Arizona DOT Infrastructure Resilience
Risk & Resilience in TAMPs
Asset Management, Extreme Weather, and Climate Trends
Blending Risk/Science/Technology/Engineering

Steven Olmsted
Arizona DOT
Environmental Planning
TRB 12th National Conference on Transportation Asset Management
July 17, 2018
Formalize an ADOT Resilience Program - October 2015

Facilitate ADOT’s engineering/technical capability to manage risk and long term asset management strategies - the assets (bridges, culverts, pavement, and roadside vegetation/stabilization) in relation to the extreme weather-climate risk 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.

AASHTO TERI Database idea #884 October 2013
Became NCHRP 25-25, Task 94, *Integrating Extreme Weather into Transportation Asset Management Plans*
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3723
And through the continuous improvement adoption of Life Cycle Planning (LCP)

Overarching EX W & Climate LCP Drivers

- 23 U.S.C. 119, 101(a)(2), 150(a) & (b)(2); 23 CFR Part 667; Order 5520
- All other relevant Asset Management Rule items
- Arizona Management System (AMS LEAN initiatives)

Arizona DOT specific LCP Drivers

- Execution of grant related tasks, TAMP Agency Risk Register, Resilience Program Risk Register, State Transportation Improvement Plan, ADOT 5-yr Construction Program, Climate Engineering Assessment for Transportation Assets (CEA-TA), Arizona DOT Influence Model - Surface Transportation System Resilience to Climate & Extreme Weather Events
Life Cycle Plan

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 needs recharging continues to be cost prohibitive, new and novel 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 now encompasses 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 complimented the long-term delivery of these complex transportation systems. At the 2013 Transportation Research Board (TRB) Annual Meeting, Session 197 Maintaining Climate Change and Extreme Weather Resilience into Transportation, 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

Resilience Program:
Economic Analysis Plan
UT 116 MP 426 to Chile
PROJECT NO. 116-6102-712 (S.C.
FEDERAL AID NO. 219-15-0.1.9)
Apache County
Hillbrook District

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

Identify EX W & CC project and program candidates. Vulnerability Assessment

Develop economic analysis process. Justification

Optimize operation and maintenance of an increasingly aging stock, which is subject to evolving loads (e.g., from live loading and climate-induced loading) in response to this changing climate. The project goal has been increased interest by infrastructure owners and managers in the use of probabilistic methods for the assessment and management of their assets. Employed once a determinative assessment has maintained a robust/rehabiliteed/replace now template.

Arizona DOT Resilience Program

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Systematically record localized resilience efforts GIS/TAMP – Risk Management

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. Yet longstanding underinvestment in infrastructure has resulted in the poor condition of much of U.S. infrastructure, with an estimated $1.6 trillion of investment needed by 2030. New methods for benefit cost analysis, return on investment studies, and major rehabilitation timelines are needed to consider probabilistic, proact the project goal has been increased interest by infrastructure owners and managers in the use of probabilistic methods for the assessment and management of their assets. Employed once a determinative assessment has maintained a robust/rehabiliteed/replace now template.

ADOT has been 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, and pavement, as well as vegetation/retaliation. A broad range of performance, risks, and management practices are characterized in the range of resilience in FASTACT.

Infrastructure Whole Life Management Optimization

The project will provide an framework to develop an overarching framework for infrastructure asset management planning that provides the basis for the development of a comprehensive framework for the management of transportation assets. The project will provide an framework for the management of transportation assets. The project will provide an framework for the management of transportation assets. The project will provide an framework for the management of transportation assets. The project will provide an framework for the management of transportation assets.

Assess Options A & B, C, D, etc. - Risk Management

Design economic analysis process. Justification

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

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Climate models can provide insight into future conditions, projecting air temperature, precipitation, evapotranspiration, and other factors of interest to engineers, at various temporal and spatial resolutions. However, there is a considerable disparity in the outputs provided from climate models for impacts analysis and the inputs needed by engineers for planning and design. These discrepancies include mismatches in temporal scales, spatial scales, and datasets extraction and preparation requirements, study site data, and scenario uncertainties. A lack of coordination for the appropriate selection of models in different engineering applications, and the need for improved methods for input to different elements of an improved climate model.

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Impacts
Impacts
Impacts
Impacts
Impacts

OCT 27, 11
DISTANCES OF INTEREST = a + b (or versions of them) TO MONITOR

[Diagram of a geological site with annotations regarding distances and features]
Impacts
Impacts
Impacts

RAIN ON THE WAY?

AZ - CA - NV

MOISTURE BEING PULLED NORTH

T'STORM CHANCES INCREASE

HEAVY RAIN & FLASH FLOODING POSSIBLE

SEATTLE  BILLINGS  DENVER  DALLAS

LAS VEGAS  LOS ANGELES  PHOENIX

NORBERT
Impacts
Impacts
Link EX W & Climate to AM - Proposed Methodology

- Identify key stressors and their associated weather-related risk
- Identify vulnerable assets
- Identify impacts - ADOT system
- Compile data – GIS Resilience Database - systematically record known locations and resilience building actions
- Identify case study area(s)
  - Identify root cause during different stages of asset lifecycle (creation, maintenance, preservation, rehabilitation/reconstruction)
  - Identify direct modeling or proxy indicator approach
  - Identify mitigation strategies / decision trees, including adaptation options and selection criteria driven initially through (Mobility, Safety, Asset preservation, Asset performance)
- Develop / Incorporate a new whole life cost asset class methodology into decision making and TAM reporting

Phase 1
ADOT / FHWA 2015 Vulnerability Assessment

Phase 2
ADOT / FHWA 2018 Asset Management – Infrastructure Resilience

Phase 3

Root Cause Screening - TOC reports and/or known system risks/climate data

**Direct** - Design probabilistic modeling approach to produce an array of results
Optimize operation and maintenance of an increasingly aging stock, which is subjected to evolving loads (e.g. both live loading and climate induced loading). In response to this challenge the past decade has seen increased interest by infrastructure owners and managers in the use of probabilistic methods for the assessment/management of their assets. Employed once a deterministic assessment has rendered a repair/rehabilitate/replace now scenario.

**Proxy Indicators** – An indirect measure or sign that approximates or represents a phenomenon in the absence of a direct measure or sign.
GIS - Obtain and Finalize Data

**Already Captured Data**
- ADOT’s USGS Data
  - Flood gauges
  - Wildfire
  - Drought
- Layers from ADOT’s USGS Flood map
- Dust storm data (I-10 pilot)
- 5-yr program priority project information
- Bridges (including scour)
- Culvert

**New 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
- Pavement
Laguna Creek Bridge Bank Protection
Laguna Creek Bridge Bank Protection
Laguna Creek Bridge  (Ground based LiDAR project)
Reach Monitoring in Dynamic Channels

*Understanding bank erosion and impacts to infrastructure*

Laguna Creek 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
Reach Monitoring Products *Collecting data for the future*

Discharge magnitude and frequency | Velocity data
---|---
High-res. aerial photographs | Topographic models
Post-wildfire data collection | Maximum scour data
Channel change data | Vegetation change over time | Vegetation density data
Roughness values/drag coefficients
Reach visualization

Rating refinement | 2D model calibration
3-D Erosion Change Detection Mapping
Laguna Creek Construction
November 2017 – State Route 160 Laguna Creek Bridge (Final grading and seeding)
Post Construction Monitoring

USGS Drone Data Capture – On-going Monitoring - Built Condition and Wash Meander / Ox-bow
## North Carolina State

Shane Underwood – School of Civil, Construction, and Environmental Engineering
North Carolina State University – Climate Data Downscaling remainder of State (Pvmnt)

<table>
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<tr>
<th>Modeling Center (or Group)</th>
<th>Institute ID</th>
<th>Model Name</th>
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<td>ACCESS1.0</td>
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<td>Beijing Climate Center, China Meteorological Administration</td>
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<td>CESM1(BGC)</td>
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<tr>
<td>Centre National de Recherches Météorologiques / Centre Européen de Recherche et Formation Avancée en Calcul Scientifique</td>
<td>CNRM-CERFACS</td>
<td>CNRM-CM5</td>
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<td>Commonwealth Scientific and Industrial Research Organization in collaboration with Queensland Climate Change Centre of Excellence</td>
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<td>Max Planck Institute for Meteorology</td>
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Developing an asset class probabilistic engineering approach that assesses the stressors inherent to the built structure itself.
While different methods to quantify the economic impact of climate change for infrastructure can be found in the literature, none of these methods succeed in producing life cycle asset management plans that are robust to a wide variety of future climates. New methods for benefit cost analysis, return on investment studies, and major rehabilitation timeline analyses are needed that incorporate probabilistic approaches, and minimize regret by DOTs under a changing climate.
Part 667 - Developing a Process

- FHWA Emergency Relief Program (ERP) provides funds for the repair and reconstruction of highways and roads that have sustained serious damage from catastrophic failures or natural disasters, including extreme weather events. Since fiscal year 2012, Congress has appropriated approximately $5.7 billion to the ERP.
- MAP-21 and FAST Act National Highway Performance Program External - Asset Management Plan Final Rule
- 23 CFR Part 667 Periodic Evaluation of Facilities Repeatedly Requiring Repair and Reconstruction due to Emergency Events
- Statewide Evaluation §667.1 43 State DOTs shall conduct statewide evaluations to determine if there are reasonable alternatives to roads, highways, and bridges that have required repair and reconstruction activities on two or more occasions due to emergency events.
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Part 667 - Developing a Process

ADOT
Questions?

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