Agency Resilience

Critical Transportation Infrastructure Protection

State
- Arizona State Emergency Response and Recovery Plan (SERRP)
- Planning Branch – AZ Department of Emergency and Military Affairs (ADOT)

ADOT
- Emergency Preparedness Management
  https://azdot.gov/business/highway-maintenance/emergency-preparedness-management
- Business Continuity - pandemic - Director’s Office revamp
- Roadway - Incident Response Unit
- Physical, chemical, biological – dedicated Emergency Manager
- Road Weather AZ 511 app / ADOT Alerts app
- Cyber - IT Security Risk Management & Compliance team
- Transportation Infrastructure - Weather & Natural Hazard

Business Case and Communications Tools
FHWA 5520 - anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions

Program Definition - The management of assets (bridges, culverts, pavement, and roadside vegetation/stabilization) in relation to the extreme weather-climate risks of; intense precipitation, system flooding, wildfires, wildfire-induced floods, drought-related dust storms, rockfall incidents, slope failures, and measurable climate trends (especially as it relates to precipitation and direct effects of increased surface temperatures); by regions or specific segments, emphasized as critical to contribute to the safety of the traveling public, improve weather and natural hazard risk management, and improve the long term life cycle planning of transportation infrastructure.
# Internal Working Group

<table>
<thead>
<tr>
<th>ADOT Pilot Project Team</th>
<th>Business Case and Communications Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSMO System Risk</td>
<td>Brent Cain, Transportation Systems Management and Operations Division, Director</td>
</tr>
<tr>
<td></td>
<td>Brent Connor, Geotechnical Design Section Leader and Planning Engineer</td>
</tr>
<tr>
<td>Geotechnical Design</td>
<td>David Benton, Bridge Group Manager</td>
</tr>
<tr>
<td>Bridge Asset Class Risk</td>
<td>Derek Arson, ADOT Traffic Management Group Manager</td>
</tr>
<tr>
<td>Traffic Management</td>
<td>Don Angell, ADOT Emergency Manager</td>
</tr>
<tr>
<td>Emergency Management</td>
<td>Jesse Gutierrez, Deputy State Engineer for Statewide Operations</td>
</tr>
<tr>
<td>Statewide Operations - District Risk</td>
<td>J.J. Liu, Geotechnical Group Manager</td>
</tr>
<tr>
<td>Geotechnical/Geomorphology Risk</td>
<td>Kevin Robertson, Surface Treatment Engineer &amp; Pavement Condition &amp; Evaluation Manager</td>
</tr>
<tr>
<td>Materials and Pavement Risk</td>
<td>Nye McCarty, Flagstaff Regional Materials Engineer</td>
</tr>
<tr>
<td>Roadside Vegetation Risk</td>
<td>Kristin Gade, Roadside Resources Specialist – 2015 EW &amp; Climate Vulnerability Co-Team Lead</td>
</tr>
<tr>
<td>Bridge Hydraulics</td>
<td>Nicholas Fiala, Transportation Engineering Specialist</td>
</tr>
<tr>
<td>Architecture/Landscaping</td>
<td>LeRoy Brady, Chief Landscape Architect</td>
</tr>
<tr>
<td>Materials</td>
<td>Paul Burch, Assistant State Materials Engineer</td>
</tr>
<tr>
<td>Construction Program Delivery Risk</td>
<td>Steve Boschen, Infrastructure Delivery and Operations, Director</td>
</tr>
</tbody>
</table>
Eligible Risks Inventory

- Intense Precipitation
- System Flooding
- Wildfires
- Wildfire-Induced Floods
- Drought-Related Dust Storms
- Rockfall Incidents
- Slope Failures
- Increased Surface Temperatures
Impacts Narrative

There is currently a multitude of natural hazard and weather related stressors present in Arizona, but they can largely be separated into two categories: extreme heat and extreme precipitation.

The negative impacts of extreme heat include: pavement deformation, shorter pavement construction windows, heat-related worker safety issues, and public safety during lengthy delays. Extreme heat can also lead to an increase in dust storms, due to a decrease in vegetation coverage on soil, as well as contributing to an increased number of wildfires. Areas affected by wildfires may see increases of runoff to levels that the current drainage system cannot handle. On the other hand, extreme heat has the benefit of reducing the amount of freeze-thaw impacts to pavements and a reduced amount of snow removal.
Impacts Narrative - continued

Precipitation levels are expected to remain consistent for the near future. However, if precipitation levels rise, the existing drainage and pump stations in the state may become overwhelmed. Another impact of oversaturated soils includes the increased likelihood of rock falls, subsidence, and landslides. Lower number of precipitation events but a higher intensity is a concern. This scenario can heavily impact rural and urban areas alike for safety and economic development.
A critical part of ADOT’s TAMP financial plan is the agency’s investment strategy. A major contributor to that investment strategy is the identification of ways to maintain the asset categories by using risk-based lifecycle planning strategies. One of the fundamental ways in which an Agency can begin to sort and prioritize risk is through the use of the TAMP required risk register. Inherently, there are regulations, constraints, and existing commitments on available funding sources. Once ADOT considers all the asset needs against available resources, making room for extreme weather and measurable long-term climate (EX W & C) trend mitigation strategies is difficult.
Even in light of those difficulties, ADOT prioritized conducting EX W & Climate vulnerability assessments, developing a Resilience Program, conducting extreme weather event modeling and engineering analysis, working with climate models, and begin resilience building.

In concert with using lifecycle planning to support asset management decision making and incorporating risk management into TAMP reporting, an Agency needs a formal financial process to consider extreme weather and climate in financial decision making.
### Resilience Financial Decision Making Steps (3)

<table>
<thead>
<tr>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of - Agency/SEO /5-yr Construction Program/Divisions/Districts</td>
</tr>
<tr>
<td>Screen through - Resilience Program</td>
</tr>
<tr>
<td>Looking for - All historical actions and known locations to catalogue (GIS)</td>
</tr>
<tr>
<td>Identified by - Design/Construction/Operations/Maintenance</td>
</tr>
<tr>
<td>Financially justified with - Resilience Investment Economic Analysis (RinVEA)</td>
</tr>
<tr>
<td>Programmed using - Financial tool box</td>
</tr>
<tr>
<td>Support garnered - Decision maker consensus</td>
</tr>
</tbody>
</table>
### Resilience Financial Decision Making Steps (4)

1. Funding confirmed - Project Resource Board, Project Management, Project Finance
2. Resilience Scope of Work developed blending Risk/Science/Technology/Engineering
3. Funded projects commences
4. System resilience advances
5. Lessons learned gained
6. Feedback loop to TAM Program Manager and Resilience Program Manager
7. Feedback loop to methodology - Risk/Science/Technology/Engineering

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**Investment Decision Tools**
A need for a process to assess cost viability and develop a tool to integrate extreme weather and climate justification into asset management and financial decision making. It amounts to a:

- CBA (total systems / sustainability centric)
- Project Justification
- Resilience Investment
The main objectives of the RinVEA is to conduct basic economic analysis (CBA Analysis) that included the following basic parameters:

- Protect the new $5.2M roadway investment
- Address severe erosional and drainage issues that has led to a 25%-100% degradation at sixty-one (61) of the eighty-six (86) CMP drainage structures
- Address drainage excavation, barrow and slope stabilization issues at those structures and severely compromised stormwater management capabilities along this segment of SR 191
- Comply with and proactively address expected regulatory actions on stormwater management, FHWA Order 5520, Presidential Executive Order on Federal Flood Risk Management, and MAP21 asset preservation performance requirements
- Upgrade ADOT’s application of risk-based assessment modeling at the asset class, project development, and localized hydrological event level
- Further ensure use of SR 191 in the remote far northwest of Arizona and a main Apache County connector between SR 264 and US 160 in the advent of an extreme weather event
## Resilience Building Tracking

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Rt.</th>
<th>System Location</th>
<th>Resilience Work Completed</th>
<th>Project Cost</th>
<th>Resilience &amp; Financial Decision-Making Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resilience Building Project #1</td>
<td>SR 191</td>
<td>Chinle, AZ</td>
<td>31 Drainage Structures Rehab</td>
<td>$6m</td>
<td>Roadway and embankment now protected to the 50-year storm event</td>
</tr>
<tr>
<td>Resilience Building Project #2</td>
<td>SR 160</td>
<td>Laguna Creek Bridge</td>
<td>Gabion basket bank protection</td>
<td>$1m</td>
<td>Bridge now protected to the 500-yr storm event - Tribal Partner - key corridor</td>
</tr>
<tr>
<td>Resilience Building Project #3</td>
<td>SR 95</td>
<td>Fortuna Wash Bridge</td>
<td>Bridge replace</td>
<td>$9.3m</td>
<td>Bridge now protected against Fortuna Wash floodwaters flowing over the road, secured the $500m in area economic impact, reduced/eliminated considerable detour</td>
</tr>
<tr>
<td>Resilience Building Project #4</td>
<td>I-8</td>
<td>Foothills Blvd to Dome Valley</td>
<td>Roadway deterioration and clogged and corroded drainage structures due to storm events and aging repaired</td>
<td>$14m</td>
<td>Vulnerable NHS asset improved - Access for City of Yuma, Yuma Port of Entry, State of California, Yuma International Airport, USMC Air Station Yuma, Barry M. Goldwater Air Force Base, Port of San Luis SR 95, MP 01 Mexico Border</td>
</tr>
<tr>
<td>Resilience Building Project #5</td>
<td>I-17</td>
<td>New River Bridges Structures - N and S</td>
<td>Concrete floor approximately 3 feet below the channel bed underneath the bridges. Cutoff walls at both upstream (approximately 4 feet deep) and downstream (approximately 6 feet deep)</td>
<td>$2m</td>
<td>Vulnerable NHS asset improved Maricopa County and its 4.2m residents</td>
</tr>
</tbody>
</table>

|                               |        |                          |                                              |              |                                               |
|                               |        |                          |                                              |              |                                               |
| Resilience Building Project #6,7,8 underway |        |                          |                                              |              |                                               |
| Resilience #9,10 identified entering design |        |                          |                                              |              |                                               |
| Resilience Operating Project #1 (TSMO) | Phx    |                          | Pump Station Optimization Tool for operators and capital investment | $200K        | Developing predictive model of probability of pumping station failure. Variable examples: season, condition, manufacturing date, date of last repair, size, sufficiency of capacity, precipitation magnitude, and manufacturer type. |
Asset Management Risk Register - 25
Weather/Natural Hazard Risks – 6 (links to 6 other)
Agency – Extreme Weather Trends
Asset – Flooding, Scour, Pump Stations
Asset – Landslide/Slope Failure
Asset – Rockfall
Asset – Culvert Failure
Activity – Redundant Routes

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>Affect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency Risk</td>
<td>Risk to the agency that affects the implementation of the strategic goals of the asset management plan. Examples include changes in leadership, legislative actions, unfunded mandates and the ability to convey the importance of asset management to decision-makers and the public.</td>
</tr>
<tr>
<td>Financial Risk</td>
<td>Affect the availability of adequate funding or accurate prediction of future funding needed to implement the TAMM. Examples include inflation, unexpected funding shortfalls, solvency of the Highway Trust Fund, financial markets, interest rate increases and inaccurate predictions in financial plans.</td>
</tr>
<tr>
<td>Program Risk</td>
<td>Affect the ability to deliver a program of projects in a timely manner and meet performance targets. Risks may include the inability to effectively manage data, the loss of institutional knowledge via attrition, competing spending priorities, inaccurate cost-estimates and construction/materials price volatility.</td>
</tr>
<tr>
<td>Asset Risk</td>
<td>Affect individual assets, such as structural deterioration, extreme weather and obsolescence. Assets risks include flooding, landslides, hazardous materials spills, collisions with bridge elements and assets that do not meet current design standards.</td>
</tr>
<tr>
<td>Project Risk</td>
<td>Associated with projects to restore or replace individual assets. An example of a project risk is the impacts associated with lengthy construction detours in areas where redundant, alternative routes don’t exist. Project delivery risks include delays caused by environmental, utilities, right-of-way, geotechnical, procurement, scope creep and inter-governmental agreements.</td>
</tr>
<tr>
<td>Activity Risk</td>
<td>Associated activities like routine maintenance, including slow or inadequate response to damaged assets (e.g., pothole or guard rail repair) or extreme weather events (e.g., clearing blocked drainage structures, repairing scour weakened bridge foundations or risks to workers such as heat, fires, etc.).</td>
</tr>
</tbody>
</table>
## Risk Rating Scale

<table>
<thead>
<tr>
<th>Likelihood(L)</th>
<th>Level</th>
<th>Descriptor</th>
<th>Negligible</th>
<th>Minor</th>
<th>Major</th>
<th>Critical</th>
<th>Catastrophic</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Low</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Medium Low</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Medium</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Medium High</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>High</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
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<tr>
<td>Agency Action</td>
<td>Description</td>
<td></td>
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<tr>
<td><strong>Prevention</strong></td>
<td>Vulnerability and risk assessments; Hardening of structures and materials; Detection and monitoring; Asset management techniques; Resiliency Plans</td>
<td></td>
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<tr>
<td><strong>Response</strong></td>
<td>Training; Emergency response guidelines; Practice drills; Alternative service strategies</td>
<td></td>
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<tr>
<td><strong>Recovery</strong></td>
<td>Alternative routing; Fast contracting and project initiation; Staff allocation plans</td>
<td></td>
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<tr>
<td><strong>Investigation (Root-cause)</strong></td>
<td>Engineering studies; Probabilistic analysis; Service planning reviews</td>
<td></td>
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<tr>
<td><strong>Learning</strong></td>
<td>After action reports; Research; Performance assessments</td>
<td></td>
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</tbody>
</table>

**Asset Management Tools**
A Climate Engineering Assessment for Transportation Assets (CEA-TA)
Incorporating Probabilistic Analysis into Extreme Weather and Climate Change Design Engineering

Steven Olmsted, Arizona Department of Transportation; Alan O'Connor, Trinity College Dublin; Constantine Samaras, Carnegie Mellon University; Beatriz Martinez-Pastor, Trinity College Dublin; Lauren Cook, Carnegie Mellon University

Abstract
Transportation infrastructure is a complex system of assets required to deliver a myriad of services and functions. As fiscal constraint for the development and rehabilitation of such structures remains, and publics expect infrastructure to be cost effective, robust, and resilient, approaches to long term planning and project development, engineering design, and life cycle assessment are paramount. The management of these infrastructure systems has now evolved from a decentralized, project-based focus, to one that emphasizes enterprise-wide endeavors—administration, technology adoption, planning, design, construction, operations, and maintenance. In addition, the expansion of risk analysis for extreme weather management and climate change adaptation has complicated the long term delivery of these complex transportation systems. At the 2012 Transportation Research Board (TRB) Annual Meeting, Session 137, Maintaining Climate Change and Extreme Weather Resilience into the Future, the Arizona Department of Transportation (ADOT) introduced the challenge ahead for public entities to coordinate a host of known and unknown extreme weather and climate change issues.

CEA-TA – A Structured Sequence

Identity Key W & C project and program candidates – Vulnerability Assessment

Develop economic analysis process – Justification

Design probabilistic modeling approach to produce an array of results – Quality Control

Define limits of simulation runs that incorporates latest science/engineering – Policy

Resilience Program
Economic Analysis Pilot
US 155 M 402 to China
FEDERAL AID NO. 3TP-[9-1E21](5) Apache County

Optimize operation and maintenance of an increasingly aging stock, which is subjected to evolving needs (e.g., both flood and climate issues leading to predictable asset failure)

ADOT has seen systematically capturing data sets for extreme weather and climate change use through an extensive geographic information system (GIS) effort that will subsequently support ADOT’s transportation asset management planning (TAMP). ADOT’s studies showed concern with the climate and extreme weather vulnerability of bridges, culverts, pavement, and road vegetation. Legislation – Focus in MAP-21 on performance-based management and risk-based asset management programs, inclusion of “resilience” in FAST Act.

Civil infrastructure systems are among the largest local, state and Federal investments, and these infrastructure systems are critical to U.S. economic, environmental, and social outcomes. Identifying vulnerabilities in infrastructure has resulted in the poor condition of much of U.S. infrastructure, with an estimated $1.4 trillion of investment needed by 2030. New tools for benefit-cost analysis, return on investment studies, and major rehabilitation timeline analysis are needed that incorporate probabilistic approaches, and mimicking what benefits for DOT under changing climate. The results of CEA-TA is that the transportation system is improved for the future.
USGS Partnership - Reach Monitoring in Dynamic Channels

Understanding bank erosion and impacts to infrastructure

Laguna Creek Pilot Project Reach Monitoring:

- Rapid deployment stream gage
- Surface velocity radar sensor
- Particle tracking video cameras
- Indirect discharge measurements
- Repeat LiDAR scans of bridge structure and surrounding channel
- sUAS (drone) survey

Agency Dennehotso, AZ project photos
After experiencing significant impacts to mobility of the system due to geohazards in the analysis period of 2010 to 2015, ADOT has proactively managed many geohazards through preventative projects thought the Slope Management Subprogram. Geohazards such as landslides, rockfall, debris flow, sink holes, and heaving roadway subgrade have impacts to the maintenance, mobility and risk allocation in an asset management model.
The 2021 effort, already underway, will assess measurable climate trends against the impacts to ADOT’s pavement asset class, surface treatments and materials, difficult to manage known freeze-thaw zones, and impacts to roadside vegetation/stabilization (biotic and seeding). All these have been framed to remain in the context of future asset management reporting for infrastructure health opportunities.

More specific to climate adaptation efforts
Roadside Vegetation / Stabilization

Recovery Area Diagrams

Rural Interstate

Rural Highway

Guardrail Treatment

Urban Freeway with Frontage Roads

Sight Line Diagrams

Frontage Road

Recovery Area Information

Width Criteria

Notes

- Maximum Roadside Recovery Area (RAR) using single row vegetation management (SRVM) and weed control.
- Vary RAR area of vegetation that will reach a cumulative root diameter of 0.1" before the next scheduled maintenance.

Engineering Tools
Resilience GIS Database

Data
- ADOT’s USGS Data
- Drought & Wildfire
- Layers from ADOT’s USGS Flood map
- Dust storm data (I-10 pilot)
- 5-yr program priority project information
- Bridges (including scour program)
- Culvert
- ADOT system base layers
- Geohazard locations
- Soils
- Live Feeds

Data
- ADOT/USGS Project Work
- Resilience (Extreme Weather and Climate) Building
- Resilience Investment Economic Analysis assessment locations
- Climate Engineering Assessment for Transportation Asset (CEA-TA) locations
- Every Day Counts CHANGE 2-D modeling projects
- 2050 and 2100 climate data downscaling mapping
- Statewide drainage dashboard
- Weather event dashboards

Engineering Tools
Post Construction Monitoring Process

USGS Drone Data Capture – On-going Monitoring - Built Condition Wash Meander / Ox-bow

Engineering Tools
Post Construction Monitoring Process

2-D Erosion Change Detection Mapping

Engineering Tools
Develop Geographic Specific Climate Models

- Large, geographically diverse study area (over 30,000 square miles)
- High spatial resolution climate data desired
- Stressors included both average and extreme temperature and precipitation
- Helpful existing tools (e.g., FHWA CMIP Processor), but customization required
- Modest resources for collection and processing
## Climate Data Selection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projections and Historical Data Source</strong></td>
<td>Downscaled CMIP5 Bias Corrected Constructed Analogs (BCCA) daily projections with accompanying historical data</td>
</tr>
<tr>
<td><strong>Emissions Pathway</strong></td>
<td>Representative Concentration Pathway 8.5</td>
</tr>
<tr>
<td><strong>Downscaled General Circulation Models (GCM)</strong></td>
<td>NorESM1-M, HadGEM2-ES, CSIRO-MK3.6, CanESM2, MPI-ESM-LR, MPI-ESM-P, GFDL-ESM2M</td>
</tr>
<tr>
<td><strong>Horizontal Spatial Resolution</strong></td>
<td>1/8° (~7.5 mile or ~12km)</td>
</tr>
<tr>
<td><strong>Temporal Resolution</strong></td>
<td>Daily for 1950-2000 (backcastings from models in addition to historical data), 2025-2055, and 2065-2095</td>
</tr>
<tr>
<td><strong>Model Outputs</strong></td>
<td>Temperature (daily maximum and minimum) and precipitation (daily total)</td>
</tr>
<tr>
<td>Climate Output Metrics</td>
<td></td>
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<tr>
<td>----------------------------------------</td>
<td></td>
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<tr>
<td>Maximum 1-Day Precipitation Event (by time period)</td>
<td></td>
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<tr>
<td>100-/200-Year Maximum Precipitation Event using Generalized Extreme Value distribution</td>
<td></td>
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<tr>
<td>Minimum Annual Precipitation</td>
<td></td>
</tr>
<tr>
<td>Average Annual Precipitation</td>
<td></td>
</tr>
<tr>
<td>Average Number of Days Per Year in which Precipitation Exceeds Baseline Period’s 99th-Percentile Precipitation Event</td>
<td></td>
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<tr>
<td>Average May-June-July-August Precipitation</td>
<td></td>
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<tr>
<td>Average Daily Maximum Temperature</td>
<td></td>
</tr>
<tr>
<td>Average Number of Days Per Year in which Temperature equals or exceeds 100 degrees</td>
<td></td>
</tr>
<tr>
<td>Average Number of Days Per Year in which Temperature equals or exceeds 110 degrees</td>
<td></td>
</tr>
<tr>
<td>Average Number of Days Per Year in which Temperature falls below or is equal to 32 degrees</td>
<td></td>
</tr>
<tr>
<td>Average Daily Minimum Temperature</td>
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</tbody>
</table>
Highway Stormwater Pumps – Reliability Tool

Increasing Accuracy
Pumping stations are critical hardware that must operate during the most extreme events to ensure roadway reliability. Yet little is known about the factors that contribute to pumping unit and station failure.

Developed a dynamic reliability analysis decision-support tool which considers individual pump component vulnerability, overall pump station vulnerability, and the risk of pump station failure (given vulnerability and traffic flow) to provide information to aid operators considering hardware and environmental conditions in prioritizing maintenance and rehabilitation.
Highway Stormwater Pumps – Reliability Tool

Prioritization Map Page: Ranking data is displayed visually on a geo-spatial map of pump stations in the Phoenix Metro area.
Statistical Model Description (E. Bondank)

Used description of which pump station component failed in the telemetry data, created a statistical model for each of the components to estimate their vulnerabilities.

Used a form of non-linear statistical regression called a logistic model which can predict the probability of binary outcomes (such as pump failed or not failed). Transformed the data into panel data to assess for each rain event day, whether each pump station had a failed component.

The logistic regression equation is shown in the equation. The predicted values are calculated using the cumulative probability distribution function of the standard logistic.

\[
P(\text{Failure} = 1) = \frac{1}{1 + e^{-z}}
\]

2020 Arizona State University Metis Center Sustainable Infrastructure Award
What Resilience Tools and Analysis are next - GIS

Resilience GIS Database Event Dashboards

Bush Fire impacted SR 87 & 188 195,000 Acres

Dashboard layers:
• Debris Flow
• Bush Burn Severity
• Bush Fire Watersheds
• Rain Gages
• Pressure Transducers
• Roads with Mile Posts
• Main Highways
• Scour Critical Bridges
• NOAA Radar live feed
• Watches, Warnings, Advisories live feed
• NDFD Precipitation live feed
• Active Hurricanes live feed
Climate Adaptation

- Arizona was laid out in 12 km x 12 km grid (total of 2680 grid elements)
- Grids are consistent with format of downscaled climate data from
  https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html
- 19 climate models
- Considered two time periods
  - 2025-2055
  - 2065-2095
- 2021 Pavement binder and freeze thaw project
- Transportation will need 2125 climate data
Design Engineering Tool

Developing bridge asset class probabilistic engineering approach that assesses the stressors inherent to the built structure itself – live loading, extreme weather loading, climate induced loading using watershed, runoff data, topo, hydraulics, bridge design, and computation of the probability of failure at the considered limit state(s).

A. O’Connor
Four Partnerships – Trinity College Dublin, Carnegie Mellon University, North Carolina State, and Texas Transportation Institute CAARTEH consortium:

- Finalize Resilience Performance Measures, Indicators, Metrics
- Further Economic Analysis Processes
- Further Life Cycle models to monitor resilience investment
- Account for the differences in the deterioration model with new climate-informed asset management models
- Customized intensity-duration-frequency (IDF) curves
While different methods to quantify the economic impact of weather & natural hazard for infrastructure exist, advancing resilience tools for:

- Cost benefit analysis
- Return on investment
- Risk thresholds identification (fortify – rebuild – or absorb event risk)
- Identifying specific durability limit states
- Major rehabilitation timeline analyses
- Resilience bond adoption - Improved public agency awareness

are needed that incorporate probabilistic approaches, and minimize regret by DOTs under changing extremes and climates.