DESIGNING AND BUILDING RESILIENT TRANSPORTATION NETWORKS

How a Geographic Approach, with GIS Technology, Benefits the Roads, Bridges, and Tunnels of the Future

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CONTENT

Smart Transportation Infrastructure Needs Smart Technology

Our roads, tunnels, railways, and bridges are so much more than a necessity for getting from point A to point B. Now more than ever, the conduits that promise reliable and safe passage for people, goods, and services must be able to withstand extreme weather events as well accommodate growing populations and rapidly evolving vehicle technologies.

The work of building stronger, smarter infrastructure necessitates knowing even more about precisely where projects are being built and how they will impact the surrounding natural environment. This means taking a geographic approach, using a geographic information system (GIS). ArcGIS® from Esri is the leading mapping and spatial analytics software. It is designed to support the mission and business objectives of organizations around the globe–and it's used on some level by nearly every Department of Transportation (DOT) nationwide.

As the US makes an unprecedented investment in fortifying and building critical transportation networks at the federal, state, and local levels, one thing is clear: The routes and infrastructure must be sustainable enough to be traveled for generations to come.

Before any asphalt is laid, cement is poured, or rebar is installed, GIS can be used to analyze data at each precise location and predict what may happen there in the future, saving costs for planning, operations, and maintenance. The critical context

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of location helps not only project prioritization but also design decisions, such as how to reduce impact on natural surroundings, how to use existing resources to maximize build-out, and how to build in buffers from potential natural events.

As climate events make the future more uncertain, technology can help us build resilience into transportation networks and infrastructure. By visualizing infrastructure via a GIS-based digital twin—a virtual representation of structures and assets as they exist in the real world—an agency can see where and when to make fixes, and where problems are in proximity to workers and equipment. Accessing it all in a cloud-based, mobile environment allows those workers to update and share their actions in real time.

Jack Dangermond, president and founder of Esri, has noted that the thousands of projects to result from infrastructure funding "are going to be directed by environmental factors, by social factors, and by economic factors so that these projects can get the maximum value out of the investments this country is making."

As we strive for resilient and equitable upgrades to infrastructure, GIS will be essential in prioritizing, planning, and maintaining transportation networks.

"We can understand where—that's the big question—where these investments should be made and, more importantly, what is the impact of these investments," Dangermond said.

Increasing Frequency of Extreme Events

There has been a staggering rise in the number of severe weather events over the past 20 years, driven largely by rising global temperatures and other climate changes, according to the United Nations. Globally, the annual number of floods and other hydrological events has quadrupled since 1980 and doubled since 2004, highlighting the urgent need to plan and adapt accordingly. Climate-related events such as extreme temperatures, droughts, floods, storms, and wildfires are increasing at an alarming rate. They are causing failures, damages, and delays to our transportation networks–thus threatening mobility and safety along transportation corridors.

The results have been costly. The number of billion-dollar disasters–a total of 22–in the US set a record in 2020 at a collective cost of $95 billion, according to National Oceanic and Atmospheric Administration (NOAA).

Impact on Transportation

Hurricane Ian, which made landfall in western Florida and Cuba in September 2022, is estimated to have cost as much as $100 billion, according to reports following the event. The storm damaged numerous bridges including the three-mile-long Sanibel Causeway linking the coast of Fort Myers with Sanibel Island. Years earlier, in 2017, Hurricanes Harvey, Irma, and Maria were responsible for much of the nearly $322 billion in disaster damage nationwide, the highest annual amount in US history.

In Vermont in 2011, Hurricane Irene washed out more than 2,000 roadway segments, undermined more than 1,000 culverts, and damaged more than 300 bridges, according to the Vermont Agency of Transportation [per https://vtrans.vermont.gov/]. The costs to rebuild were estimated to amount to roughly $1 billion. These costs are attributed to infrastructure repairs alone and do not include lost revenue or the impacts on the supply chain and businesses.

Regulatory Response

"Global climate change's potential impacts on infrastructure create some of the most significant and challenging issues facing transportation planners and asset managers today," according to a statement from the Federal Highway Administration (FHWA).

It's now the official policy of the US DOT to "integrate considerations of climate change impacts and adaptation into DOT planning, operations, policies, and programs." The department encourages state DOTs, metropolitan planning organizations, tribal governments, and other agencies to develop cost-effective strategies to minimize climate-related and extreme-weather risks.

The FHWA has been instrumental in funding pilot studies and developing methods to help transportation agencies incorporate climate resiliency into planning, design, and asset management.

Recent federal funding initiatives, including the Infrastructure Investment and Jobs Act, have added urgency to the government's emphasis on climate adaptation. Transportation agencies are now advised to invest in technologies, such as GIS, that can help meet resiliency objectives.

Location Intelligence across Agencies and Enterprises

There is broad consensus that GIS technology optimizes analysis of climate-related risks as well as opportunities, such as those related to renewable energy. GIS maps and dashboards play an important role in communicating climate impacts to policy makers and the public.

For Allie Kelly, executive director of The Ray, a nonprofit that works with local governments to help build highways supporting net-zero carbon emissions, GIS mapping has been key. "You have to have tools and maps in order to understand how the roadsides can be utilized for clean energy infrastructure . . . like roadside solar arrays," she said.

Among governments and nongovernment organizations alike, GIS will be essential to planning, delivering, and maintaining resilient transportation networks for generations to come.

"We rely on maps not just to know where we've been and how our progress is going, but also where we're going and how to get there," Kelly said. "The plot twist at the end of the story is that transportation actually saves the day. . . . There are so many assets and so many opportunities that we can unlock in the sector in order to deliver clean energy, clean transportation, and more capacity on the grid."

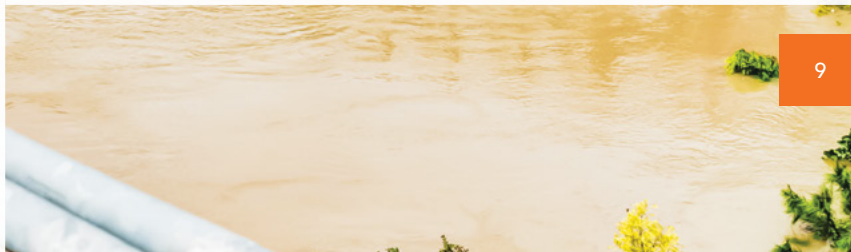
As the US embarks on a sweeping overhaul of transportation infrastructure, agencies will need to do more than just rebuild and repair aging infrastructure. They will need to use an enterprise-wide GIS to empower decision-making and prioritization across each project's life cycle.

The Role of GIS in Transportation and Climate Resiliency

Sophisticated GIS models and simulations can assist people in understanding climate risk specific to each location, asset, and network. Many governments and transportation agencies need local estimates of sea level rise, increased precipitation, extreme temperature events, and other impacts. Within GIS, these predicted impacts can be overlaid on precise digital elevation models with data captured from lidar, together with slope measurements (to calculate increased landslide potential) and the existing inventory of transportation infrastructure.

GIS is critical to transportation-focused climate resiliency efforts—agencies can do the following with GIS:

- Collect and manage the inventory of existing transportation assets and infrastructure. This includes asset registry; detailed information about current conditions and the expected life cycle; and smaller assets that may play a larger role as precipitation patterns change, including culverts, drains, and storm sewers.
- Quickly and accurately understand the importance or criticality of each asset, determined by its social and economic importance and the availability of alternatives.
- Assess the relative importance of various assets based on how many people would be impacted by a failure and to what degree. Calculations can include qualitative assessments such as risk tolerances and community values.



The Business Case

Transportation departments are working to break the respond, rebuild, and repeat cycle as they face increasingly extreme weather events. By first measuring vulnerabilities using GIS, these agencies are preparing to rehabilitate and build structures that will outlast their predecessors and withstand future conditions and population growth. They are bolstered by GIS technology, which gives them the ability to visualize where assets and services may be at risk and analyze project data alongside location-specific information like demographics, terrain, and weather patterns—before breaking any ground. GIS empowers decision-makers to prioritize projects by urgency and resource availability, getting the most out of available dollars. With precise map-based records of all transportation assets, these agencies will be able to track operations and maintenance, stay ahead of damages, and do so efficiently.

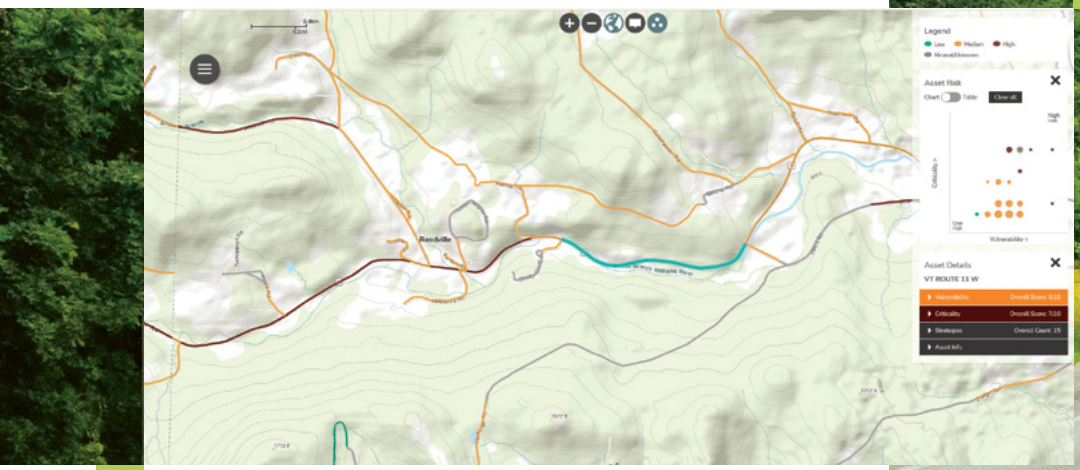
USER STORY

Vermont Agency of Transportation

Vermont Agency of Transportation (VTrans) has been developing a class-leading suite of GIS-based solutions to help the state prepare for weather-related events. Called the Transportation Resilience Project Tool, the data- and GIS-based application is designed to give VTrans a measure of where the agency is in terms of flood resilience.

The application combines calculations of criticality for each of the transportation assets, together with the vulnerability of those assets to three different components of riverine flooding—inundation, erosion, and deposition—for 10-, 50-, and 100-year storms.

Read the full story.



"It's often hard to find the data that you need to measure what's most important, but these new tools will provide that information. I'm very confident of that."

Joe Segale
Policy, Planning, and Research Director, VTrans

USER STORY

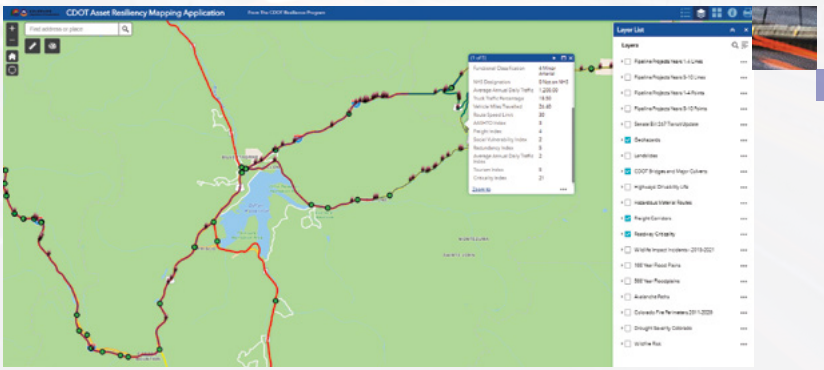
Colorado Department of Transportation

GIS tools are providing the Colorado Department of Transportation (CDOT) with a strong foundation on which to build its infrastructure resiliency efforts. The department is using GIS to ensure that it preserves and rebuilds its infrastructure in the most strategic and cost-effective way.

After a series of devastating floods in 2013, CDOT undertook a study to evaluate the vulnerability of state highways and the cost to harden the state's infrastructure to withstand future climatic events.

The core of the study–relying on GIS–examined risk together with the consequences of an asset failure. Estimates included not only the cost to the state to make repairs, but also the cost to the public and businesses when the roadway was inoperable. "How much would it cost to buy down the risk?" and "Is it worth the investment?" were the core questions. In this way, CDOT sought to develop a defensible methodology for understanding the return on investment for making proactive infrastructure investments.

Read the full story.



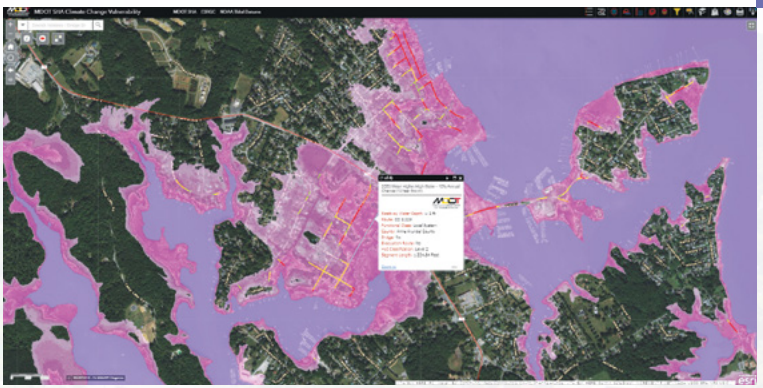
USER STORY

Maryland DOT State Highway Administration

The Maryland DOT State Highway Administration (MDOT SHA) has been conducting climate change vulnerability assessments for several years, initially identifying threats posed to specific roads and bridges in Anne Arundel and Somerset Counties.

In 2018, with federal funding support, MDOT SHA expanded its assessments to include bridges statewide, integrating results and climate risk information into existing asset management, planning, and other processes.

This work has matured into the GIS-based Climate Change Vulnerability Viewer (CCVV). The web application is now a support tool for MDOT SHA senior managers and planners as well as other transportation agencies throughout the state.



"The best way to [show why resilience is important] is to put a dollar figure on it. It comes down to, 'This is what you do now, but if you don't consider certain other things, this is how it could play out in the long run.' Often the suggested changes are only minor.…Cost-benefit analyses have shown how the potential impacts of not making changes can be even more severe downstream, involving a lot more money and time."

Toria Lassiter
Assistant Chief, Innovative Planning & Performance Division, MDOT SHA

Read the full story.

USER STORY

Southeast Michigan Council of Government

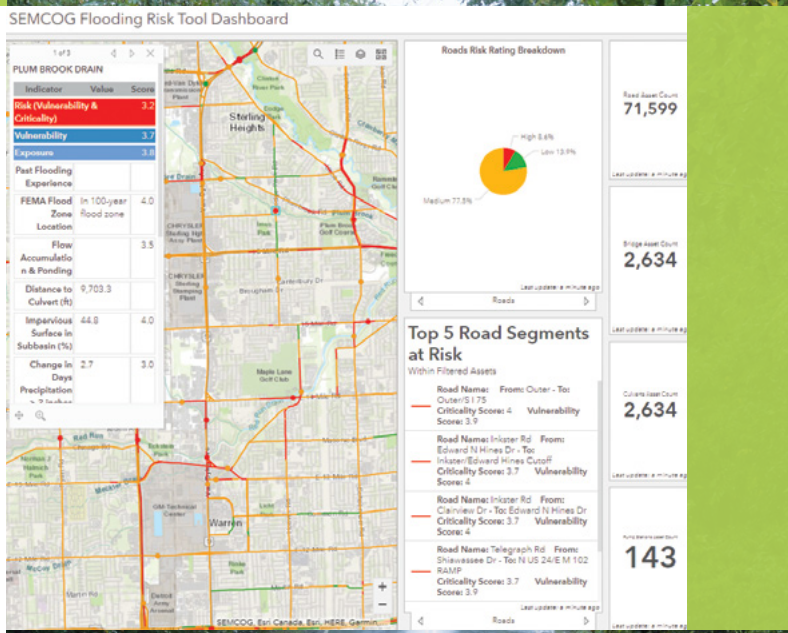
After a series of floods in Lower Michigan, the Southeast Michigan Council of Governments (SEMCOG) embarked on an initiative to help its region focus on resiliency measures. Partnering with the Michigan Department of Transportation, SEMCOG leveraged GIS technology from Esri.

The GIS-based Flooding Risk dashboard, which launched in 2020, helps SEMCOG identify roads, bridges, culverts, and pump stations at risk of flooding at locations across seven counties in the state's southeast region. By calculating a criticality and vulnerability score for each asset, SEMCOG was able to analyze the areas of greatest risk and highest impact from climate events.

Ultimately, the dashboard is helping Michigan cities and counties better prepare for potential damages to roads and other infrastructure due to serious flooding.

"As we continue to use this tool moving forward, we can tweak the indicators to better understand what areas and assets are in poor condition and at higher risk of flooding earlier on."

Rachael Barlock
Water Resources Engineer, Office of Environment and Infrastructure, SEMCOG



GIS Helps Build a Strong Foundation for Resilient Transportation

The ability to visualize and effectively communicate climate-related risk and impacts can help government leaders better understand climate change and develop responsible sustainability plans. The work starts with a clear picture of how an infrastructure project will impact the natural environment as well as the local community. GIS provides that picture and facilitates a deeper, much-needed understanding.

Explore a wide range of GIS solutions designed to optimize the planning, design, and delivery of resilient infrastructure projects.

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