DESIGNING RESILIENT TRANSPORTATION NETWORKS WITH GIS

Planning for Greater Resiliency with GIS

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The Increasing Frequency of Extreme Weather Events

One of the most visible consequences of a warming world is an increase in the intensity and frequency of extreme weather events. In fact, there has been a staggering rise in the number of extreme weather events over the past 20 years, driven largely by rising global temperatures and other climatic changes, according to a new report from the United Nations. Globally, according to the new data, the annual number of floods and other hydrological events have quadrupled since 1980, highlighting the urgency of adaptation to climate change. Climatological events—such as extreme temperatures, droughts, and forest fires—have more than doubled since 1980, while meteorological events, such as storms, have doubled in the same period.

In fact, 2020 set a new record in the US for the largest number of disasters with damages costing over $1 billion, according to the National Oceanic and Atmospheric Administration (NOAA).

Impact on Transportation

The cost of the 22 major events in 2020 totaled over $95 billion and resulted in 262 deaths. While 2020 contained the largest number of weather events costing over $1 billion, actually 2017 had the highest annual cost of disasters—just under $322 billion, largely driven by the costs of Hurricanes Harvey, Irma, and Maria.

The Houston Area Council of Governments estimated over $3 billion would be needed to repair damage from Hurricane Harvey and mitigate the risk of future flooding for the Houston area alone. The Vermont Transportation Agency estimated that Hurricane Irene in 2011 washed out more than 2,000 roadway segments, undermined more than 1,000 culverts, and damaged more than 300 bridges. The cost to rebuild everything was estimated at roughly $1 billion. And these costs are just for the infrastructure and do not include the impacts on the supply chain and businesses or the revenue lost due to the storms.

Regulatory Response

As the Federal Highway Administration (FHWA) stated, "Global climate change's potential impacts on infrastructure create some of the most significant and challenging issues facing transportation planners and asset managers today." While climate scientists had conducted extensive research on global warming previously, it was not until 1999 that the US Department of Transportation (DOT) established the Center for Climate Change and Environmental Forecasting to address issues of transportation-related emissions to the atmosphere. By 2007, the transportation community began to consider the impacts of climate change on transportation infrastructure more broadly, reflected in the release of the Transportation Research Board (TRB) Special Report 290 titled *Potential Impacts of Climate Change on U.S. Transportation*.

By 2011, the official policy of the US DOT was to "integrate considerations of climate change impacts and adaptation into the planning, operations, policies, and programs" of the department's various modal divisions, and to encourage state departments of transportation, metropolitan planning organizations (MPOs), tribal governments, and others, to develop cost-effective strategies to minimize climate and extreme-weather risks.

FHWA has been instrumental in funding a number of pilot studies as well as in the development of methodologies to help transportation agencies incorporate climate resiliency into their planning, design, and asset management programs.

The Role of GIS

There is wide consensus that geographic information system (GIS) technology provides the foundation for much of the analytical work in understanding these impacts. But just as importantly, GIS plays a key role in effectively communicating climate impacts to policy makers and the public. "Data visualization is so important," Dr. Katharine Hayhoe, of the Climate Science Center at Texas Tech University, recently stated. "In fact, I would go so far as to say that you could be doing the best science in the world, but if you do not visualize that science, it could end up being completely useless to anybody but you."

This point was further emphasized by Shannon Carroll, director of sustainability integration at AT&T. "One of the things we quickly realized was that if we're going to talk about climate change, probably the best thing we could do is give folks a visual representation of that," Carroll said. "You have to think about the end user. You could give them a bunch of datasets, but how useful is that, really?"

USER STORY

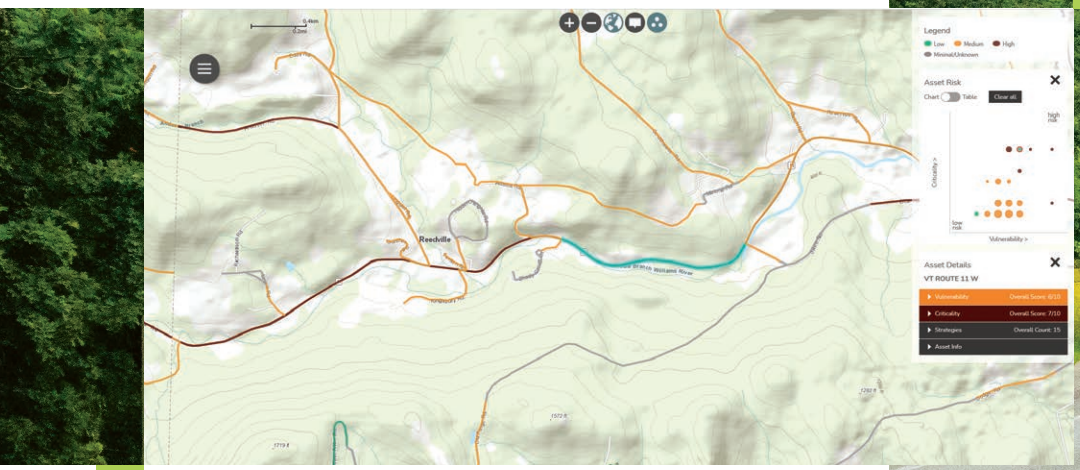
The Vermont Agency of Transportation

The Vermont Agency of Transportation (VTrans) has been developing a class-leading suite of GIS-based solutions that will help the state better prepare for the effects of weather-related events.

The Transportation Resilience Project Tool, a GIS-based application, is designed to give VTrans a measure of where the department is in terms of flood resilience.

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

To learn more, visit go.esri.com/Vermont-builds-resilience-2021.



"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

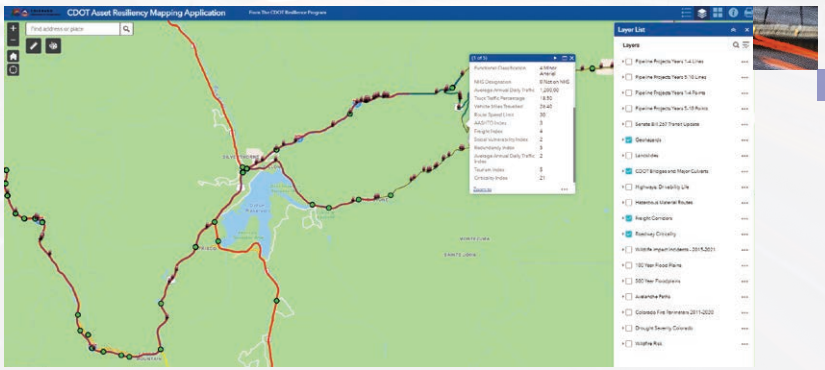
Colorado Department of Transportation

GIS tools are providing the Colorado Department of Transportation with a strong foundation on which to build its infrastructure resiliency efforts, ensuring that the department preserves and rebuilds its infrastructure in the most strategic and cost-effective way for the future.

In the aftermath of a series of devastating floods in 2013, the Colorado Department of Transportation (CDOT) undertook a study to evaluate the vulnerability of state highways as well as the cost to harden the state's infrastructure to withstand future climatic events.

The core of the study—relying on GIS—examined the risk of future climatic events together with the consequence of an asset failure; this includes both the cost to the state to repair a roadway and the cost to the public (and business) when the roadway was inoperable. The core questions were these: How much would it cost to buy down the risk, and would it be worth the investment? In this way, CDOT sought to develop a defensible methodology for understanding the return on investment of proactive infrastructure improvements.

To learn more, visit go.esri.com/cdot-building-back-better-2021.



USER STORY

Maryland State Highway Administration

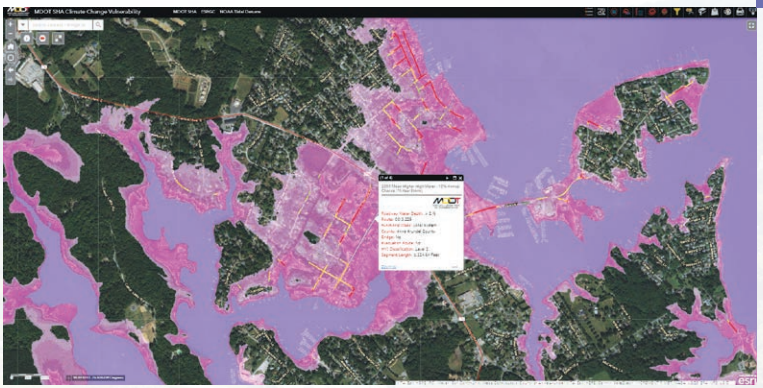
The Maryland State Highway Administration is leveraging GIS to show how, with just small changes to existing processes, infrastructure resilience can be improved and help the state better prepare for an uncertain future.

As far back as 2014, the Maryland Department of Transportation State Highway Administration (MDOT SHA) carried out a climate change vulnerability assessment. This identified the threats posed to specific roads and bridges in Anne Arundel and Somerset Counties. In 2018, with funding support from the FHWA, MDOT SHA carried out further work to refine its approach and expand coverage to include bridges statewide. MDOT SHA was also tasked with identifying and implementing specific opportunities to integrate the vulnerability assessment results and other climate-risk information into existing asset management, planning, and other processes.

This has resulted in the Climate Change Vulnerability Viewer (CCVV), a support tool for MDOT SHA senior managers, planners, and other transportation agencies throughout the state. The CCVV is an Esri ArcGIS Online web application that showcases geospatial data products related to climate change—in particular, sea level changes—and the potential effects on State of Maryland transportation infrastructure.

"The CCVV visualizes our analyses," says Toria Lassiter, assistant chief, Innovative Planning & Performance Division, MDOT SHA. "We have a hazard vulnerability index analysis for all state-owned pavements, and the FHWA's VAST [Vulnerability Assessment Scoring Tool] has been used on bridges statewide."

To learn more, visit go.esri.com//marylandDOT-resilient-infrastructure-2021.



USER STORY

Southeast Michigan Council of Government

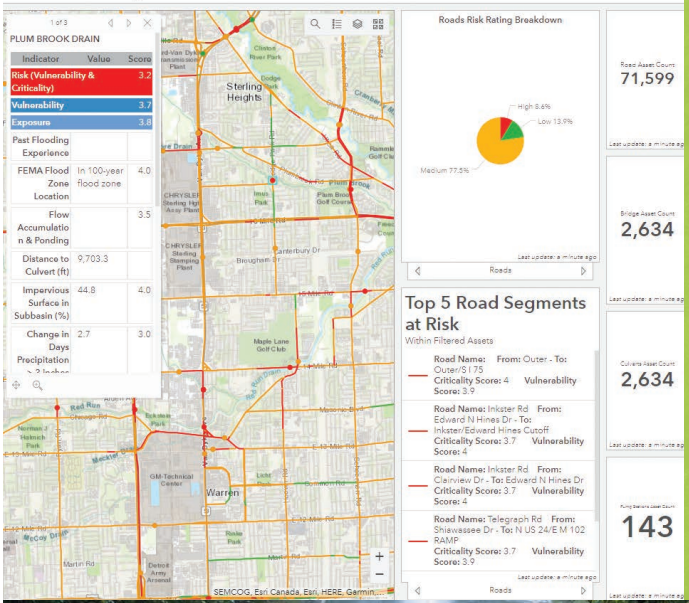
The Southeast Michigan Council of Government is assisting local jurisdictions to prepare for a changing (and wetter) climate.

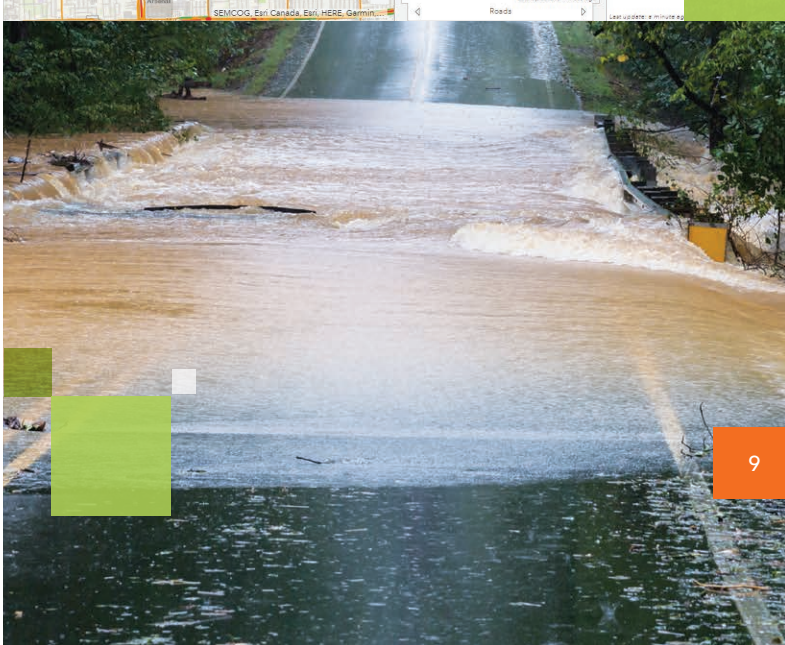
After devastating floods in lower Michigan, the Southeast Michigan Council of Governments (SEMCOG) embarked on an initiative to help the region better prepare for an uncertain future climate by focusing on resiliency measures. Partnering with the Michigan Department of Transportation, SEMCOG leveraged Esri's GIS technology to help identify the transportation infrastructure at highest risk. The Flooding Risk tool, which launched in 2020, helped SEMCOG identify areas at risk of flooding—including roads, bridges, culverts, and pump stations—for the seven counties in the southeast region of Michigan. By calculating a criticality score and a vulnerability score for each asset in a GIS-enabled dashboard, SEMCOG was able to analyze the areas of greatest risk and highest impact from climate events, to help cities and counties better prepare for the damage serious flooding could cause to their roads and other infrastructure.

"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

SEMCOG Flooding Risk Tool Dashboard





The Importance of GIS in Climate Resiliency

It is clear that we will be facing an ever-increasing number of extreme-weather events in the future. Whether damage is from fires in the West, increased flooding in the Midwest, or hurricanes and sea level rise in the East, transportation agencies must prepare for greater future uncertainty.

There is wide consensus that GIS provides the foundation for much of the modeling and analytical work in understanding the impacts of climate change. There are three major areas where GIS is critical to transportation-focused climate resiliency efforts. First, GIS helps collect and manage the inventory of existing transportation assets and infrastructure. This includes not only an agency's asset registry but also the detailed information about the current condition and expected life cycle of those assets. Ideally, this would include many of the small assets that may play a large role under changing precipitation patterns—culverts, drains, and storm sewers.

Secondly, GIS plays an important role in understanding the importance or criticality of each asset. The criticality of an asset is often determined by its social and economic importance and the availability of alternatives. GIS-based network and accessibility models can help assess the relative importance of various assets based on the number of people who would be impacted—and the hardships that would be imposed—by a failure of any of those assets. These calculations can often include qualitative assessments such as risk tolerance and what the community values.

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The Importance of GIS in Climate Resiliency

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Thirdly, GIS is central in providing the basic input data to climate change impact models, which help determine the vulnerability and the degree of exposure of various transportation assets. Many transportation agencies rely on local university climate scientists to downscale global or regional models of climate change, and to help determine more precise estimates of sea level rise, increased precipitation, incidence of extreme temperature events, and other impacts. These predicted impacts are often overlaid on precise digital elevation models captured from lidar, together with slope measurements (to calculate increased landslide potential) and the existing inventory of transportation infrastructure. The current and future condition of an asset helps determine the vulnerability of that asset to these climate impacts.

We have seen several outstanding examples of GIS-based climate change applications in the stories included here, and a number of Esri partners are building sophisticated models to help local governments and transportation agencies better model and understand the potential future impacts of various climate events (see, for example, http://casestudies.atkinsglobal.com/city-simulator/). What is most clear, looking forward, is that transportation professionals will need to incorporate climate change impacts into their planning, design, and asset management programs to help harden our transportation infrastructure for a changing future.

To get more resources, visit go.esri.com/esri-environmental-sustainability-highways-resources.

How GIS Tools Can Help Build a Strong Foundation for Your Resiliency Efforts

The ability to visualize and effectively communicate the risk of climate impacts can help government leaders not only better understand climate change but also develop responsible, sustainable plans for making their communities and the transportation infrastructure more resilient and better prepared to withstand unforeseen climate events. Understanding precedes action. And GIS helps accelerate understanding.

If you would like to see how to get started with a climate resiliency program, you can leverage our account team here at Esri to help you understand our wide range of GIS-based solutions.

Contact the Esri account team to discuss the best climate resiliency solution for you. Email transportation@esri.com or, to get more resources, visit go.esri.com/esri-environmental-sustainability-highways-resources and submit your contact information for additional information.

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