U.S House of Representatives Committee on Science, Space and Technology
Subcommittee on Investigations and Oversight

The Need for Resilience: Preparing America's Transportation Infrastructure for Climate Change

Testimony of

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Chairwoman Sherrill, Ranking Member Norman, and Members of the Subcommittee, thank you for inviting me to testify before the Subcommittee regarding transportation infrastructure resilience. My name is Greg Winfree and I am the Agency Director of the Texas A&M Transportation Institute (TTI). Established in 1950 and part of the Texas A&M University System, TTI is a state agency and the largest and most comprehensive higher education-affiliated transportation research center in the United States. TTI has conducted work in all 50 states and in 51 countries.

The Texas A&M University System is one of the largest systems of higher education in the nation, with a budget of $4.7 billion. Through a statewide network of 11 universities and seven state agencies, the Texas A&M System educates more than 153,000 students and makes more than 22 million additional educational contacts through service and outreach programs each year. System-wide, research and development expenditures exceeded $996 million in FY 2017 and helped drive the state's economy.

Prior to joining TTI in 2016, I served as the Assistant Secretary of the U.S. Department of Transportation's (USDOT) Office of the Assistant Secretary for Research and Technology. In this role I was responsible for a $450 million budget and oversaw more than 1,000 scientific, data analysis and administrative staff members who support USDOT's multi-modal transportation initiatives. The program offices under my purview included: the John A. Volpe National Transportation Systems Center; the Research, Development and Technology Coordination Office (which administers the University Transportation Centers Program); the Bureau of Transportation Statistics; the Positioning, Navigation, Timing and Spectrum Management Office; the Intelligent Transportation Systems Joint Program Office; and the Transportation Safety Institute.

Between 1980 and 2017, the U.S. was hit by 227 weather disasters that caused more than $1 billion in losses; 98 of those happened in Texas. More than one third (91) of those disasters struck between 2010 and 2017, with nearly half (43) striking Texas directly. Harvey, the last major storm to hit Texas in 2017, was the costliest in history, leaving behind $190 billion in damage.

Hurricane Harvey shut down the Port of Houston for eight days, forcing ships to wait offshore or divert to other U.S. ports and choking off the region's oil and gas supply. Railroad operations came to a halt, requiring extensive inspection and repairs on hundreds of miles of track. Persistent floods from 50 inches of rain weakened infrastructure foundations, collapsing entire roadway sections, compromising response times for emergency crews and stranding countless people.

We have historically responded to severe weather events in a reactive way, turning to established rehabilitation and repair practices to return service to pre-disaster levels. As our population and its demands on our infrastructure system grow, while funding to meet those demands lags behind, that strategy no longer makes sense. Instead, we should focus more on preparation and planning. That effort requires that we adopt new paradigms to make our infrastructure more resilient.

TTI and Transportation Resilience

With the multiple extreme weather events in recent years, TTI has been involved in several significant efforts and initiatives to mitigate these devastating occurrences.

A collaborative effort of Texas A&M and TTI, the 138,000 square-foot Center for Infrastructure Renewal (CIR) is a state-of-the-art research center that is a leading source for developing transformative infrastructure solutions. The center, which was funded by the Texas Legislature in 2015, provides the facilities and the multidisciplinary research environments for attracting significant cross-industry and government agency participation, as well as educating the 21st century workforce needed to build and operate this new infrastructure. The research conducted at the CIR improves the safety, security, longevity, efficiency, performance, resiliency, financial feasibility and sustainability of state and national infrastructure in nine critical infrastructure sectors, including transportation systems. The Center's 12 laboratories focus on the development of transformative infrastructure solutions, innovating new materials, technologies and processes to create solutions that last longer, have lower costs and can be built in less time.

In 2005, Hurricanes Katrina and Rita created many disturbing realities for Gulf Coast states, including the need for safely evacuating large numbers of coastal residents. Through TTI's University Transportation Center funding (the UTC Program will be discussed in greater detail later in this document), TTI researchers developed a Bluetooth travel-time monitoring system that was implemented in 2010 to monitor traffic flow on evacuation routes to enable transportation officials to make better decisions during evacuation scenarios. The system is installed on over 1,000 centerline miles of Texas highways, including hurricane evacuation routes.

In 2008, TTI participated in a taskforce formed by the Governor of Texas to mitigate hurricane evacuation issues that arose during Hurricane Rita. The evacuation resembled a parking lot, as residents along the coast converged on Houston escape routes, where half of all city residents were trying to flee at the same time. Running out of fuel and drinking water and enduring 100 degree temperatures, motorists were stalled for hours, with the typically 3-hour drive to San Antonio or Dallas taking 20+ hours. The taskforce helped develop new hurricane response strategies and contra-flow plans, organized and announced evacuation routes by zip code, and tailored education-outreach materials about hurricane preparedness.

In September 2017, TTI led a National Symposium on the Barriers and Opportunities for Infrastructure Renewal. Members of the Trump Administration and other high-level state and federal officials, as well as private-sector stakeholders, were in attendance, including Congressman Bill Shuster, then Chairman of the U.S. House Transportation and Infrastructure Committee. Transportation resilience was one of the critical needs identified in the discussion.

In 2017, TTI pavements and materials experts led accelerated construction workshops throughout the state to assist the Texas Department of Transportation (TxDOT) personnel in Hurricane Harvey rebuilding efforts. TTI researchers also analyzed pavements that were under as much as seven feet of water for as long as 14 days. These roads exhibited structural anomalies such as air bubbles and domes that were examined and rehabilitated as needed to ensure they were safe for travel.

In 2018, TTI developed a first-of-its-kind flood warning system that warns motorists in real time about locations where roadway flooding is likely to occur using data from 170 existing flood sensors maintained by the Harris County Flood Control District. Residents are able to view the warning areas by accessing the TranStar traffic management system website or through the mobile app. Houston media also relay the warnings on their radio and television broadcasts and information is communicated via social media.

A recent TTI research effort funded by the Federal Highway Administration (FHWA) and administered by TxDOT used the Houston region as a laboratory to explore and improve transportation resilience. Among the recommendations were the use of thicker pavement structures, adequate drainage and elevated roadways.

TTI is also using Mobile LiDAR (a surveying sensor that uses pulsed laser light) to collect vast amounts of geometric data at highway speeds for DOTs. This is used to assess performance of roadway ditches to ensure they are deep and steep enough to help mitigate roadway flooding. While it might sound trivial, roadsides have been in place as long as roadways and have received much less maintenance. The easiest way to improve pavement structure and performance is to keep water from entering the pavement substructure. This work helps roadway managers accomplish this.

USDOT, state DOTs and Transportation Resilience

One of the topics that I was asked to address in this testimony is the capabilities of the DOT research enterprise to enhance resilience in transportation. While I am not aware of any research programs at any of the USDOT modal agencies that are specifically dedicated to transportation resilience, I do know of efforts to address this issue in FHWA's established general research programs. Some examples are:

- **An FHWA-sponsored Sustainable Pavements Technical Working Group is developing a "Pavement Resilience Guidebook."** TTI is participating in this comprehensive effort. One of the objectives is to determine the impact of climate change on pavement systems and how resilience can be considered in their design, construction and maintenance. Preliminary information has been developed that:
    - identifies climate impacts (higher average temperature, more freeze thaw events, higher precipitation, etc.);
    - identifies pavement vulnerabilities (pavement distress, accelerated aging, etc.);
    - adapts materials (harder binders, use of polymers, etc.); and
    - adapts design (change design parameters such as concrete pavement joint design, etc.).
- **The FHWA TechBrief: Climate Change Adaptation for Pavements, August 2015 (FHWA-HIF-15-015):**
  https://www.fhwa.dot.gov/pavement/sustainability/hif15015.pdf
  This Tech Brief provides an overview of climate change and pavement-specific impacts, and addresses specific hard-surfaced pavement adaptation strategies that could be implemented now and in the future. The recommendations of the TechBrief include:
    - Increased monitoring of key pavement performance parameters, searching for trends to determine when design, materials, construction, or preservation efforts should be changed.
    - In pavement design, the use of predictive climate models in place of historical climate data, and the use of design strategies that allow flexibility in responding to future adaptation needs.
    - Investigating the use of more robust paving materials and designs that perform better in more extreme temperature, precipitation, and flooding scenarios.
    - Adjusting construction seasons and temperature limitations as needed while concurrently reviewing worker safety and comfort requirements.
    - Understanding that pavement systems can be severely damaged by extreme weather events, but that resilience efforts should focus more on embankment height/construction considerations and relocation of roads rather than fortifying pavement structures against these events. Fortification should be a last resort option where no feasible relocation exists.

- **FHWA Building Resilient Transportation Brochure, January 2019: https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/brt_brochure2019.pdf**
  - FHWA has partnered with state DOTs, Metropolitan Planning Organizations (MPOs) and others across the country to assess vulnerabilities and analyze opportunities to improve resilience. Projects vary in scope and emphasis and include: state-wide vulnerability assessments, analyses of engineering options for improving resilience of specific road segments, analysis of opportunities to protect assets by mimicking nature, incorporating climate risks into asset management, and deploying and monitoring adaptation solutions.
  - FHWA is developing resources, including a white paper, case studies, and a handbook, on options and real world examples for integrating resilience into the transportation planning process.

On the state DOT level, the 2015 Fixing America's Surface Transportation (FAST) Act (Pub. L. No. 114-94) requires state transportation agencies to address resiliency in their transportation planning processes and develop a Transportation Asset Management Plan (TAMP) that integrates climate change and extreme weather event resilience approaches into transportation asset management. How transportation agencies address these requirements is generally left up to the individual agencies.

Although a few transportation agencies (specifically the Arizona Department of Transportation, California Department of Transportation, and Colorado Department of Transportation) have begun incorporating climate change and extreme weather event information into plan development and asset management, most state departments of transportation (DOTs) currently emphasize planning for disaster response and recovery.

In a TxDOT research report developed by TTI and entitled, "Developing a Resilient Texas Transportation System," issued in November 2018, several strategies are recommended that would improve the resiliency of Texas's transportation system. Examples include:

- Build/rebuild assets to withstand anticipated environmental conditions (e.g., using moisture-resistant pavement layers such as pavement sublayers stabilized with asphalt and cement, and using materials to withstand higher numbers of very hot days).
- Adapt existing assets to mitigate the impacts of extreme weather events (e.g., improving drainage and reinforcing embankments).
- Adopt dynamic or seasonal restrictions for trucks during times of high heat to minimize or prevent pavement damage.
- Site new facilities outside floodplains or reconstruct at-risk highways using design standards/guidelines considering more conservative flood frequency events (i.e., 500-year flood occurrences as opposed to 100-year flood occurrences) or greater for lower-classification roadways. This would result in these roadways and bridges having higher

than usual profiles, more substantial drainage systems, and possibly longer bridge lengths to handle extreme flooding events.

- Increase system redundancy. For example, designate two or more roadways to provide emergency evacuation routes during extreme weather events. This may result in significant reconstruction of such designated facilities (e.g., adding emergency evacuation lanes or raising the profile of the roadways) to provide travelers with more than one option for evacuation during extreme weather events. Redundancy can also be provided by other modes of transportation, including transit modes.
- Implement more frequent maintenance schedules (e.g., cleaning culverts more frequently).

The American Association of State Highway and Transportation Officials (AASHTO) is actively involved in helping its members (which consist of state DOTs nationwide) to address transportation resiliency issues. Some of these initiatives include pooled-fund programs addressing the effects of extreme weather and strategies for mitigation and adaptation; case studies of lessons learned from state DOTs who have experienced extreme weather events; and a Center for Environmental Excellence that is currently conducting resiliency research. In fact, four of the most recent projects awarded in April 2019 address transportation resilience, in response to research priority statements developed by the AASHTO Committee on Transportation System Security and Resilience.

UTCs and Transportation Resilience

The University Transportation Centers (UTC) Program began in 1987 when it was included in the Surface Transportation and Uniform Relocation Assistance Act of 1987. The legislation authorized a competition for 10 regional centers nationwide. Since then, the UTC Program has been reauthorized in every transportation bill. Over time, the program expanded to include multiple tiers and even designated (or "earmarked") UTCs. However, since the passage of the Moving Ahead for Progress in the 21st Century Act (MAP-21) all UTCs in the program have been competitively awarded. The current structure of the program as authorized in the Fixing America's Surface Transportation Act (the FAST Act) consists of three tiers: five National UTCs, 10 Regional UTCs and 20 Tier 1 UTCs. Additionally, there is a competition currently underway funded through the appropriations process that will award two additional national UTCs in the areas of infrastructure and congestion reduction. These two new centers will be the first UTCs to be funded outside of the transportation reauthorization process.

Prior to the passage of MAP-21, individual UTCs developed their research programs according to themes they proposed in the competition process, or according to specific topics mandated when the UTC was designated in the bill. For competitively awarded UTCs, proposals were required to discuss how their proposed theme and programs would support USDOT's priorities.

Since the UTC program has been competitively awarded following the passage of the last two reauthorization bills, the tier structure seems to have stabilized, as has the proposal process. In both cases, UTCs were required to select one of USDOT's priority focus areas on which to concentrate, as opposed to self-determining a theme and demonstrating how it fit USDOT's priorities. MAP-21 directed the USDOT Secretary to determine the focus areas for the competition, and the FAST Act named the focus areas specifically. In both cases, transportation resilience, while not specifically called out as a focus area, was included as an item in the scope of one or more focus areas.

In the MAP-21 competition, resilience could be included within the "State of Good Repair" and/or "Environmental Sustainability" focus areas, and in the FAST Act Competition resilience was specifically called out as a topic area within the "Preserving the Existing Transportation System" focus area. It could also be included in the focus areas of "Preserving the Environment" and "Improving the Durability and Extending the Life of Transportation Infrastructure."

Because the UTCs throughout the history of the program have either self-determined their themes, responded to congressionally directed themes (in the case of designated UTCs), or selected one of the USDOT-determined focus areas, UTCs have always had the capability to choose to conduct transportation resilience research. And some have – a review of current UTCs shows that seven of the 35 selected in the most recent competition have an emphasis on resiliency as part of their programs. Those UTCs, their lead institutions and links to their websites are as follows:

- The Transportation Infrastructure Durability Center (TIDC)., University of Maine, **https://www.tidc-utc.org/about-us/#rt1**
- Center for Advanced Infrastructure and Transportation (CAIT), Rutgers **https://cait.rutgers.edu/about/**
- The Center for Integrated Asset Management for Multi-Modal Transportation Infrastructure Systems (CIAMTIS), Pennsylvania State University, **https://r3utc.psu.edu/research/thrust-areas/**
- The Transportation Consortium of South Central States (Tran-SET), Louisiana State University, **http://transet.lsu.edu/about-us/**
- Inspecting and Preserving Infrastructure through Robotic Exploration (INSPIRE), Missouri University of Science and Technology, **https://inspire-utc.mst.edu/**
- C2SMART: Connected Cities with Smart transportation, New York University, **http://c2smart.engineering.nyu.edu/research-areas/**
- Center for Safety Equity in Transportation (CSET), University of Alaska, Fairbanks, **http://cset.uaf.edu/3779/#t3748-target**

In the current competition for the two new National UTCs, it would be reasonable to assume that the national center focusing on infrastructure would include a resilience component, as the comprehensive approach expected of a national center should address that topic. This approach should include not just recovery from extreme events but the "hardening" of infrastructure assets to better withstand them. Policy and planning should be considered as well as traditional civil engineering transportation infrastructure research. In fact, TTI's current proposal for the national infrastructure center includes all of these elements, with resilience as one of its fundamental research pillars.

Research recommendations

There are many opportunities for research topics in the field of transportation resiliency. Resilience requires a multidisciplinary approach that should involve not only pavement and structural engineers and transportation planners, but climatologists, hydrologists, community champions and a host of other disciplines that don't normally work together. Specific research topic recommendations include:

- Multiple data sets of varying levels of complexity – including roadway flood data, GPS and LiDAR data, roadway elevation data, climate data, FEMA data and storm surge data – just to name a few, need to be analyzed and put into a useful, more accessible form, such as a data clearinghouse. DOTs or MPOs don't have the resources or funding to manage all of the data sets themselves.
- We currently don't have good tools to anticipate the impact of an extreme weather event. More robust software systems are needed to calibrate existing models to more accurately calculate anticipated flooding events on infrastructure, for example, and to evaluate the resulting damage.
- Current efforts are focused on the flooding impacts on infrastructure damage to roadways, while the traffic operations impacts are not considered. The operational impacts of devastating weather events are even more costly, such as road closures and their effects on traffic congestion on lower arterial streets as well as the resulting economic effects.
- There have been a variety of resiliency studies and best practices developed by individual DOTs in areas such as vulnerability assessments, storm surge modeling, asset management, and risk management. Efforts should be made to identify these state best practices and replicate them throughout the country.
- Robust models to evaluate the impact on pavement service life given a flooding event need to be developed and monitored to search for trends that develop over periods of time to better understand the link between climate metrics and pavement performance. Research could determine the best ways to address any necessary changes in materials, design, construction and maintenance.
- Culvert management systems (similar to existing pavement management systems) need to be developed.
- Designers and engineers rely on manuals, AASHTO and Federal guidance, and other established procedures. Resilient design practices need to be developed and incorporated into these resources.

A recent National Cooperative Highway Research Program publication **Resilience in Transportation Planning, Engineering, Management, Policy, and Administration: A Synthesis of Highway Practice,** published in 2018, conducted a comprehensive literature review, a survey of state DOTs and case examples to document resilience efforts. The authors found that research is needed in the following areas:

- Performance measures need to be developed for resilience. Research can determine measures for resilience and the benefits expected from resilience investments. How do agencies measure success in this area?
- The relationship between risk assessment, management and resilience is not well understood. How should agencies balance the need for resilience with varying levels of risk?
- How does resilience correlate with other priorities, such as safety, infrastructure condition and operations? These have clear performance metrics and established monetary and other benefits linked to them. No such correlations exist for resilience, and this makes it difficult for agencies to justify spending limited resources on resilience benefits as opposed to others.

Any extreme weather event poses severe risks to our transportation system, but also to our economy and our very existence. Increasingly frequent and severe storms leave behind devastation with massive financial costs associated with loss of service, repair and recovery. Other costs, like those that result from permanent rips in the fabric of communities, can never be recovered.

We can't prevent major weather disasters. But by investing resources into better planning and engineering, and focusing on resilience long before disaster strikes, we will be far better able to weather whatever comes our way.

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