborhoods face compounding risks, and where updated data justify changing permitting requirements, service levels, or investment priorities. A selection of these datasets has been included in the Appendix.
2. **Integrated geospatial environments**
   A fundamental change in recent years is not just the volume of data, but the ability to integrate and analyze it as a unified system. Integrated geospatial environments now allow local governments to view climate hazards, infrastructure networks, land use, mobility patterns, and demographic characteristics together, rather than as separate layers. This integrated view is powerful: it can expose how risks spread through interconnected systems, how a disruption in one sector imposes knock-on effects in another, and where targeted interventions could have the greatest system-wide benefit. Decision-makers are no longer limited to answering "where is the hazard causing failure?" but can now answer "how does this failure amplify and interact across the systems people depend on?" This matters when cities must determine how actions in one sector—such as transportation or energy—will affect outcomes in another, and when trade-offs must be negotiated among agencies with shared responsibility for system performance.

1 Throughout this guide, references to data, analytics, modeling, and artificial intelligence describe decision support tools that help planners and officials explore scenarios, understand risk, and test options. These tools do not provide certainty or guarantees, nor do they replace professional judgment, local knowledge, or statutory decision-making processes. Their value lies in supporting more informed, transparent, and defensible infrastructure decisions under conditions of uncertainty.

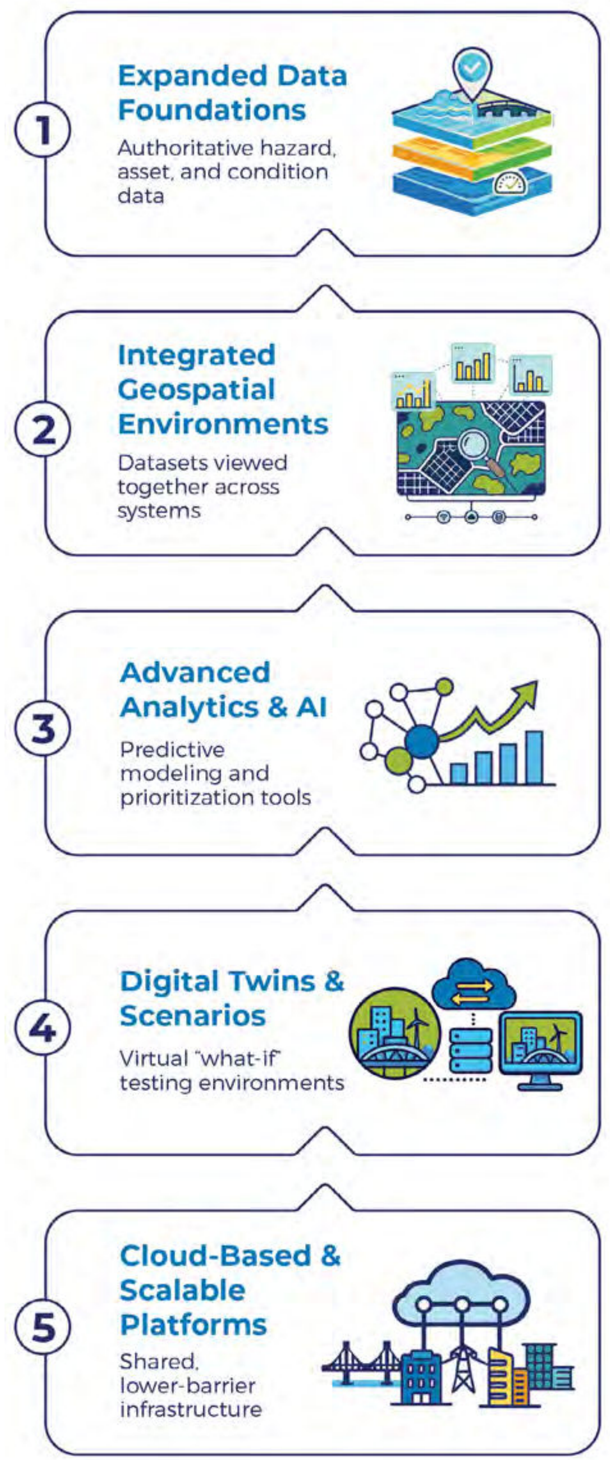
Table 2. Next-Generation Digital Tools for Systemic Resilience Planning

Digital Tool	Description	Purpose	Examples
Expanded data foundations	All the raw inputs that describe hazards, assets, conditions, and the environment	Establish a consistent, authoritative baseline for risk and exposure	• Open hazard and climate datasets • Satellite and lidar imagery • Remote sensing and sensor networks • Asset condition and life cycle data • Federal and state resilience platforms
Integrated geospatial environments	Visualizing datasets in one place	Reveal how risks interact across infrastructure systems	• GIS as a shared system view • Combined hazard, asset, land-use, and network topology layers • Cross-infrastructure visibility • System-wide stress-testing
Advanced analytics and artificial intelligence	The intelligence layer that drives insight and foresight	Anticipate vulnerabilities and evaluate options with greater confidence	• Predictive models for storms, flooding, wildfire, and hydrology • Asset degradation and failure probability modeling • Risk scoring and prioritization • Data-driven scenario exploration and risk indicator tools
Digital twins and scenario environments	The virtual workspace for planning and testing decisions	Test strategies before investing and align decisions across sectors	• Dynamic, data-linked digital representations of physical world • "What-if" simulations of cascading failures • Adaptation scenario analysis • Shared planning environments for cross-agency collaboration
Accessible, scalable platforms	The delivery system that makes dynamic decision-making practical	Ensure that communities of all sizes can use advanced tools	• Cloud computing and shared services • Regional or multijurisdictional analytics • Standardized data formats • Lower technical and staffing barriers

3. **Advanced analytics and artificial intelligence**
   Layered on top of these integrated geospatial environments are the growing capabilities of advanced analytics, predictive modeling, and artificial intelligence. Predictive maintenance models can help assess relative failure risk across assets; machine-learning hazard forecasts can support earlier and more informed understanding of flooding, wildfire, or heat impacts with greater precision; and scenario engines can explore long-term futures under a range of climate and development pathways. Generative AI now supports planning teams by synthesizing complex technical material, identifying patterns in large datasets, generating scenario narratives, and highlighting emerging risks that would otherwise require weeks of manual analysis. These capabilities do not replace planning expertise, they scale it—allowing human judgment to operate on a stronger analytical foundation. This matters when cities must decide whether to invest now or defer action, compare competing adaptation options, or defend risk-informed decisions to elected officials, auditors, and the public.
4. **Digital twins and scenario environments**
   Digital twins create dynamic, virtual representations of assets, networks, or entire regions to mimic the behavior of their real-world counterparts. They allow decision-makers and other stakeholders to explore "what-if" conditions on a more realistic representation of their system than was previously possible—from the impact of pump station failures during extreme rainfall, to the effects of a blocked corridor on emergency services, to how urban tree canopy expansion alters neighborhood heat exposure and energy demand during heat waves. More importantly, digital twins are increasingly linking sectors and agencies, revealing shared vulnerabilities and supporting coordinated adaptation strategies. This unified approach offers a common planning environment where engineers, planners, and emergency managers can align around shared evidence and evaluate interventions together. This matters when cities must test the system-wide implications of proposed projects, decide between alternative designs, or coordinate emergency preparedness and recovery strategies across multiple operators and jurisdictions.
5. **Accessible, scalable platforms**
   All of the abovementioned capabilities are becoming accessible because of the growth of secure, cloud-scale platforms that host large datasets, power advanced analytics, and facilitate collaboration across jurisdictions. Cloud-based computing, shared data standards, and prebuilt analytical services are reducing the cost, complexity, and staffing requirements historically associated with advanced modeling. Consequently, small and midsized communities—historically constrained by limited technical capacity—can now access the same modeling and analytical power as major cities, without building bespoke systems. These cloud-enabled environments support regional data sharing, multi-agency planning, and the operational integration needed for modern resilience governance. This matters when smaller jurisdictions must decide how to support decision-making capacity given staff and budget constraints, how to share costs and expertise, and whether to act independently or collaborate regionally.

Taken together, these technologies are moving resilient solutions from static assessments to dynamic, evidence-driven decision-making. They enable cities not only to understand vulnerabilities, but to test strategies, compare trade-offs, and coordinate action across sectors with a level of precision that was previously unattainable.

The Five Capability Layers



Technological breakthroughs now make
system-level resilience possible for cities of all sizes

ABOUT THE BUILT TO ENDURE SMART GUIDE

This Smart Guide is designed to be a practical toolkit for the people responsible for making infrastructure decisions at the municipal and state levels:

- Local elected officials, city managers, and agency leaders
- Planners, public works directors, and infrastructure program managers
- Engineers, architects, and designers
- Utility owners and operators
- Regulators, permitting authorities, and oversight bodies
- Community-facing leaders engaged in communication and public trust

Local officials and their delivery partners operate approximately 87% of all US infrastructure (Edwards 2017). They plan, regulate, finance, design, build, operate, and oversee infrastructure systems. By translating systems-based resilience principles into practical advice, this guide aims to help municipal governments and their partners—with the support of accessible data and technology—anticipate future climate conditions, prioritize investments, and plan, deliver, and manage infrastructure systems that provide resilient, reliable services (Van Nostrand 2023).

The Built to Endure Smart Guide emphasizes planning, policy, governance, and decision support as prerequisites for action, but these foundations must ultimately be paired with sustained capital to deliver results. Financing resilience, while essential, is beyond the scope of this guide.

In the United States, resilience investments are typically supported by a combination of funding and financing options, including municipal bonds, federal and state grants, utility revenues, and, in some cases, public-private partnerships and dedicated fees. Increasingly, access to capital depends on a city's ability to demonstrate risk, prioritize investments, articulate long-term value and "resilience dividends," and align projects with clear policy and governance frameworks (CDRI 2025). Accordingly, this guide focuses on the planning and policy choices that shape infrastructure decisions, while recognizing that resilience finance merits separate, dedicated treatment.

BUILDING RESILIENCE, BLOCK BY BLOCK

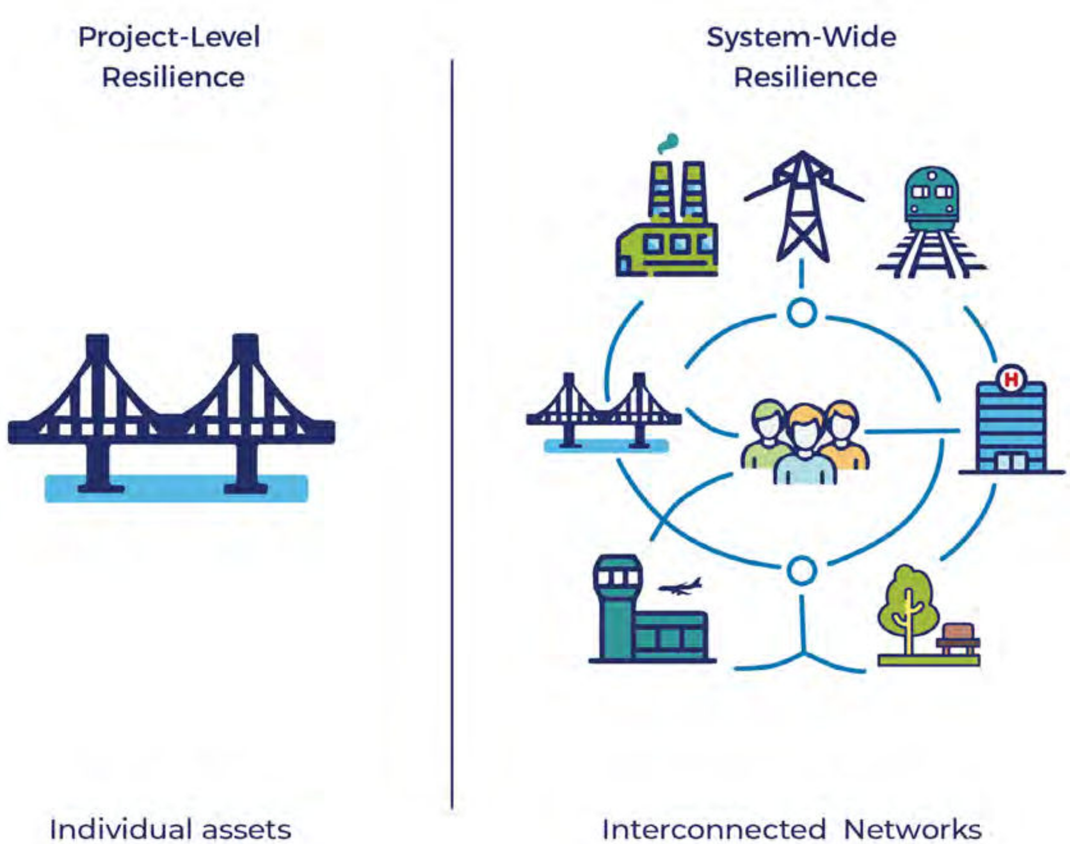
This Smart Guide outlines strategic and practical approaches for embedding systems-based resilience through three core building blocks:

1. Strategic resilience planning
2. Policy and regulatory effectiveness
3. Community and decision-maker empowerment

Across all three building blocks, technology and data analytics can play a critical role, enabling municipal decision-makers to better allocate resources, prioritize capital investments, manage trade-offs across agencies, and justify risk-informed decisions to the public.

Within each building block, we highlight key actions that decision-makers can take to address systems-level infrastructure risks. Particular emphasis is placed on how data, technology, analytics, and data platforms can enhance resilience by improving foresight, coordination, and decision quality. The Smart Guide also includes real-world case studies that illustrate how some communities have begun translating these capabilities into measurable resilience outcomes.

Project-Level versus System-Wide Infrastructure Resilience



Strategic Resilience Planning

Embed resilience considerations in all planning and capital decision-making to ensure that all system-wide risks, interdependencies, and vulnerabilities are addressed throughout the full infrastructure life cycle.

What?

Strategic resilience planning is a forward-looking approach that helps local governments ensure that infrastructure systems can withstand, adapt to, and recover from disruptions — whether from extreme weather, flooding, heat, cyberattacks, or operational disruptions.

Why?

Infrastructure systems are tightly interconnected, and failures rarely stay isolated. Without a structured means of assessing risks and interdependencies, localities remain vulnerable to cascading impacts during storms, outages, or other emergencies.

A threat, vulnerability, and risk assessment demonstrates these dynamics (Hanif et al. 2021). For example, extreme precipitation (threat) may overwhelm undersized culverts or bridges designed to outdated standards (vulnerability), resulting in reduced transportation capacity (risk). The impacts can extend well beyond physical damage and may affect emergency response times, public safety, economic activity, quality of life, and long-term recovery costs. Recognizing these connections helps decision-makers identify where proactive investments can prevent disproportionate disruptions and protect community lifelines.

How?

Key elements required for local governments' strategic resilience planning typically include:

Scope and adaptation goal-setting: Define system boundaries and measurable resilience objectives. Establish a long-term planning horizon that captures future climate, demographic, and economic changes (Boltz et al. 2022).

> *Case study connection:* The Norfolk, VA, *Vision 2100* framework established a long-term planning horizon that defines where the city will protect, adapt, or transition in response to sea-level rise, chronic flooding, and land-use changes. By clearly setting adaptation goals and system boundaries, the city aligned zoning, capital planning, and coastal investments around shared resilience objectives.

Threat, vulnerability, and risk assessment: Evaluate exposure, system-wide vulnerabilities, and interdependencies across assets and services managed by multiple agencies. Identify weak points where disruptions could spread across the community.

> *Case study connection:* After severe flooding, Kentucky used lidar, terrain modeling, and digital twins to assess bridge flood exposure and vulnerabilities across entire watersheds rather than individual bridges alone. This system-wide analysis revealed how damaged bridges and undersized crossings increased isolation risks for rural communities and emergency services, informing more effective recovery and mitigation decisions.

Scenario building and technology-enabled analysis: Use modeling, simulations, and scenario chains to examine how systems behave under future climate conditions, population growth, or compounding hazards, and reveal where failures could cascade across departments or community lifelines (Hurtado and Gomez 2021). Help decision-makers determine which risks to address first, how to allocate responsibilities across departments, and how to sequence actions within constrained capital improvement programs.

> *Case study connection:* Through connected digital twins, the UK Climate Resilience Decision Optimiser (CReDO+) modeled how power, water, and telecommunications networks respond to future flood and heat scenarios. Scenario testing exposed cascading failures and enabled utilities to evaluate coordinated adaptation strategies before investing.

Investment analysis and prioritization: Rank resilience actions using cost-benefit, trade-off, and system-value assessments. Prioritize interventions that strengthen critical connections and deliver the greatest community-wide benefit.

> *Case study connection:* The UK's CReDO+ compared the costs of climate-driven disruptions with the benefits of coordinated resilience investments across utilities. Modeling showed that joint interventions delivered far greater avoided losses than independent actions by individual utilities, providing a clear basis for prioritizing investments with the highest system-wide value.

Together, these steps support coordinated, anticipatory action and allow local governments to make informed, system-aware decisions during planning, design, operations, and capital investment.

Data and Technology Opportunities in Practice

Local governments are already applying new digital tools and diverse datasets to enhance their planning capabilities. In Kentucky, rapid, data-driven bridge assessments helped rural communities prioritize recovery after severe flooding. The city of Norfolk has demonstrated the ability of accessible mapping and scenario tools to reveal how flooding, land use, and infrastructure performance intersect at a neighborhood scale. And in the United Kingdom, CReDO+ shows how linking digital twins across multiple utilities can expose shared climate risks and support coordinated investment decisions.

Together, these advances give jurisdictions the ability to develop scenarios in real time, illuminate interdependencies, and move toward continuous, risk-informed decision-making grounded in a more accurate picture of how systems behave under stress.

Case Study: Kentucky
Using Digital Twins to Strengthen Post-Flood Planning

A virtual rendering of a replacement bridge in Kentucky as part of the state's efforts to recover from historic flooding in 2022

Image Credit: Qk4

Summary

Kentucky rapidly deployed digital engineering tools after catastrophic flooding to map system-wide damage, prioritize bridge repairs, and support rural communities lacking technical capacity.

Context and Challenge

In July 2022, extreme flooding swept through Eastern Kentucky, damaging hundreds of bridges and isolating rural communities dependent on limited road networks. Many municipalities lacked enough engineering staff, GIS analysts, or hydrologists, making it difficult to assess damage, prioritize repairs, or evaluate wider vulnerabilities. Traditional assessment methods, manual inspections and fragmented datasets, were too slow for the scale of the disaster and provided limited insight into system-wide patterns of risk. The state needed a rapid, data-driven method for understanding flood impacts, triaging damaged assets, and guiding recovery in ways that restored lifelines for communities across Eastern Kentucky, particularly for rural areas.

Action/Approach

The state government, through the Kentucky Transportation Cabinet, partnered with engineering firms to deploy drones, lidar, terrain modeling, and laser scanning to capture high-resolution data on damaged bridges and surrounding terrain. These datasets were used to construct digital twins that were virtual replicas of affected corridors, enabling engineers to visualize flood pathways and pinpoint structural vulnerabilities. The modeling extended beyond individual bridges, revealing watershed-scale patterns that helped identify where repeated flooding was likely and which communities faced the greatest transportation risks. The digital twins supported decisions about restoring temporary access, prioritizing bridge repairs, and coordinating emergency services with local leaders. The data now forms a critical planning resource for updating standards and mitigating future flood impacts across the region.

Results

The digital assessment process accelerated recovery by enabling rapid triage of damaged assets and restoring connections to dozens of rural communities much more quickly than manual assessments would have allowed. The unified evidence base helped ensure that repairs prioritized community need, safety, and long-term risk. The models provided Kentucky with a detailed record of flood behavior that now informs mitigation strategies, capital planning, and design standards.

What Other Cities Can Learn

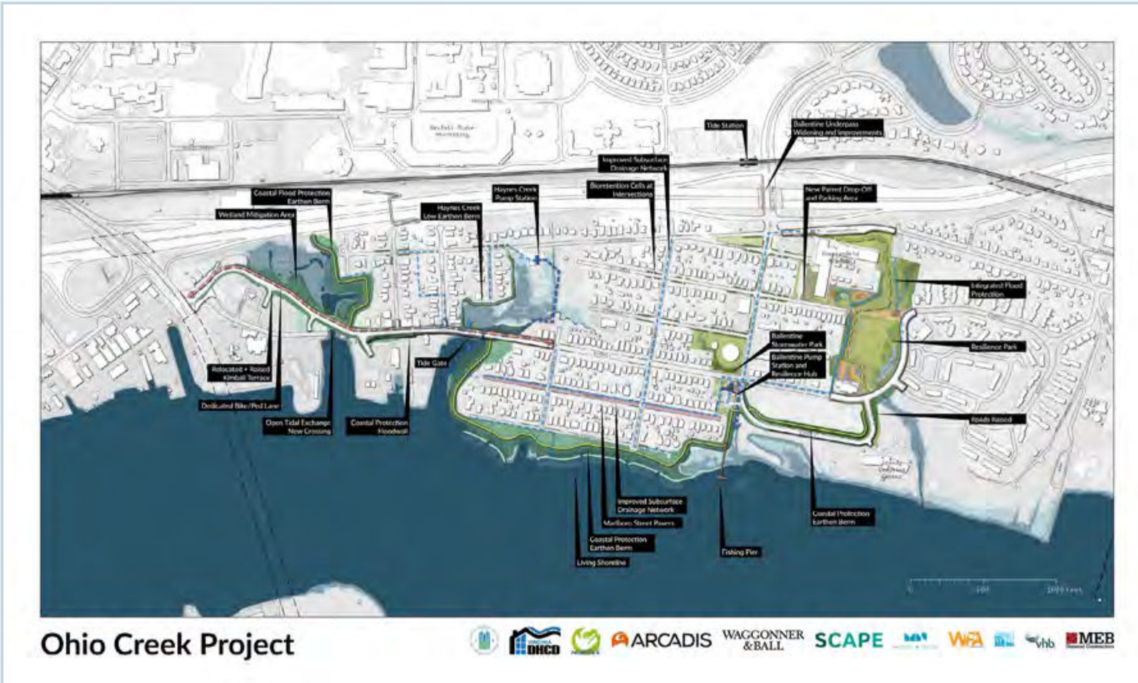
- State-led digital capacity can fill critical technical gaps for rural communities.
- Digital twins reveal watershed-scale vulnerabilities that traditional inspections overlook.
- Data collected during disasters can become a long-term planning asset, improving resilience over time.

"In moments of crisis, our small municipalities and rural communities are often the hardest hit and the hardest to reach. The digital models developed after the floods gave us the insight we needed to restore access quickly and plan smarter for the future. This is how we make sure no Kentucky community is left behind."

—**Jacqueline Coleman**, 58th Lieutenant Governor of Kentucky

Don Sniegowski/Flickr

Case Study: Norfolk, VA
Integrating Accessible Modeling into Citywide Resilience Planning



An overview of all the Ohio Creek Watershed Project features funded by a $112 million National Disaster Resilience Competition grant under the US Department of Housing and Urban Development

Image courtesy Norfolk Office of Resilience

Summary

Norfolk integrated accessible flood modeling and long-range scenario planning into zoning and capital decisions, enabling a citywide strategy for managing chronic coastal flooding and sea-level rise.

Context and Challenge

Norfolk—a city of approximately 235,000—faces chronic tidal flooding, storm surge, and some of the fastest rates of sea-level rise on the Atlantic Coast. These hazards routinely disrupt neighborhoods and strain drainage and transportation systems. By the early 2010s, increasingly frequent flooding exposed the limitations of traditional drainage improvements and piecemeal coastal defenses. The city needed a forward-looking system that could anticipate future conditions, guide land-use and zoning decisions, and evaluate long-term investment pathways under multiple climate scenarios.

Action/Approach

Norfolk developed a planning framework, Vision 2100, using readily accessible GIS modeling, flood mapping, and scenario analysis. The framework established an 80-year planning horizon and categorized areas into typologies for reinforcement, adaptation, or long-term transition. The GIS-based flood modeling combined elevation, storm surge, and stormwater data to illustrate neighborhood and infrastructure flooding exposure under current conditions and under different sea-level rise scenarios.

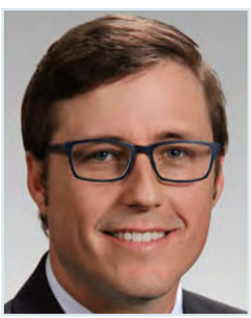
Insights from this modeling were codified into zoning reforms, including the **Coastal Resilience Overlay and Resilience Quotient**, which set elevation, drainage, and mitigation requirements for new development and provides incentives for development in lower-risk areas. The analytics also guided major infrastructure investments, such as the US Army Corps of Engineers' $2.6 billion coastal storm risk management project.

Results

Norfolk translated accessible modeling tools into practical planning and regulatory reforms, creating a coherent resilience strategy across departments. Long-term scenario planning improved alignment between land-use decisions, capital programs, and coastal protection investments. The city has become a nationally recognized example of how accessible modeling can guide sophisticated, system-wide resilience planning.

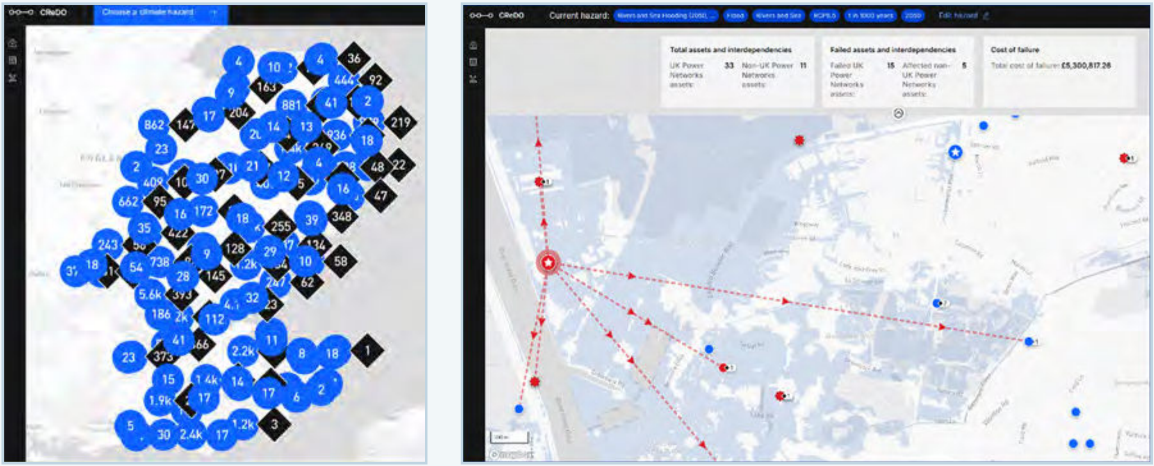
What Other Cities Can Learn

- Cities do not need advanced systems to make informed resilience decisions; accessible modeling tools can drive major policy and investment changes.
- Embedding hazard data into zoning and standards ensures long-term consistency across public and private development.
- Scenario planning strengthens the credibility and effectiveness of major capital investments.



"Smart resilience isn't about having the most advanced tools—it's about using the right ones well with the right data. Our modeling and mapping give us the clarity to guide where we build, where we protect, and where we invest. That's how we're securing Norfolk's future."
—**Kyle Spencer,** Chief Resilience Officer,
City of Norfolk

Case Study: United Kingdom
Climate Resilience Decision Optimiser (CReDO+)



CReDO+ map view

Left: Large scale integration of data on energy sites (blue circles) and customers and other sector infrastructure (black diamonds). Right: Zoom in on synthetic data demo of cascading risk from river and seas flood hazard.

Image courtesy of CReDO+.

Summary

CReDO+ shows how connected digital twins can reveal cross-sector infrastructure dependencies and guide coordinated investments that greatly reduce climate-driven system failures.

Context and Challenge

Climate Resilience Decision Optimiser (CReDO+) was created to help UK infrastructure operators understand how climate-driven disruptions affect interconnected networks. Energy, water, and telecommunications providers historically worked with siloed datasets and limited visibility into how failures propagate across systems. Extreme events such as floods, heatwaves, or storms routinely exposed the fragility of these networks, yet operators lacked a shared analytical environment to understand where vulnerabilities concentrated or how failures might cascade. With climate risk intensifying, decision-makers needed a way to evaluate system-wide exposure, identify critical interdependencies, and guide investment strategies based on cross-sector performance rather than isolated asset conditions.

Action/Approach

The CReDO+ project, led by UK Power Networks and funded by the Ofgem Strategic Innovation Fund, developed a connected digital twin platform for participating utilities, allowing their infrastructure networks to be modeled collectively within a unified analytical environment. Using real and synthetic data, the platform simulates the behavior of electricity, gas, water, and telecommunications systems under different climate scenarios, enabling operators to visualize cascading failures and quantify system-critical assets.

The tools allow stakeholders to compare the costs and consequences of disruptions against the benefits of coordinated interventions. Connected Places Catapult, an innovation accelerator funded by the UK government, convened the utilities, supported data-sharing agreements, and structured the collaborative modeling process. The platform is powered by Computational Modelling Cambridge Ltd.'s World Avatar knowledge graph technology, ensuring semantic interoperability and extensibility across disparate utility data. The shared digital infrastructure enables decision-makers to test different investment strategies and identify options that maximize resilience across all three networks.

Results

Modeling demonstrated that coordinated interventions delivered significantly greater benefits than isolated actions. One local flood simulation showed that a joint £1.1 million investment could mitigate £17.2 million in damages, more than if each operator invested independently. National-scale cost-benefit analysis estimated that increased flood and heat resilience could yield £4.4 billion in benefits by 2080 through avoided damages and operational costs and improved services to connected customers across the system. CReDO+ provided infrastructure providers with a common evidence base, improving understanding of interdependencies and enabling more strategic prioritization of resilience investments.

What Other Cities Can Learn

- Cross-utility collaboration strengthens resilience by revealing how failures spread across systems.
- Digital twins enable utilities to identify critical assets and evaluate coordinated strategies that produce greater economic and social benefit.
- Municipalities can adopt similar approaches even with incomplete datasets; collaborative modeling fills important information gaps and supports system-wide planning.

"CReDO+ will deliver a platform that allows us to better understand infrastructure interdependencies, improve planning investment, and ultimately increase resilience."
—**Elliot Christou**, Data and Technical Lead at Connected Places Catapult

Policy and Regulatory Effectiveness

Align local policies, standards, and regulatory processes so that system-wide resilience is embedded into everyday infrastructure decisions.

What?

Policy and regulatory effectiveness is what turns resilience planning into enforceable practice. Once local governments understand system-wide risks and interdependencies, they must translate that knowledge into the policies, standards, and procedures that shape how projects are designed, permitted, financed, and maintained.

Effective policy frameworks ensure that resilience is not a discretionary feature of individual projects. Instead, expectations for future climate conditions, system performance, and risk reduction are built directly into zoning, permitting, design standards, capital planning, procurement, and operations. This creates consistent incentives for developers, utilities, and municipal departments to make decisions that support long-term, system-wide performance—regardless of budget cycles or staff turnover.

Embedding resilience in policy can also provide continuity. As data, climate conditions, and technologies evolve, governance structures ensure that updates can be incorporated across departments in a coordinated, durable way.

Why?

Investments in systemic infrastructure resilience often suffer from misaligned costs and benefits: those who fund resilience measures may not be the ones rewarded by these measures. For example, a private utility may be asked to install redundancy that protects a regional economic cluster more than its own customers. A developer may be required to fund and construct a stormwater retention park on their site that manages runoff while also functioning as a public amenity with walking trails, play features, or open space. Without policy tools that clearly signal expectations and enable cost-sharing, communities often default to the least-cost, short-term options, resulting in chronic underinvestment in resilience.

By embedding resilience requirements into zoning, permitting requirements, service standards, and capital planning, governments can signal risk-informed standards to developers, utilities, lenders, and residents. This translates long-term risk reduction into near-term decision-making. Policies make resilience predictable, enforceable, and aligned across public and private actors—supporting more equitable, financially sound outcomes.

How?

Local governments can use a mix of regulatory, institutional, and fiscal tools to embed system-wide resilience into daily practices:

Regulatory reform: Update zoning, land-use ordinances, and permitting requirements to reflect current and future risks. Such reforms might include directing development away from floodplains, wildfire zones, or unstable slopes; requiring stormwater management measures for new development; or mandating climate-informed design criteria as a condition of approval.

Case study connection: Norfolk revised its zoning ordinance to embed sea level rise and flood risk into land-use decisions. Through its Coastal Resilience Overlay, the city established higher elevation and stormwater standards and steered development toward lower-risk areas, ensuring that routine permitting supports long-term flood resilience.

Standards alignment: Integrate resilience into technical design and operational standards across departments. This may include adopting updated rainfall, heat, or flood datasets for design assumptions; defining performance expectations for critical services such as stormwater drainage, mobility delays and disruptions, and power outages; and requiring climate-informed modeling in infrastructure design.

Case study connection: Miami, FL, embeds climate and hydrological data directly into its infrastructure standards using data-driven hydrologic models to guide pump sizing, stormwater upgrades, and capital priorities. These digital requirements are now formalized into policy, shaping all major infrastructure investments.

Institutional reorganization: Coordinate across siloed sectors and stakeholders to ensure all departments operate under a unified resilience framework. Reforms might focus on cross-departmental review of capital projects and incorporating resilience criteria in budgeting and procurement processes.

Case study connection: Miami's Office of Resilience and Sustainability exemplifies this institutional model, coordinating more than 20 departments and ensuring that zoning, capital planning, and budgeting apply a resilience lens to decision-making.

Fiscal restructuring: Use fiscal tools to prioritize system-wide risk reduction. This might include incorporating resilience criteria in capital improvement programs; prioritizing investments through use of life cycle cost-benefit calculations, sustainable/social return on investment (SROI) analyses, or system-value assessments; and linking performance with funding mechanisms such as utilities fees, special districts, or bond requirements.

Case study connection: The Salt Lake City, UT, Water Reclamation Facility upgrade demonstrates how fiscal and policy alignment can support resilient, community-oriented design. By using the Envision framework and SROI analyses, the city made whole-life, risk-informed decisions about seismic stabilization, redundancy, and community benefits—ensuring a resilient facility aligned with regulatory requirements and system-wide needs.

Data and Technology Opportunities in Practice

Local governments can use data foundations and analytical tools to strengthen regulatory effectiveness and ensure that resilience standards are applied consistently across systems and projects. Integrated geospatial environments, digital permitting systems, AI-enabled risk indicators, and cloud-based review platforms give regulators the ability to look beyond minimum design criteria and evaluate how proposed projects influence overall system performance. Moreover, systemic resilience approaches are notably hard to sustain over time, factoring in staff turnover, shifting political priorities, and fragmented data ownership. Shared analytical environments and common data platforms can potentially help reduce these frictions and promote long-term sustainability .

These capabilities are already shaping practice. Miami has incorporated data-driven hydrologic modeling directly into stormwater permitting and capital decisions. Norfolk uses forward-looking flood modeling, integrated mapping platforms, and scenario analysis to inform land-use designations, capital alignment, and regulatory review.. Salt Lake City's use of Envision, combined with geotechnical, seismic, and climate analyses, demonstrates how data-driven review can strengthen compliance with design requirements. And in the United Kingdom, CReDO+ shows how connected digital twins can link multiple utilities to reveal cross-sector climate risks and guide coordinated regulatory expectations.

For many smaller jurisdictions, limited capacity and uneven data access remain barriers. Regional collaboration—through shared data standards, cloud platforms, and coordinated analytics services—can lower the cost of adoption, reduce administrative burden, and ensure that even resource-constrained municipalities can participate in risk-informed, system-wide regulatory decision-making.

Daniel Piraino/Flickr

Case Study: Miami, FL
Institutionalizing Resilience Through Data-Driven Decision-Making

Miami skyline

Image courtesy of the City of Miami

Summary

Miami embedded resilience across all its departments by incorporating unified sea level rise projections into governance, ensuring climate data directly shapes planning, permitting, and capital investments.

Context and Challenge

Miami faces increasing risks from sea level rise, tidal flooding, major storms, and extreme heat. These hazards threaten property values, infrastructure systems, and municipal budgets. Before the city's reforms, resilience efforts were fragmented across departments, limiting the ability to coordinate long-term climate adaptation.

Action/Approach

Miami first established the Office of Resilience and Sustainability in 2016 to embed resilience considerations across more than 20 departments. This required that capital planning, zoning, and budgeting processes incorporate future climate and social-vulnerability risks. Beginning in 2019, the city developed strategic frameworks—including the **Resilient305** strategy, **Miami Forever Climate Ready strategy**, and **Miami Forever Carbon Neutral** strategy—as well as coordinated regionally by committing to use the **Unified Sea Level Rise projection from the Southeast Florida Regional Climate Change Compact**. These frameworks set measurable goals for flood mitigation and carbon neutrality, creating the policy backbone for resilience investments. The city then incorporated sea level rise, ground water rise, and water quality needs into hydrologic modeling to update its **Stormwater Master Plan**, supporting predictions of flooding, optimization of pump operations, evaluation of adaptation scenarios, and cost-benefit trade-offs. Then, in 2023, Miami codified resilience requirements by updating the City's Comprehensive Plan to include Coastal High Hazard Areas (CHHA) that are particularly vulnerable to the effects of tropical storm events. The city created maps to show the extent of the CHHA, accounting for sea level rise, which drives design, permitting, and capital budgeting processes. By fusing data and governance, Miami has transformed resilience from a series of projects into a permanent system of decision-making.

Results

Resilience became institutionalized through governance reforms, data integration, and policy mandates. The city improved transparency, coordination, and the quality of capital project decisions. Predictive analytics strengthened long-term investment planning and reinforced Miami's ability to manage climate-driven risks.

What Other Cities Can Learn

- Governance is the foundation of system-wide resilience.
- Advanced analytics are most effective when paired with policy requirements that ensure consistent use.
- Embedding resilience into capital budgeting strengthens long-term accountability and investment discipline.

"Embedding climate data into infrastructure planning and budgeting has helped Miami move resilience from isolated projects into everyday decision-making."
—**Sonia Brubaker,** Chief Resilience Officer, City of Miami

formulanone/Flickr

Case Study: Salt Lake City, UT
Certification and Standards Ensure Resilience and Sustainability of an Upgraded Water Reclamation Facility

Salt Lake City Department of Public Utilities water reclamation facility upgrade under construction, beyond stormwater retention pond

Image courtesy Will Peterson, AECOM

Summary

Salt Lake City leveraged an existing sustainability framework and rating system, Envision, to align resilience demands, project stakeholder goals, and regulatory requirements when upgrading a major wastewater facility.

Context and Challenge

Salt Lake City's Water Reclamation Facility was nearing the end of its service life and faced tightening water quality regulations. The site also faced significant seismic and flooding risks, creating substantial operational challenges. The city needed to upgrade the 48-million-gallon-per-day facility without interrupting wastewater service while also addressing environmental hazards, budget constraints, and community expectations.

Action/Approach

The city used the sustainable infrastructure framework and rating system, Envision, to evaluate decisions holistically, including climate risk, community impact, life cycle value, and system reliability. Designers applied sustainable return-on-investment methodologies to weigh costs and long-term benefits, guiding choices around seismic stabilization, flood resilience, energy reliability, and operational continuity. A construction manager/general contractor delivery model ensured collaboration across designers, builders, and operators from project inception. Resiliency objectives also drove development of emergency planning, management, and operations across the Salt Lake City Department of Public Utilities and regional stakeholders during the design phase. The city incorporated community engagement tools, including environmental justice mapping analyses, and multilingual outreach, to shape design decisions and manage potential impacts.

Results

The upgraded facility—scheduled for completion in 2026—has been designed to operate through earthquakes, power outages, and flooding. It will serve as a modern, community-oriented public asset that reflects regional priorities and ensures long-term wastewater reliability. The approach strengthened coordination among delivery partners and embedded resilience into every phase of design and construction.

What Other Cities Can Learn

- Established frameworks such as Envision support consistent, system-wide resilience integration.
- Collaborative delivery models enhance decision quality and operational continuity.
- Community-oriented design improves public trust and project outcomes.

"This project is a generational investment, and it was key to make sure we were prioritizing the community and the environment, today and through the long-term."
—**Holly Lopez**, Policy and Public Affairs Director, Salt Lake City


SLC.gov

Community and Decision-Maker Empowerment

Strategic resilience plans and policies only succeed when the local officials, delivery partners, and community members responsible for implementing and using them understand risks, have tools to act, and are meaningfully engaged in shaping decisions.

What?

Local officials, technical delivery partners, and residents all play critical roles in infrastructure decision-making. True empowerment means equipping these actors with the information, skills, tools, and confidence needed to interpret risks, evaluate trade-offs, and apply resilience principles consistently.

This requires more than sharing data. It involves translating complex technical analyses into clear guidance; providing training, toolkits, and modeling platforms; and creating opportunities for residents and stakeholders to explore scenarios and understand system-wide vulnerabilities. When these capabilities are in place, resilience becomes a shared responsibility embedded throughout daily decision-making.

Why?

Implementation frequently breaks down because people—not plans—lack the capacity or clarity to act. Public works and planning teams may face highly technical analyses that are difficult to translate into procurement, project scoping, or development review. Meanwhile, infrastructure owners and operators, consultants, and developers tend to meet minimum requirements unless expectations are explicit. Residents are often asked to support major investments without a clear understanding of the risks involved or the benefits delivered.

This environment often leads to fragmented approaches, duplicated efforts, and project-by-project decisions that fail to account for system-wide risks. They also undermine public trust—particularly when communities cannot see how resilience decisions connect to their own safety, service reliability, or costs.

When communities are meaningfully engaged, outcomes become more equitable , ensuring that decisions regarding resilience reflect community priorities, that risks are communicated transparently, and that the benefits of resilience are not limited to those with the greatest influence or resources.

How?

Empowerment happens when local governments invest in the knowledge, tools, and processes that make resilience actionable. Effective approaches include:

Translating technical analysis into clear guidance: Convert hazard modeling, scenario, and cost-benefit assessments into actionable insights for elected officials, technical partners, and the public.

> *Case study connection:* North Carolina's Flood Resiliency Blueprint demonstrates this translation at scale: it converts statewide hazard and infrastructure data into visual, scenario-based tools that municipal officials can use directly in land-use, zoning, and capital planning discussions.

Providing training, tools, and digital platforms: Ensure that staff and community partners can use modeling tools, digital twins, dashboards, and other analytical resources, even if they are not technical experts.

> *Case study connection:* The Wellington, NZ, digital twin exemplifies this approach by turning complex hazard and climate modeling into an intuitive, interactive experiences that residents and decision-makers can explore together. This creates shared understanding of risks and strengthens support for long-term adaptation choices.

Creating consistent expectations for delivery partners: Align consultants, developers, utilities, and financiers around shared resilience requirements so that resilience is embedded in concept design, procurement, investment appraisal, and project delivery.

> *Case study connection:* Local governments can mirror the standardization seen in Salt Lake City's use of Envision-based evaluation, ensuring that every project contributes to system-wide goals.

Using clear, transparent communication to build public trust: Explain how risks manifest across systems—for example, how a power outage can interrupt water supply or emergency response—so that the public understands why certain preventative investments are necessary.

> *Case study connection:* Wellington's community-facing visual tools and North Carolina's map-based Blueprint both show how accessible visualization improves trust and clarity in decision-making.

Supporting informed public participation: Provide communities with accessible risk information, opportunities to explore "what-if" scenarios, and input channels. This ensures that resilience priorities align with community needs, not only engineering analyses.

> *Case study connection:* The Corona, CA, experience underscores the importance of community-centered communication during emergencies: when staff could operate remotely and maintain continuity, the city was able to sustain public services and communication even during wildfire displacement—protecting residents and maintaining trust.

Applying advanced cost-benefit analysis and avoided loss metrics: Help local leaders understand how resilience investments reduce long-term costs, service disruptions, and recovery burdens—strengthening political and public support.

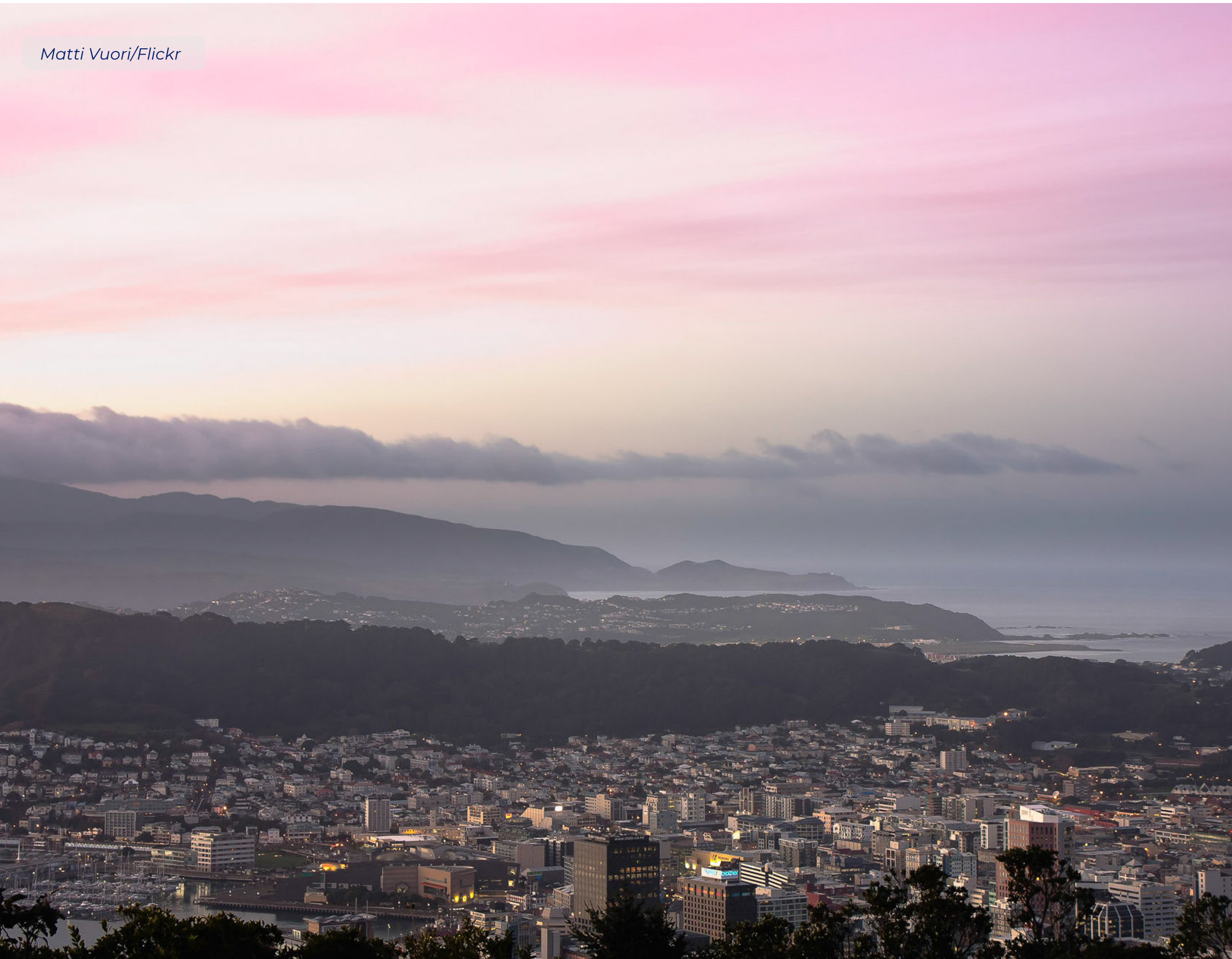
> *Case study connection:* Salt Lake City used SROI analysis through the Envision framework to evaluation design options for upgrading its water reclamation facility. By weighing upfront costs against avoided losses from seismic failure, flooding, service disruptions, and regulatory noncompliance, city leaders were able to clearly justify resilience investments to stakeholders and align technical decisions with long-term community value.

Data and Technology Opportunities in Practice

Empowerment depends on people having access to information they can understand, trust, and act on. New visualization tools, public-facing digital twins, and AI-enabled translation and explanation services help translate complex technical analysis into formats that nonspecialists can engage with. Wellington's city-scale digital twin, for example, enables residents to interact with flood, landslide, and sea level rise scenarios in real time. North Carolina's Resiliency Blueprint provides intuitive mapping and scenario tools that create a shared evidence base for land-use and investment decisions.

Technology also strengthens empowerment by supporting continuity of decision-making during disruption. In Corona, secure, location-independent access to systems and data allowed staff to maintain essential functions and public communication during climate-driven emergencies, reinforcing trust when conditions were most uncertain. Across many jurisdictions, AI-enabled multilingual alerts, equity-aware geospatial layers, and accessible scenario tools are helping ensure that risk information reaches the people and neighborhoods most affected.

By making insights more accessible, transparent, and timely, these technologies support clearer communication and stronger public confidence. When paired with training, shared platforms, and communities of practice, they help embed resilience understanding across institutions and neighborhoods—shifting it from a specialized technical task to a broader civic capability.


Matti Vuori/Flickr

Case Study: North Carolina
From Statewide Data to Local Decisions

Figure 7. Flooding following Hurricane Helene disrupted infrastructure in Western North Carolina

Image courtesy ***Bill McMannis***

Summary

North Carolina is developing a statewide, scenario-based decision-support tool that gives local governments shared data and clear visualizations to guide land-use and infrastructure resilience planning.

Context and Challenge

North Carolina faces varied flood risks across its coastal, piedmont, and mountain regions, yet municipalities have historically operated with fragmented and outdated datasets and inconsistent methods for assessing vulnerability. Local officials often lack tools to compare scenarios, evaluate land-use choices, evaluate risk-reduction options, and communicate risk to governing boards and residents. Without a shared, credible evidence base, resilience decisions risk becoming reactive or disconnected from long-term outcomes. A statewide approach is needed to provide shared data, consistent assumptions, and analytical tools that can be used by decision-makers at all levels.

Action/Approach

The state created the Flood Resiliency Blueprint program (Blueprint) to proactively plan and implement flood resilience projects and policies. The goal of the Blueprint is to provide local governments, the state, and partners with data, tools, and support to guide investments that minimize the cost and disruption of future flooding, while strategically funding priority projects and addressing gaps in current mitigation efforts. A centerpiece of the Blueprint program is the Blueprint Decision Support Tool, an integrated platform that merges statewide hazard, infrastructure, environmental, and socioeconomic data into a map-based program. The platform translates complex analyses into clear, visual, scenario-based information that is usable at the municipal level by planners, elected officials, and community members. The Flood Resiliency

Blueprint tool provides users accurate, data-driven flood risk and vulnerability assessments, and allows users to explore how different mitigation strategies or policy choices within their own jurisdiction may perform under current and future conditions. Collaboration mechanisms ensure that local knowledge informs updates while municipalities benefit from centralized analytics and standardized assumptions.

Results

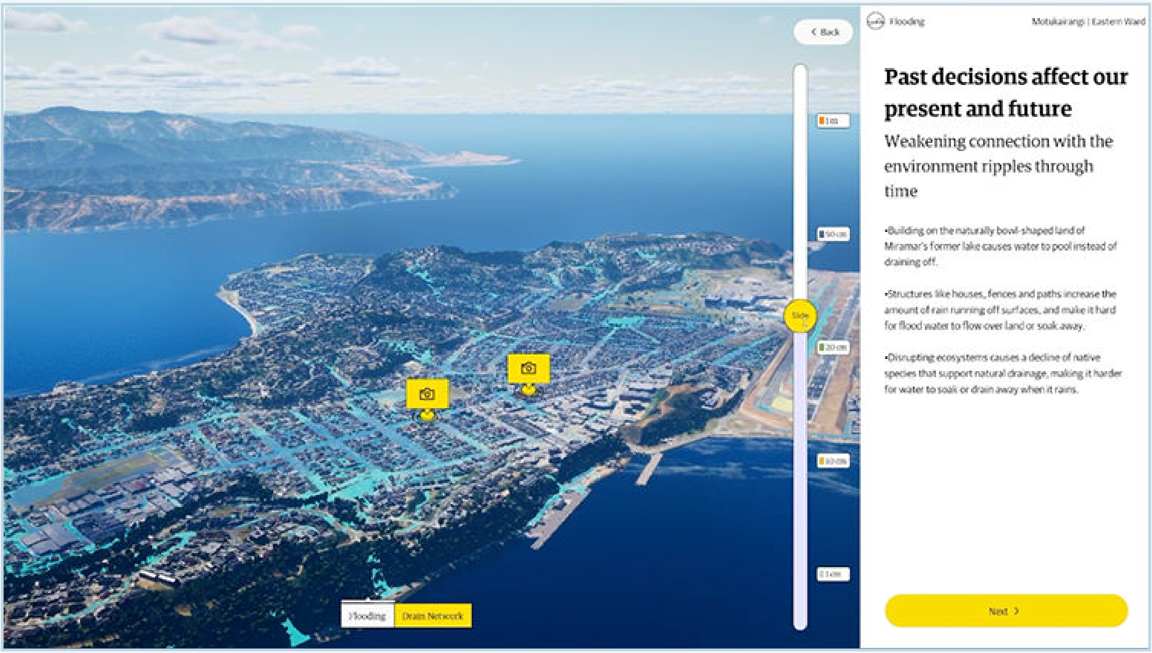
The Blueprint is beginning to improve consistency and transparency in resilience planning across agencies and jurisdictions across North Carolina. Local governments now use the tool to inform zoning, capital improvements, and community engagement. The state government has also used the platform to identify priority basin projects for $96 million in funding authorized by the North Carolina General Assembly.

What Other Cities Can Learn

- State-led analytical platforms expand local capacity without requiring major local investment.
- Shared datasets and common frameworks enhance cross-jurisdictional coordination.
- Scenario-based tools help decision-makers evaluate trade-offs.

"The Flood Resiliency Blueprint gives communities a shared, credible foundation for decision-making. By putting consistent data and future scenarios in one place, local leaders can better understand risk, compare options, and make more informed choices."
—**Stuart Brown**, North Carolina
Flood Resiliency Manager

Case Study: Wellington, NZ
Using Digital Twins to Build Shared Understanding and Community Support



Wellington's Our Changing City public engagement tool

Image courtesy Wellington City Council

Summary

Wellington created an interactive digital twin that helps residents visualize climate risks and participate meaningfully in adaptation planning using both scientific and Indigenous knowledge.

Context and Challenge

Wellington faces significant climate risks from steep terrain, low-lying coastal areas, and aging infrastructure. These hazards make the city vulnerable to flooding, landslides, and sea level rise. The city needed a way to communicate complex climate risks in ways that residents could understand and use to participate in adaptation planning.

Action/Approach

With funding from the Bloomberg Global Mayors Challenge, Wellington developed a digital twin using a 3D animation development tool that integrated GIS, hazard modeling, weather data, and sea-level rise projections. The interactive touchscreen installation, Our Changing City, was installed in community spaces to engage residents directly. The digital twin incorporated Māori knowledge systems alongside scientific data, supporting culturally grounded and inclusive dialogue. The modular architecture allowed for future expansion and cross-departmental use, supporting long-term engagement and planning.

Results

The digital twin transformed climate engagement by helping residents visualize neighborhood-level impacts of flooding, landslides, and sea level rise and explore adaptation options interactively. It strengthened public understanding of climate risks and created more informed conversations between residents and decision-makers.

What Other Cities Can Learn

- Digital twins can democratize access to complex climate information.
- Integrating indigenous and scientific knowledge improves inclusivity and trust.
- Interactive visualization strengthens community support for adaptation decisions.
- Modular design enables scalability and cross-departmental use.

"Climate change is here and is indisputably having an impact on our lives. From our coastlines to our hillsides, every part of our city will be challenged by climate change. Innovative technologies will be a crucial ally in how we mitigate the impacts of climate change, so new digital tools will ensure our communities have the information to face these challenges head-on as we co-create a more resilient Wellington."

—His Worship the Honourable **Andrew Little**, Mayor of Wellington

Wellington City Council

Case Study: Corona, CA
Maintaining Essential City Services During Climate-Driven Disruptions

Corona faced wildfires while community leaders were out of state

Image courtesy CAL FIRE

Summary

Corona shows how operational resilience, enabled by location-independent digital systems, can ensure continuity of government services during climate-driven disruptions, even when staff and leadership are physically displaced.

Context and Challenge

Corona, a midsized California city, faced a severe wildfire at a time when senior leadership was out of state. The event revealed that, as with many midsized cities, essential operations were tightly coupled to physical buildings, local networks, and onsite staff. When staff were displaced, delays cascaded across emergency response, community services, and administrative functions. Corona recognized that its operating model lacked the resilience required for a future of more frequent fires, heat events, and climate-driven disruptions.

Action/Approach

City leadership **shifted to a location-independent operating model** that enabled all staff to access essential systems securely from any location. The city restructured digital permissions and system oversight to improve reliability and decentralize critical information. This approach ensured that government operations, emergency coordination, and community services could continue uninterrupted during disruptions. The reforms also modernized everyday governance, reducing single points of failure and improving long-term operational resilience.

Results

During subsequent disruptions, Corona maintained continuity of operations with minimal delays. Processes that once took days were completed in minutes, and emergency communication remained stable even when staff were dispersed. The shift enabled the city to provide uninterrupted support to its residents during climate-driven events.

What Other Cities Can Learn

- Operational resilience is as important as physical infrastructure resilience.
- Location-independent systems reduce vulnerability to disruptions.
- Modernized digital operations strengthen public safety and trust.

"Designing our operations to work from anywhere reduced single points of failure and made the city more reliable during emergencies and day-to-day operations alike."
—**Jacob Ellis**, City Manager, City of Corona

Sergei Gussev/Flickr

Table 3. How Data and Technology Support Better Infrastructure Decisions Across the Building Blocks of Resilience

Building Block	How Technology Helps in Practice	Illustrative Examples from This Guide
Strategic resilience planning 	**Helps governments understand how risks affect entire infrastructure systems and test priorities before committing funding** • Integrates climate, hazard, asset, and land-use data • Models how disruptions cascade across systems • Tests future scenarios and adaptation options • Compares investments based on system-wide benefit	• System-scale mapping and scenario analysis in Norfolk • Data-informed recovery prioritization in Kentucky's post-flood bridge program • Cross-sector digital-twin analysis of climate risk through the UK's CReDO+
Policy and regulatory effectiveness 	**Helps turn resilience goals into consistent rules, standards, and review processes that shape everyday decisions** • Updates design standards using current risk data • Flags higher-risk proposals during permitting • Aligns zoning, service standards, and capital planning • Supports defensible, transparent regulatory decisions	• Hydrologic modeling embedded in standards and capital planning in Miami • Risk- and life cycle-based evaluation of major facilities in Salt Lake City informed by geotechnical, seismic, and climate risk analyses applied through structured resilience frameworks
Community and decision-maker empowerment 	**Helps staff, leaders, and communities understand risks, trade-offs, and priorities and act on them with confidence.** • Visualizes future flood, fire, and heat risks • Translates technical analysis into usable insight • Supports training and shared learning • Maintains continuity during disruptions	• Scenario-based, visual decision support through the North Carolina Resiliency Blueprint • Community-facing digital-twin engagement in Wellington • Continuity of operations and public communication in Corona

Getting Started: Practical Entry Points for Local Governments

Municipalities do not need to start from scratch to strengthen infrastructure resilience. There are existing resources that are widely used, trusted, accessible to communities of all sizes, and can directly support the core building blocks outlined in this guide.

Getting started can be approached through two complementary, low-barrier steps:

1. **Accessing data and tools:** Municipalities can draw on largely free, online platforms and websites that provide access to the resources needed to assess risks, define resilience goals, establish credible data foundations, test assumptions, and prioritize actions.
2. **Accessing technical support:** For communities that lack the time, staff capacity, or technical expertise to carry out this work internally, a range of local, regional, and national partners can help use these tools, technology, and data for actionable insights and early implementation.

Step 1: Accessing Data and Tools

Many high-quality resources are available online, a sample of which are found in the Appendix. As a starting point, this guide highlights two federal decision-support platforms: The NIST Community Resilience Resources and US Climate Resilience Toolkit. Each provides foundational data, planning and analytical tools, case studies, and instructional guidance. The NIST resource emphasizes resilience from a physical infrastructure and systems performance perspective, while the Climate Resilience Toolkit is organized around a climate-risk and decision context. Each can be used on their own or in combination with each other or other resources in the Appendix.

NIST Community Resilience Resources (nist.gov/community-resilience)

The NIST Community Resilience program offers a strong entry point for municipalities that want a structured, systems-based approach to resilience planning and investment. At its core is the Community Resilience Planning Guide for Buildings and Infrastructure Systems and its companion Playbook, a six-step framework that helps local governments move from understanding local context and hazards to setting resilience goals, evaluating alternatives, and implementing actions. The framework emphasizes how interconnected systems such as buildings, energy, water, transportation, and communications perform and recover together, rather than treating assets in isolation. The guide is particularly useful for informing capital planning, infrastructure standards, and long-term policy decisions. The Playbook's templates, planning briefs, and case studies translate the six-step framework into practical actions, provide step-by-step guidance and examples that help municipalities organize teams, engage stakeholders, and integrate resilience into existing plans.

To support the planning process, NIST Community Resilience Resources also include interactive tools that help communities evaluate options and trade-offs. The Alternatives for Resilient Communities (ARC) is an interactive system modeling tool for developing alternative sets of actions that meet community resilience and cost goals, given hazard and interdependency information and socioeconomic data. NIST's Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems, along with the EDGe$ (Economic Decision Guide Software) online tool, help compare the long-term costs and benefits of resilience investments, supporting clear prioritization, budget discussions, and communication with decision-makers.

US Climate Resilience Toolkit (toolkit.climate.gov)

The US Climate Resilience Toolkit is another potential entrance for communities seeking to understand climate-related risks and adaptation options. It brings together authoritative federal climate data, projections, tools, and case studies and organizes them around practical planning needs. Resources such as the Steps to Resilience guide, sector and hazard pages, videos and tutorials, and interactive maps help users understand local climate-related hazards, identify potential impacts of greatest concern, and implement climate resilience plans. Users can also search for a wide variety of data sources and tools compiled from agencies across the federal government by sector, asset type, hazard, and planning and implementation stage.

The strength of the Climate Resilience Toolkit lies in helping cities examine what climate risks they face currently, how they may change locally, and what impacts those changes could have on infrastructure, services, and populations. The Toolkit's data and tools can be used to inform comprehensive plans, climate action plans, and vulnerability assessments. They also can provide critical inputs for structured planning and investment frameworks such as those found in the NIST Resilience Resources.

Step 2: Accessing Technical Support and Capacity

Outside consultants are always an option for cities seeking to advance resilience planning and analysis. However, many small and midsized communities can make meaningful early progress without immediately engaging formal consulting services. A range of alternative support options—often lower-cost and easier to access—can help cities begin using available digital resources, data, and tools despite limited internal capacity.

The approaches that follow are intended to lower the barrier to entry and support early, practical actions. They can help cities build confidence, clarify needs, and generate initial insights that inform whether, when, and how more formal programs, investments, or procurements are pursued over time.

Learn from Peer Experience

One effective way for cities to build early momentum is by learning how their peers have approached similar challenges. Built to Endure includes nine case studies that illustrate how cities and regions have translated resilience concepts into practical planning, governance, and investment actions under real-world constraints. Many of the resources listed in the Appendix also include case examples embedded within broader tools and guidance.

For communities that want to focus specifically on peer learning—rather than navigating case studies dispersed across multiple platforms—a growing number of initiatives are dedicated to collecting, synthesizing, and sharing resilience case studies in accessible, practitioner-oriented formats. Examples include:

- Cornell Tech's Resilience Scanner uses AI to map and organize technology-enabled climate adaptation and resilience solutions deployed by cities worldwide. It helps local leaders see what solutions exist, where they are being used, and how emerging technologies can amplify planned or ongoing investments.
- The Infrastructure Sustainability and Learning Initiative (ISLe) convenes infrastructure practitioners online in virtual learning hubs to share applied lessons on challenges across the infrastructure lifecycle.

Leverage Existing Local and Regional Capacity

Many cities already have access to potential technical support through universities, utilities, and government agencies. Local universities can contribute applied research, data analysis, community surveys, and scenario testing through faculty and student projects. Utilities often conduct risk assessments and long-term capital planning that can inform community resilience priorities. Regional organizations, state agencies, and councils of governments can provide data, modeling, and coordination across jurisdictions. State and federal programs also may provide access to subject matter experts, data and modeling tools, facilitation, and hands-on support to help communities scope challenges, complete risk assessments, develop resilience strategies, or test pilot approaches. Leveraging these resources allows communities to advance early resilience efforts without creating new programs or hiring outside consultants. Examples include:

- In Ithaca, NY, the city worked with Cornell University and the Rocky Mountain Institute to analyze building energy use and electrification scenarios using existing data, informing next steps before major investments.
- FEMA Hazard Mitigation Assistance (HMA) programs provide free technical guidance during grant development through FEMA and state hazard mitigation agencies. As communities prepare applications for resilience grant programs, FEMA guidance and state-administered support help clarify eligibility requirements, hazard mitigation planning alignment, benefit–cost analysis expectations, and required documentation. For small and midsized communities, participating in the HMA application process can help build familiarity with mitigation planning requirements and data needs, even if a grant is not ultimately awarded.

Tap External Capacity Support

Many cities can supplement internal capacity by drawing on external organizations that provide planning, analytical, and implementation support, not only funding. Nonprofit organizations and networks, philanthropic initiatives, corporate support, and pro bono advisory services can play a critical role in early planning and capacity support. These resources are often used for discrete efforts, such as early-stage planning, scenario analysis, or pilot design, enabling cities to move forward without long-term staffing commitments. Examples include:

- Resilient Cities Network, which grew out of the Rockefeller Foundation's 100 Resilient

Cities initiative, has supported cities in building internal resilience capacity through technical assistance and shared learning.

- Bloomberg Associates provides pro bono advisory support tailored to cities, focused on helping local governments address specific, city-defined operational and policy challenges. Backed by Bloomberg Philanthropies, Bloomberg Associates deploys experienced former mayors, city managers, public finance experts, planners, and technologists to work directly with city leadership and staff on practical problem-solving rather than long-term consulting engagements.
- Accelerator for America supports cities through peer networks and targeted technical assistance focused on delivery and competitiveness.

CONCLUSION

This Smart Guide is grounded in a straightforward premise: resilience is achievable when planning, policy, and people are aligned, and when those efforts are supported by tools that make complex information easier to understand and use. Resilience is not delivered by any single asset, technology, or agency. It emerges when communities adopt a systems perspective, coordinate across agencies and partners, and embed long-term risk, equity, and performance considerations into routine decisions about infrastructure and land use.

Technology plays a critical enabling role in this shift, but is not a substitute for leadership, judgment, and community relationships provided by local governments. When thoughtfully applied, digital tools help decision-makers see interdependencies, test trade-offs, communicate risk, and prioritize investments with greater confidence. They lower barriers to participation, improve transparency, and make complex information usable for planners, engineers, elected officials, and residents alike. In doing so, technology strengthens—not replaces—human judgment and institutional capacity at the heart of resilient infrastructure.

Table 3 highlights how these capabilities support the three building blocks of systemic resilience outlined in this guide. Across strategic planning, policy and regulatory reform, and community and decision-maker empowerment, technology helps translate resilience from intention into practice by connecting analysis to decisions and decisions to real-world outcomes.

The *2025 ASCE Report Card for America's Infrastructure* underscores why this shift is urgent. While recent federal infrastructure investments are beginning to reverse decades of decline, infrastructure systems are still not keeping pace with climate-driven disruptions and the cascading failures that follow. The next chapter for US infrastructure must therefore be defined not only by higher investment, but by resilient, system-wide decision-making that endures. Local governments sit at the center of the nation's resilience challenge. Building infrastructure that lasts is a shared responsibility—and with practical governance reforms, inclusive engagement, and the thoughtful use of digital tools, communities of all sizes can move from reacting to risk toward shaping resilient futures together.

APPENDIX—FURTHER RESOURCES

Table A1. Additional Resources for Municipalities

Resource	Type	Description	Link
NIST Community Resilience Resources	Platform with playbook, decision support models, metrics, case studies	NIST's platform provides practical guidance, tools, and metrics to help communities plan for, withstand, and recover from disruptive events by focusing on how buildings, infrastructure systems, and social functions work together. Centered on the NIST Community Resilience Planning Guide for Buildings and Infrastructure Systems, these resources help local officials define performance goals, assess dependencies across systems, and prioritize actions that support faster and more equitable recovery.	https://www.nist.gov/topics/community-resilience
US Climate Resilience Toolkit	Platform with guidance, tutorials, instructional materials, case studies	This platform provides access to tools, data, and case studies to help decision-makers address climate-related risks. It curates resources from multiple federal agencies to support planning, risk assessment, and resilience actions across sectors such as infrastructure, water, health, and emergency management. It serves as a centralized entry point to authoritative climate information and practical examples that can inform resilience planning and policy decisions.	https://toolkit.climate.gov
FEMA National Resilience Guidance	Guidance framework with associated materials	FEMA's National Resilience Guidance and the related materials available through the FEMA Resilience Gateway help communities understand and strengthen resilience across all sectors and stressors. The framework emphasizes integrating risk information, mitigation, preparedness, and recovery considerations into long-term planning and investment decisions, rather than treating resilience as a standalone activity. The accompanying Resilience Gateway serves as a centralized access point to FEMA guidance, planning resources, tools, and case studies.	https://www.fema.gov/emergency-managers/national-preparedness/plan/resilience-guidance
FEMA Community Lifelines	Platform with guidance, templates, and implementation guidance, visual tools, training materials	This framework centers on preparing for, maintaining, and restoring the capabilities of seven lifelines—such as energy, transportation, communications, and health—during and after disruptions. FEMA resources help emergency managers, local officials, and infrastructure partners establish shared priorities, improve situational awareness, and coordinate actions across sectors, particularly in the near-term before, during, and immediately after disasters.	https://www.fema.gov/emergency-managers/practitioners/lifelines

Table A1. Additional Resources for Municipalities *(continued)*

Resource	Type	Description	Link
Infrastructure Pathways	Platform with curated tools, guidance documents, and case studies across the infrastructure life cycle	This open-access resource is designed to help infrastructure practitioners integrate climate resilience and systems thinking into every phase of the infrastructure lifecycle. It compiles and organizes guidance from hundreds of reports, tools, case studies, and best practices, structured around life cycle stages from policies and planning through design, construction, operations, and end-of-life, so users can find relevant actions for their role and phase of work. The highlights roles and resources for different practitioner groups, such as governments.	https://infrastructure-pathways.org/overview/
Connect to Change	Guidance document	This short primer introduces a systems thinking perspective for addressing complex challenges in the built environment. It explains why infrastructure, climate, and community outcomes are shaped by interconnected decisions across institutions, sectors, and time, and outlines simple ways practitioners can begin working more collaboratively and systemically.	https://be-connective.com/wp-content/uploads/2025/07/Connect-to-change.pdf
CISA Infrastructure Resilience Planning Framework (IRPF)	Guidance document with links to informational resources, modeling and analytic tools, templates case studies	This planning framework is intended to help localities, regions, and the private sector plan for the security and resilience of critical infrastructure services in the face of multiple human and natural threats and changes. It provides a structured, step-by-step approach—supported by extensive references to tools and resources—to help identify critical infrastructure, understand threats from natural and man-made hazards, develop resilience actions, and track implementation.	https://www.cisa.gov/resources-tools/resources/infrastructure-resilience-planning-framework-irpf
US EPA Climate Resilience Evaluation and Awareness Tool (CREAT)	Web-based tool and training modules	The EPA Climate Resilience Evaluation and Awareness Tool (CREAT) is a free, decision support tool designed to help water utilities and operators assess climate risks and evaluate adaptation options for drinking water, wastewater, and stormwater systems. CREAT guides users through a structured process to identify climate threats, assess vulnerabilities and consequences, and compare resilience strategies using scenario analysis and economic metrics such as avoided costs and return on investment.	https://toolkit.climate.gov/tool/climate-resilience-evaluation-awareness-tool-creat

Table A1. Additional Resources for Municipalities *(continued)*

Resource	Type	Description	Link
IN-CORE (Interdependent Networked Community Resilience Modeling Environment)	Software, training materials, case studies	This freely available simulation-based platform helps communities analyze how hazards affect interconnected infrastructure systems and recovery outcomes. IN-CORE complements the NIST Community Resilience Planning Guide by providing quantitative tools to test scenarios, explore cascading failures across systems such as power, water, and transportation, and compare resilience investment options. IN-CORE is most effective when used by staff or partners with technical skills in data analysis or modeling. Communities lacking this capacity can also access fee-based technical assistance through the IN-CORE team or partners.	http://resilience.colostate.edu/in_core/
EDHEC-CLIRMAP (CLimate-Induced Regional MAcroimpacts Projector)	Decision support platform and interactive map	This decision-support platform helps policymakers and planners understand how climate change is likely to affect infrastructure and economic performance at regional, national, and long-term scales. For practitioners working at the local scale, it is most useful as a strategic context-setting tool—showing how climate risks such as flooding, heat, or sea-level rise are projected to evolve across regions and how those trends may influence long-term investment priorities and resilience pathways.	https://climateinstitute.edhec.edu/data-visualisations#edhec-clirmap
Developing Key Performance Indicators for Climate Change Adaptation and Resilience Planning	Framework and guidance	This structured framework provides step-by-step guidance for local governments and agencies to develop clear, actionable key performance indicators that translate climate adaptation and resilience goals into measurable outcomes. It helps governments select key performance indicators s that align risks, actions, and objectives, enabling consistent tracking, evaluation, and adjustment of resilience strategies over time.	https://nicholasinstitute.duke.edu/publications/developing-key-performance-indicators-climate-change-adaptation-and-resilience
American Society of Adaptation Professionals' Ready-to-Fund Resilience Toolkit	Guidance document	This toolkit describes "how" local government leads and partners can design more fundable projects by pulling specific policy levers, seeking key partnerships, using innovative accounting practices, inverting power structures, and rethinking and redesigning internal processes. The step-by-step process will help local government and their partners better prepare themselves and their communities for climate resilience funding and finance.	https://adaptationprofessionals.org/ready-to-fund-resilience-toolkit/

Table A1. Additional Resources for Municipalities *(continued)*

Resource	Type	Description	Link
Resilience Scanner	Tool	The Resilience Scanner uses AI and data-driven methods to identify case studies of climate resilience and adaptation solutions used by municipalities across the globe. The tool scans large bodies of publicly available information to catalog adaptation solutions and link them to specific climate risks, infrastructure needs, and local contexts.	https://resilience.urbantech.info/
NOAA Climate Data Online	Foundational data and tools	This portal provides historical weather and climate observations, including temperature, precipitation, and extremes, used to establish baselines and analyze observed trends.	https://www.ncei.noaa.gov/cdo-web
NOAA Atlas 14	Foundational data and tools	This portal translates historical rainfall records into precipitation frequency estimates (e.g., 10- or 100-year storms) that inform infrastructure design and stormwater standards.	https://hdsc.nws.noaa.gov/hdsc/pfds
FEMA National Flood Hazard Layer	Foundational data and tools	This portal provides and maps regulatory flood hazard information used for floodplain management, insurance, permitting, and infrastructure planning across the United States.	https://www.fema.gov/flood-maps/national-flood-hazard-layer
FEMA Resilience Analysis and Planning Tool	Foundational data and tools	This portal provides nationally consistent data on hazard exposure, expected losses, social vulnerability, and resilience for screening and comparative risk analysis.	https://experience.arcgis.com/experience/0a317e8998534c30a9b2d3861c814d42/page/RAPT-2025
USGS National Elevation Dataset	Foundational data and tools	This portal provides elevation, hydrography, land cover, and base geospatial layers widely used in infrastructure and hazard analysis.	https://apps.nationalmap.gov/downloader/
USGS Water Data for the Nation	Foundational data and tools	This portal provides data on streamflow, groundwater, and water quality that support flood, drought, and watershed-scale infrastructure planning.	https://waterdata.usgs.gov
US Census Bureau American Community Survey	Foundational data and tools	This portal provides detailed demographic, housing, income, and commuting data critical for understanding population vulnerability and service needs.	https://www.census.gov/programs-surveys/acs
USDOT National Transportation Atlas Database	Foundational data and tools	This portal provides nationally consistent data on transportation networks and facilities to support analysis of connectivity, dependencies, and system disruptions.	https://www.bts.gov/geospatial/national-transportation-atlas-database

Table A1. Additional Resources for Municipalities *(continued)*

Resource	Type	Description	Link
US EPA EnviroAtlas	Foundational data and tools	This portal integrates and maps data on ecosystems, environmental conditions, and human health to help cities understand how infrastructure decisions affect community outcomes.	https://www.epa.gov/enviroatlas
Built Environment Connective Key Concepts document	Glossary	This document provides a foundational overview of key concepts and terms associated with bringing systems approaches to the built environment.	https://be-connective.com/wp-content/uploads/2025/06/Connect-to-change_Key-concepts.pdf

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