The national Transportation Resilience Innovations and Summit Exchange (RISE) was held on October 8-10, 2018 in Denver, Colorado. The Summit attracted over 450 participants who attended sessions on a wide range of topics focused on how to make the transportation system more resilient. As part of the meeting, state departments of transportation (DOTs) were asked to prepare posters on aspects of their resilience program that they were most proud of. This document presents images of these posters. In its entirety, it represents a diverse set of activities across all types of DOTs that illustrate how agency actions can enhance the resilience of the transportation system.

The following 44 state DOTs and transportation agencies from other countries attended RISE

- Alaska Department of Transportation & Public Facilities
- Arizona Department of Transportation
- Arkansas Department of Transportation
- California Department of Transportation
- Colorado Department of Transportation
- Connecticut Department of Transportation
- Delaware Department of Transportation
- D.C. Department of Transportation
- Georgia Department of Transportation
- Hawaii Department of Transportation
- Idaho Transportation Department
- Illinois Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Kentucky Transportation Cabinet
- Louisiana Department of Transportation and Development
- Maine Department of Transportation
- Maryland Department of Transportation/Maryland State Highway Administration
- Massachusetts Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Missouri Department of Transportation
- Montana Department of Transportation
- Nebraska Department of Transportation
- Nevada Department of Transportation
- New Hampshire Department of Transportation
- New Jersey Department of Transportation
- New Mexico Department of Transportation
- New York State Department of Transportation
- North Carolina Department of Transportation
- North Dakota Department of Transportation
- Oregon Department of Transportation
- Pennsylvania Department of Transportation
- South Carolina Department of Transportation
- Tennessee Department of Transportation
- Texas Department of Transportation
- Utah Department of Transportation
- Vermont Agency of Transportation
- Virginia Department of Transportation
- Wyoming Department of Transportation
- Washington State Department of Transportation
- West Virginia Department of Transportation
- Wisconsin Department of Transportation

International Representatives

- Ministry of Infrastructure and Water Management, Rijkswaterstaat, The Netherlands
- New Zealand Transport Agency
- Transport Canada
A Climate Engineering Assessment for Transportation Assets (CEA-TA)
Incorporating Probabilistic Analysis into Extreme Weather and Climate Change Design Engineering

Abstract

Transportation infrastructure is a complex system of assets required to deliver a myriad of services and functions, including: transportation; development and rehabilitation of such systems remains, and the endless retrofitting continues to be cost prohibitive, new and innovative strategies for long-term planning and strategic approaches to infrastructure, engineering and life cycle assessment are paramount. The management of these infrastructure systems has evolved over time, and in particular, the emphasis on resilience, sustainability, and the integration of innovative solutions to mitigate the impacts of climate change. The Arizona Department of Transportation (ADOT) introduced the challenge ahead for public agencies to coordinate a host of key missions: to maintain and replace existing infrastructure and climate change initiatives.

New challenge: Consider the balance between predictable asset deterioration curves, the sudden and unpredictable nature of extreme weather events, and long-term climate trends. New models to assess risk and life cycle analysis, and appropriate adaptation strategies. This paper will present a new approach to incorporate these issues and the future risks into the planning and design process.

Arizona DOT Resilience Program

The assurance infrastructure is a complex system of assets that requires a multidisciplinary approach to assess the risk and develop appropriate strategies to address extreme weather and climate change impacts. The Arizona DOT’s Resilience Program is focused on developing a comprehensive approach to assess and mitigate the impacts of climate change on transportation infrastructure.

(CEA-TA) - A Structured Sequence

Why is Moving to a Probabilistic Approach Ever Needed?

This question could cover many aspects. The short answer is yes. In addition to understanding and planning for future climate change, it is also important to consider the variability and uncertainty in weather patterns and their impact on transportation infrastructure. The probabilistic approach provides a framework to assess the risk and potential impacts of extreme weather events and climate change on transportation assets.

Optimizing operation and maintenance of an increasingly aging stock of transportation assets is essential in evolving models to simulate the effects of extreme weather events and climate change. This approach provides a robust framework to assess the risk and potential impacts of extreme weather events and climate change on transportation assets.

Systematically assess and mitigate climate change

ADOT has been systematically capturing data to assist with extreme weather and climate change impacts. The agency has considered various factors, such as historical data, weather patterns, and climate modeling techniques, to assess the potential risks and develop strategies to mitigate the impacts.

Infrastructure whole life management optimization

An essential component of the CEA-TA model is the ability to optimize the whole life management of transportation infrastructure assets. The model incorporates a probabilistic approach to evaluate the impact of various climate change scenarios on the performance and life cycle costs of transportation assets.

Acknowledgment

This work was supported by the U.S. Department of Transportation’s Federal Highway Administration (FHWA) through the ADOT Resilience Program. The authors gratefully acknowledge the support of the FHWA and the ADOT Resilience Program.

References


Lisa ASTM - Risk Management

The ADOT Resilience Program has developed a framework for risk management that integrates probabilistic analysis and lifecycle management to assess the impact of extreme weather events and climate change on transportation assets.

Develop lifecycle models to monitor performance - CEA-TA

The Aress Program includes a probabilistic approach to evaluate the performance of transportation assets under various climate change scenarios. The approach provides a comprehensive framework to assess the risk and potential impacts of extreme weather events and climate change on transportation assets.
Recognizing Success

1. I-70 Risk and Resilience Pilot Strengthens a Critical Corridor

2. Comprehensive Public Communications Strategy Deployed During Massive Flood Reconstruction

3. Calculated Economic Impact of Geohazard Events Statewide

Areas for Improvement

1. Measuring Resilience

2. Incorporating Resilience into Funding Decisions

COLORADO RESILIENCE: The ability of communities to rebound, positively adapt to, or thrive amidst changing conditions or challenges—including human-caused and natural disasters—and to maintain quality of life, healthy growth, durable systems, economic vitality, and conservation of resources for present and future generations.

cdot.gov/programs/planning/cdot-resilience-program | Oana Ford | 303.512.4179 | oana.ford@state.co.us
CRITERIA FOR MAKING DECISIONS TO MITIGATE OR ADAPT TO IMPACTS OF HAZARDS/THREATS

Recent CT legislation requires that projects in a coastal floodplain (with a drainage basin over 1 square mile) consider and use a freeboard of at least 2 feet above base flood plus any additional freeboard necessary to account for the most recent sea-level change scenario for the state calculated and published by UConn’s Marine Science Division.

RECOGNIZING SUCCESS IN RESILIENCE-RELATED WORK

Climate Change and Extreme Weather Vulnerability Project. CT DOT conducted a Climate Resilience Pilot Project, sponsored in part by FHWA, in 2014.

- A systems-level vulnerability assessment of bridge and culvert structures
- Focusing on inland flooding associated with extreme rainfall events
- Focused on structures in the northwest corner of the State
- In recent years extreme precipitation events have been more frequent and intense, resulting in damage to DOT’s infrastructure in several locations
- Ultimately, 52 hydrologic and hydraulic evaluations were performed on 52 structures.
- The final report contains valuable recommendations and lessons learned.

COMMUNICATING PROGRAMS / EXPECTATIONS

A DOT handbook for regional Councils of Government, the Unified Planning Work Program, emphasizes climate change and resiliency, and has a link to FHWA’s sustainability webpage.

OPPORTUNITIES FOR IMPROVEMENT

Enhancement/development of cybersecurity strategic plan for DOT. In May 2018 CT issued a Cybersecurity Action Plan for state and local government and the private sector. It calls for each state agency to develop and/or update a cybersecurity strategic plan.
Delaware Department of Transportation - Resiliency for a Low Lying State

Outstanding Accomplishments to Date:

- SR 9 Corridor Study of climate effects on vital infrastructure (ongoing)
- SR 1 Living Shoreline Project (ongoing)

Opportunities for Improvement:

1. Continued investigations on the sea level rise effects to the state and coordinating efforts amongst all stakeholders to accelerate the deployment of effective adaptation factors and programs through holistic risk and resilience strategic management.

2. Take a holistic approach and determine how the Department of Transportation can become a leader in the mitigation of greenhouse gas emissions within the transportation industry through effective programs such as alternative fuel vehicles.

Silvana Crooke, Ph.D., ENV SP, Planning  Brian Urbaneck, P.E., Assistant Director, Maintenance & Operations
Jim Pappas, P.E., Deputy Director, Transportation Solutions
Four Things FDOT is Proud of for Enhancing System Resilience

- Emergency Pre-Event Contracts
- Emergency Shoulder Use for Evacuations
- Open Roads Policy between FDOT and FHP
- Bridge Unknown Foundation Disposition

FDOT Wants to Enhance System Resilience Through:

- Use of Composite Materials/Carbon Fiber (Corrosion Resistance)
- Emergency Generators for Rest Areas/Traffic Signals
- Florida’s Fuel Distribution System

FDOT Definition of Resilience
FDOT builds resilience into transportation planning, design, operations, and maintenance to eliminate or minimize impacts caused by planned or unplanned disruptions to Florida’s transportation systems.

Website: www.fdot.gov
POC: Brian A. Blanchard, P.E., Assistant Secretary for Engineering and Operations
What DOT Resilience Looks Like in Georgia

What Makes Us Proud

Weather Response
Planning and preparation for personnel management and deployment, procurement and storage of materials and equipment, process oversight, collaboration between offices, districts and individuals and open collaboration with other state agencies and organizations all have led to dramatically improved response to extreme weather events.

Emergency Traffic Control
Oversight of traffic patterns and management of signal phasing and timing technology have helped GDOT provide higher levels of traffic management to Georgia citizens, as evidenced during 2017’s 42-day closure of I-85 in Atlanta due to a bridge fire and subsequent collapse of the span.

Communications
Building GDOT’s visibility as a responsive, proactive state agency and issuing useful and timely information to the public during times of crisis – such as inclement weather events or emergencies like the 42-day closure of I-85 in 2017 – has greatly aided our efforts to return to a state of normalcy and elevated GDOT’s perception among key leaders and the public we serve.

Planning with Resilience in Mind

Continual Assessment
Broadening GDOT staff’s understanding of the potential for risk and threats to our existing infrastructure, and preparing to respond; an example is being at the ready to secure adequate temporary housing, at an equitable rate that adheres to state guidelines but provides the necessary shelter for team members working in extreme conditions, as well as acquiring the necessary products and resources to support our resiliency in emergency response scenarios in as timely a fashion as possible.

Consideration of New Infrastructure
Considering and planning to develop new needed infrastructure in geographic areas of Georgia which are known to have extreme weather events; such infrastructure can aid in evacuation as well as provide a quicker return for residents following these events.

How GDOT Defines Resilience
Resilience is not just about reacting and responding in times of crisis; it means building the organization so that our basic functionality supports the ability to return to a state of normalcy as expeditiously as possible. By considering and addressing our vulnerabilities and incorporating resilience into all of our processes – from planning, to project development and design, to operations, to asset management, we have become an agency that stands at the ready to deal with emergencies large and small.

WWW.INDOT.INDO

Bryan Haines bhaines@gdot.gata.gov
#WORKINGFORYOU

GDOT Georgia Department of Transportation
Transportation Resilience
Hawai‘i is rising to the challenge

Our Successes:

Working with subject matter experts to address sea level rise on coastal roads and facilities.
HDOT is updating our 2003 Statewide Highway Shoreline Protection Study with the University of Hawaii at Manoa to identify short-term and mid-term projects designed to keep our existing highways accessible while HDOT investigates long-term projects such as realignment.

Coordinated pre-emergency actions for tropical cyclone threats.
Planning out alternative emergency routes, preemptively closing routes with known concerns, and pre-storm clearing of culverts and drains.

Leveraging technology to maintain/restore access to lava impacted routes.
HDOT made use of ground penetrating radar and drones to determine if Chain of Craters Road (covered in 2016) could safely serve as an evacuation route. Heat resistant concrete panels were installed over fissures on Highway 130.

In the future

HDOT will improve...

Funding for resilience/mitigation projects.
HDOT will engage with legislators to increase funding for potential realignment projects in areas expected to be impacted by sea level rise or volcanic hazards. Example: Honoapiilani Highway in Olowalu, Maui.

By building new facilities to meet anticipated challenges.
The new pier at the centerpiece of HDOT’s Harbor Modernization Project, the Kapalama Container Terminal, will be built at 9.81 feet, or over two feet higher than the current average height of piers within Honolulu Harbor.

Resilience for HDOT means creating systems and relationships before a threat to ensure minimal disruption to the state’s vital multi-modal lifelines.

http://hidot.hawaii.gov
Contact: George Abcede & Robin Shishido
DOTPA0@hawaii.gov
Idaho Transportation Department (ITD)

RESILIENCE

Quickly returning to normal operations after a major event alters the norm. Providing flexibility through prior planning, simulations/exercises, and increased situational awareness to ensure rapid deployment of resources, execution of funds and key data capture for reimbursement.

Three things ITD is proud of:

1. **Winter Mobilization**
   - a. Technology - increasing percentage of time roads are free of snow and ice
   -   - Techniques: storm tracking, debriefing storm performance and yearly overall performance debriefing
   - b. Pathfinder - warning the traveling public ahead of the storm to inform on the best times to commute/travel

2. **I-84 Winter Repair**
   - a. Contractor support
   - b. Safety
   - c. Documentation for reimbursement from state’s Emergency Relief Funds

3. **Employee Safety**
   - a. New safety vest
   - b. Work/Rest Cycle Management fatigue Policy
   - c. Employee work zone safety – VSDO, SDO
   - d. Prevention based approach to safety incident and near miss management – Goichi factor removed
   - e. Operator equipment training program with emphasis on safe operations

Two things ITD is looking to improve:

1. **Information Technology**
   - a. Training
   - b. Robust state and organizational cybersecurity team
   - c. Reliance on third-party vendors
   - d. Insurance procedures
   - e. Mechanism for sharing with other DOTs

2. **Safety & Security of All Employees**
   - a. Changing world
     -   -   - Outside threat
     -   -   - Inside threat
   - b. Local area changes
     -   -   - Fastest-growing state in nation
   - c. Changing to a safe and prepared culture
**Resilience:** Knowing how to deal with limited resources; continue moving forward in spite of setbacks, obstacles and barriers.

Remember Abraham Lincoln? You wouldn't have, if he had given up!

The I-57 Lake Shore Drive interchange was recognized for its innovative use of a temporary bridge to accommodate inbound-I-57 traffic to southbound Lake Shore Drive, saving the public countless hours of delays by avoiding extended closures and detours during the reconstruction.

The project, selected from a field of 79 nominations from 35 states, also was in the running for the People's Choice Award determined by online voting. The project received 10,622 votes, the third most in the contest.

**IDOT** performed a vulnerability assessment in 2017 to identify all the critical infrastructure that IDOT is responsible for within the state of Illinois. The assessment looked at stresses and hazards and determined how to plan for future projects with built-in mitigation strategies.

**Traffic Incident Management (TIM)**

The Traffic Incident Management Program is administered through IDOT in conjunction with many federal, state and local agencies and responders including the towing industry. The goal is to educate all first responders within the state of Illinois on best practices, policies, procedures and laws, while ensuring their safety and the safety of the travelling public.

<table>
<thead>
<tr>
<th>Date</th>
<th>Percent Trained</th>
<th>Percent Goal</th>
<th>Percent Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 3, 2018</td>
<td>75%</td>
<td>90%</td>
<td>83%</td>
</tr>
</tbody>
</table>

There is always room for improvement...

**COMMUNICATIONS:**

- Improve upon our inter-operability within IDOT as an agency and statewide
- Improve upon our communications with partner agencies
- Improve communications with all customers (internal and external)

Learn more: idot.illinois.gov
Point of Contact: Debbie Sassen
GETTING YOU THERE
SAFELY, EFFICIENTLY, AND CONVENIENTLY

RECOGNIZING SUCCESS IN RESILIENCE-RELATED WORK

3 THINGS MY DOT IS PROUD OF

- Multi-agency response planning exercises – Black Sky event, radiological events, animal disease outbreaks
- 2016 Iowa Crude by Rail/Biofuels Transportation Study
- Historical assessment of transportation system repairs made in Iowa

OPPORTUNITIES

2 THINGS MY DOT IS LOOKING TO IMPROVE

- Develop a Resiliency Index to be used in the prioritization of projects
- Develop an across-the-board emergency response plan

DOT DEFINITION OF RESILIENCE

"The ability to prepare and plan for, absorb, recover from, or more successfully adapt to adverse events."

iowadot.gov Scott Marler scott.marler@iowadot.us
Wildfire Response

KDOT’s main objective when it comes to assisting firefighting efforts is to help with road control access. Our crews are also able to haul water to assist firefighters in the field. Once the fire has been extinguished, KDOT crews repair guardrails and sign posts along the highways in areas affected by wildfires.

Snow Fighter Training

In 2014, KDOT began a new training course to help keep Kansas moving during the snow and ice season. In the past four years, more than 800 employees have had the opportunity to learn how to combat winter weather. Plowing procedures, decision making, salt-brine production and spreader operations are part of the topics that are covered during training.

Tornado Response

After the initial tornado strikes, KDOT crews are self-responders and are often first on the scene to remove debris and clear roads. During past disasters, crews were on the scene within 30 minutes. KDOT crews help remove and push debris out of the way so first responders can assist victims. After a disaster declaration, KDOT offers further assistance to communities affected by tornadoes.

Goals: Communication Improvement

When preparing for weather emergencies or disasters, many crews are required and coordinating those responsibilities in various regions or even across the state is necessary to keep motorists moving.

The use of DMS boards, social media, kandrive, radio and television are just some of the avenues KDOT uses to inform travelers of road and weather conditions.
In 2018, the Kentucky Transportation Cabinet (KYTC) has already experienced flooding, landslides and rockfalls that have accounted for over 450 emergency repair events its roadways and bridges.

### Recognizing Success in Resilience-Related Work

In 2017 KYTC and the Kentucky Transportation Center (KTC) completed a vulnerability assessment of the state’s National Highway System (NHS) to flooding, landslides, sinkholes, and earthquakes.

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>KYTC Total</th>
<th>PGA x 60 and &lt; 60</th>
<th>PGA x 30 and &lt; 30</th>
<th>100% or More</th>
<th>Master</th>
<th>Most</th>
<th>High</th>
<th>Medium</th>
<th>High</th>
<th>Most</th>
<th>High</th>
<th>Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total NHS Road Miles**</td>
<td>6,151</td>
<td>194</td>
<td>425</td>
<td>771</td>
<td>399</td>
<td>40</td>
<td>1,554</td>
<td>1,554</td>
<td>1,554</td>
<td>1,554</td>
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<tr>
<td>Interstate</td>
<td>1,094</td>
<td>21</td>
<td>147</td>
<td>241</td>
<td>49</td>
<td>762</td>
<td>398</td>
<td>398</td>
<td>398</td>
<td>398</td>
<td>398</td>
<td>398</td>
</tr>
<tr>
<td>Parkway</td>
<td>1,024</td>
<td>69</td>
<td>161</td>
<td>216</td>
<td>75</td>
<td>396</td>
<td>174</td>
<td>174</td>
<td>174</td>
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<tr>
<td>US Highway</td>
<td>1,152</td>
<td>101</td>
<td>176</td>
<td>265</td>
<td>57</td>
<td>448</td>
<td>171</td>
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<tr>
<td>KY Routes</td>
<td>374</td>
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<td>17</td>
<td>49</td>
<td>27</td>
<td>223</td>
<td>141</td>
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<tr>
<td>Local Road</td>
<td>14</td>
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<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bridges***</td>
<td>372</td>
<td>51</td>
<td>93</td>
<td>183</td>
<td>63</td>
<td>164</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Culverts</td>
<td>792</td>
<td>52</td>
<td>21</td>
<td>21</td>
<td>66</td>
<td>84</td>
<td>40</td>
<td>35</td>
<td>27</td>
<td>27</td>
<td>27</td>
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<tr>
<td>Structures</td>
<td>1,404</td>
<td>56</td>
<td>109</td>
<td>178</td>
<td>26</td>
<td>662</td>
<td>188</td>
<td>205</td>
<td>205</td>
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</tr>
</tbody>
</table>

KYTC is currently one of six state DOTs completing a pilot project for FHWA to incorporate the effects from extreme weather and climate change into KYTC’s Transportation Asset Management program.

KYTC has forged partnerships with other agencies to discuss on-going resiliency issues, strategies, and programs specific to the infrastructure impacts from flooding and natural hazards.

- U.S. Army Corp of Engineers Silver Jacket Program
- U.S. Department of Homeland Security’s Louisville Levee Regional Resiliency Assessment Program

### Future Resiliency Activities KYTC is Working Toward Improving

Integrating natural hazard vulnerability assessment results into KYTC’s Transportation Asset Management Plan (TAMP) and into the KYTC’s project prioritization process (SHIFT). Formation of KYTC Resiliency Working Group and development of KYTC Resiliency Program website

### CONTACTS:

Scott Schurman, KYTC Resiliency Coordinator  
(502) 785-5031 / Scott.Schurman@ky.gov

Ben Blandford, PhD, KTC Project Manager  
(859) 257-7504 / Benjamin.Blandford@uky.edu

### MORE INFORMATION:

Blandford, Schurman, Walker.  
“Assessing Transportation Assets for Vulnerability to Extreme Weather and Other Natural Hazards.”  
Transportation Research Record: Journal of the Transportation Research Board, 2018.  
DOI: 10.1177/0361198118802274

Blandford, Schurman, Walker.  
“Transportation System Vulnerability and Resiliency to Extreme Weather Events and Other Natural Hazards: Final Results of Vulnerability Assessment of National Highway System for All KYTC Districts.”  
2016.  
Wind and Water: A Climate-Related Hazard Study.  
KTC District 1.  
University of Kentucky, 2016.  
DOI: 10.13033/3.K1.130421.6
Louisiana: Growing in our Resilience

Louisiana is an extremely resilient state, and DCTD is equipped to face any challenges that come its way.

RESILIENCE INNOVATION

- Study and adapt processes for integrating resilience in daily planning and practice
  - Annual Innovations Showcase
  - Application of innovations
  - Targeting resources
  - ITS

EMERGENCY RESPONSE

- Designation and communication of primary corridors to prioritize resources
- Innovative applications to protect areas from flooding and maintain system mobility
  - AqucDams and HESCO deployment

INFRASTRUCTURE RESILIENCE

- Establishment of watershed council to deploy a statewide policy implementation across governmental jurisdictions
- Study to identify vulnerable coastal bridges and create Storm Surge and Wave Atlas
  - Establish 1CO-year design surge/wave data for coastal waters
  - Identify bridges vulnerable to this type of loading from the surge/wave data and bridge information
- Armor embankment slopes
  - Used for erosion control in coastal areas

DOTD will continue to improve public perception.

www.dotd.la.gov
877-435-3683
Shawn Wilson, Ph.D., Secretary
Vince Latino, Assistant Secretary for Operations
DEFINITION OF RESILIENCE

A resilient transportation system is one that maintains its safety and functionality in both the wake of extreme events and during longer term anticipated changes in its surrounding environment.

RECOGNIZING SUCCESS IN RESILIENCE-RELATED WORK

- Surrounding Resource and landscape features that may be governed by laws/rules allowing impacts resulting from adaptation measures or surrounding community impacts.
- Timeframe for threat vs. timeframe for asset replacement
- Pilot project with University of Southern Maine's Environmental Finance Center to enable municipalities to apply TRAPPD to local infrastructure
- Participation in forums focused on community resilience in collaboration with other agencies and nongovernmental organizations.

OPPORTUNITIES FOR IMPROVEMENT

- Asset specific identification of both real-time (i.e., storm surge, slope failures) and incremental (SLR) threats.
- Expanding risk assessment to inland highways
**RISK AND CLIMATE RESILIENCY**

What are we proud of?

1. **Risk and Climate Resiliency**
   MDOT invests $3.7 million annually toward cyber-safety to protect transportation data from 8 million cyber-attacks per month, and has dedicated resources for a Risk and Climate Resiliency Program Manager who participates/supports several organizations including the Maryland Commission on Climate Change, Maryland Silver Jackets, and Coast Smart Council.

2. **Pilot Studies**
   MDOT SHA has participated in two FHWA pilot studies.
   MDOT SHA is currently conducting a pilot study for FHWA on Asset Management, Extreme Weather, and Proxy Indicators. Working with Pavement, Bridge, Planning, and Operations, several changes were identified to integrate climate vulnerability into asset management. Final report in November 2018.

3. **Vulnerability Viewer**
   Sea level change and coastal precipitation were modeled and mapped for 2015, 2050, and 2100 for the 10, 25, 50, 100, and 500-year return interval storms. This ArcGIS Online viewer is easily accessed on any device and can be utilized by the County and Local Governments for data on roadway vulnerability.

What can we improve?

Cyber security is critical to operate and maintain DOT functions. While many systems are in place to protect MDOT data, threats continue to change and become more sophisticated. Security to protect transportation data must also continue to be updated, therefore MDOT will adapt by adding Integrated Dynamic Cyber Defense in 2019-2020.

To date, only the shoreline has been modeled for potential flood impacts. To better understand how an extreme precipitation event would affect the state, it is critical to consider riverine flooding as well. MDOT is currently developing riverine flood modeling and incorporating these models into planning, maintenance, and operations decision-making. Complete flood data provides better customer service and economic opportunity to support our economy.
Massachusetts
Definition of Resiliency
The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

Three Things MassDOT has Done to Improve Resilience

1. MassDOT completed a 2015 pilot transportation infrastructure vulnerability analysis.
   - The analysis incorporated sea level rise scenarios and hydrodynamic wave numerical models, called the Boston Harbor Flood Risk model, to quantify magnitude and extent of flooding.

2. 2015 MassDOT Climate Change Summit.
   - The Summit identified climate change-related threats to key assets and infrastructure including the Boston Metropolitan Highway System.
   - 9 initiatives to enhance MassDOT’s climate preparedness and mitigation efforts were identified for implementation.

3. MassDOT collaborated with multiple state agencies to create an integrated State Hazard Mitigation and Climate Adaptation Plan.

Two Things MassDOT will do as Part of the State Hazard Mitigation and Climate Adaptation Plan

1. MassDOT will collaborate with other state agencies to develop climate change design standards.
   - These new design standards will support best management and construction practices for new and improved agency structures, roads, parks, parking lots, housing, and other facilities.
   - Estimated timeframe for completion: 3-5 years

2. MassDOT will expand and improve the Boston Harbor Flood Risk Model to create the Massachusetts Coastal Zone Model.
   - Expansion of this model will create improved sea level rise and storm surge scenarios for the present, 2030, 2050, and 2070/2100.
   - This model will consider future shoreline changes and create updated GIS mapping.
   - MassDOT will assess the storm surge vulnerability of the coastal transportation network and make data available to state agencies, coastal communities, and other stakeholders.
   - Estimated timeframe for completion: greater than 5 years

To access the Massachusetts Hazard Mitigation Climate Adaptation Plan, please visit:
https://resilientma.com

A diagram illustrating the components that contributed to each assessment:
- POPULATIONS
- GOVERNMENT
- BUILT ENVIRONMENT
- NATURAL RESOURCES AND ENVIRONMENT
- ECONOMY

Each of these four elements are analyzed to determine infrastructure vulnerability.
Making Progress in Resilience

Three things MDOT is proud of

- Greater emphasis toward inventorying non-traditional assets, such as culverts and geo-technical assets.
- Reducing the "silos" around risk and resilience through close coordination between the Safety and Security Administration and the bureaus of Transportation Planning, Development, and Bridges and Structures.
- A commitment to incorporating elements of risk and resilience in the State Long-Range Plan and the Transportation Asset Management Plan.

Two things MDOT is looking to improve

- Further enhance the data available to MDOT to help identify and mitigate against risk and hazards.
- Continue to explore options to include risk and resilience in department business processes.

DOT Definition of Resilience: “We’re working on it.”

www.michigan.gov/mdot
Recognizing Success in Resilience-Related Work:

"3 Things MnDOT is Proud Of" - September 2014

Opportunities for improvement:

1. "Flash Flood Vulnerability and Adaptation Assessment Pilot Project" (2015)
   - Incorporate resilience into Transportation Asset Management and Bridge Management and Inspection systems

2. Resilient design along US-10 in Cybulski County, WI

3. Minnesota - participate in statewide climate change adaptation and air quality groups to collaborate with other state agencies to minimize impacts and increase resilience

Collaboration:

- National - participate on committees led by FHWA, AASHTO, and TRB to stay informed on transportation-related climate strategies

Action:

- Dedicate funding for MnDOT Flood Mitigation Program
- Partner with other agencies to develop flood plans and create mitigation plans
- Promote and implement solutions to increase resilience on roadways and stormwater ponds
Montana RISEs to the Challenge

Recognizing Success in Resilience-Related Work
“3 Things My DOT is Proud Of”
• Our ability to quickly respond to infrastructure emergencies
• Our ability to apply lessons from emergencies to future resiliency efforts
• Our partnerships with local governments and contractors to that help our responses be more effective

Opportunities for Improvement
“3 Things My DOT is Looking to Improve”
• Overall Project Delivery
• Communication with the public and stakeholders
• Risk Based Investment Decision Making

Resilience is the ability to anticipate, prepare, and adapt to changing conditions and to withstand, respond, and rapidly recover from natural or human caused disruptions.

Contact email: ryan@mt.gov  Phone (406) 444-5821

https://www.mdt.mt.gov/
Recognizing Success in Resilience-Related Work
“3 Things My DOT is Proud Of”

- NDOT is delivering the largest construction and maintenance program in our history – all with the fewest number of employees in our history.
- NDOT created our first Public Engagement Manual to guide our interactions with the public and stakeholders – ensuring a team approach to fulfilling infrastructure goals.
- NDOT manages our assets with a steady hand, mindful of taxpayer investment, to provide a safe and reliable transportation system – no matter the economic climate.

Opportunities for Improvement
“2 Things My DOT is Looking to Improve”

- NDOT looks to continually foster public-private partnerships to anticipate the ever-changing technology landscape.
- NDOT seeks to nurture innovation within our ranks so we can be a leader amongst our peers.

NDOT defines resilience as the ability to leverage the power of our partnerships, our people and our public to create opportunity in the midst of adversity.
“Always Prepared and Ready to Bounce Back”

Recognizing Success in Resilience-Related Work

“3 Things My DOT is Proud Of”

- Conducts regular disaster training exercises for management and staff in collaboration with state and local agencies.
- Maintains strong relationships with FHWA and FEMA.
- Southern Nevada Freeway & Arterial System of Transportation (FAST) – Co-locate operations and emergency response of the RTC, Clark County, NDOT and the cities of Henderson, Las Vegas and North Las Vegas.

Opportunities for Improvement

“2 Things My DOT is Looking to Improve”

- Provide more outreach to the public and utilize social media on what we are doing as an agency to prepare for disasters and how they can benefit from this.
- Work closer with the Nevada National Guard on training and resource coordination in preparation of a large scale disaster.

DOT Definition of Resilience

“Prepare for the unexpected and be ready to think outside the box”

www.nevadadot.com - Thor Dyson, Assistant Director Operations / Anita Bush, Chief Maintenance and Asset Management Engineer
RESILIENCY

NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION

What Are We Doing in New Hampshire?

Recognizing Success in Resilience-Related Work

Planning for Sea Level Rise (SLR)

Networks

Strategies to Prepare

Opportunities for Improvement

- Prioritization process for projects affected by SLR and/or adaptation as part of Ten Year Plan planning process
- Enhance the incorporation of innovations and resiliency designs into transportation projects

www.nh.gov/dot/climate-change/index.htm • Public Information Office (603) 271-6495
North Dakota Department of Transportation
Resiliency - The North Dakota Way

Successes

1. Pothole Regions of North Dakota - Construction of grade raises built to the ultimate height
   - Before
   - After

2. Installation of living snow fences and snow fences near affected roadways
   - Without
   - With

3. WEB EOC - State Emergency Operations Center - (Collaboration of statewide emergency events)
   - EOC
   - Flood

Opportunities for Improvement

Planning
Work to improve design standards by designing roads with higher traffic capacity

Design
Mitigating the impact to the transportation system disruption

Resilience is NDDOT's plan to preserve and enhance our transportation assets.

NDRresponse statewide emergency website:
http://www.ndresponse.gov/
Oregon Department of Transportation’s work in preparation for the Cascadia Subduction Zone Earthquake is highlighted by:

- Seismic Vulnerability Assessment of State Highway and Local Agency Bridges
- Oregon Resilience Plan, 2013
- Partnering with Oregon Public Broadcasting and News Outlets for Resilience Messaging

ODOT is striving to further improve its resilience plan by initiating:

- Statewide Seismic Triage Assessments
- Multi-Sector Asset Interdependence Planning

OREGON DOT Seismic Resilience Definition:
“Oregon citizens will not only be protected from life-threatening physical harm, but because of risk reduction measures and pre-disaster planning, communities will recover more quickly and with less continuing vulnerability following a Cascadia subduction zone earthquake and tsunami.”

https://www.oregon.gov/ODOT/Bridge/Pages/Seismic.aspx
Albert Nako
Albert.Nako@odot.state.or.us
503-986-3333

https://www.oregon.gov/ODOT/Programs/Pages/Climate-Change.aspx
Geoff Crook
Geoff.S.Crook@odot.state.or.us
503-986-3425
Road to Resilience

Overcoming past challenges & experiences with innovative solutions

Areas to Improve

1. Keeping up with society's expectations
2. Innovating and improving design/construction techniques
3. 3D modeling
4. Alternative Delivery

Education

Tennessee Department of Transportation

Safety

Resilient in getting our employees and the users of the transportation facilities home safely.

Innovation

Resilient in quickly and effectively maintaining our transportation system.

Improve Act
Building a Stronger Transportation Program in Times of Change
Tennessee Department of Transportation

"3 Things TDOT is Proud Of"
1) Assessing the Vulnerability of Tennessee Transportation Assets to Extreme Weather (2011 report)
2) Integration of Resilience into TDOT Programs and Practices
3) Response to Extreme Events

"2 Things TDOT is Looking to Improve"
- Phase 2 of TDOT's Extreme Weather Vulnerability Assessment (Assessment of Critical Transportation Assets)
- Complete Integration of Resilience into TDOT Programs and Practices

resilience - noun
\ri-\text{i}-\text{zil-}y\text{\-en}(t)s
Definition of resilience
1: an ability to recover from or adjust easily to misfortune or change
2: The Tennessee Department of Transportation (TDOT)

https://www.tn.gov/tdot.html
Paul Degges P.E.
Improving Resilience to Floods
Highways, Bridges and Culverts

Design: Updated the hydraulics manual to include a resilient design standard

Programming: Resilience in the project selection and prioritization process

Planning: Completed the Transportation Resilience Planning Tool

Areas to Improve
- Develop Quick Response Unmanned Aerial System (UAS) Program
- Integrate Mitigation Project Planning and Funding into Agency Processes
Creating a resilient multimodal transportation system

THE WSDOT WAY

OUR PRIMARY FOCUS AREAS:

1 Asset Management
We’re working to identify, map and evaluate our assets and climate risks; this aids in understanding the threats to our system.

- WSDOT’s Climate Impact Vulnerability Assessment
This GIS map is the basis for our consideration of climate risk in planning and project design. We created an easily replicable method, tailored from FHWA’s conceptual model for determining asset vulnerability.

- Seismic Lifeline Route
WSDOT has been working to improve our seismic resiliency for over two decades. Recently, we have focused our efforts on a specific lifeline route to enable federal support and supplies to reach Federal Staging Areas across Western Washington.

- State Ferries plan for 2040 incorporates resilience in its long-range planning for terminals and ferry operations.

2 Practical Solutions
Simply stated, WSDOT views Practical Solutions as the right investment, at the right time, in the right place, using the right approach.

- We're using nature-based solutions such as placing cobble instead of rip/rap along shorelines to mimic a natural beach. It absorbs wave energy while minimizing effects or adjacent shorelines.

- By using root balls along river banks, we create a more natural approach to erosion and scour, while providing habitat for fish.

3 Project Design and Program Operations

- SR 99 Tunnel and SR 520 Floating Bridge – We considered seismic risk, scour, sea level rise and other potential disruptions as part of the project design for these large, complex projects.

- Integrated Vegetation Management – Our roadside design and management strategy restores native vegetation and allows roadsides plans; communities to evolve and mature over time, resulting in lowest lifecycle maintenance costs and maximum highway operation, environmental, and social value.

WSDOT SEeks to Improve in these Areas:

- Greater engagement of resilience planning throughout the agency.
- Ways we incorporate risk of natural hazards into life cycle cost accounting, and programming.

WSDOT's Definition of Resilience
The term “resilience” means the ability to prepare for, and adapt to, changing conditions and withstand and recover rapidly from disruptions.

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Washington State DOT Environmental Services Office
(360) 705-7126
carollee.raumhan@wsdot.wa.gov

FOR MORE INFORMATION, GO TO:
www.wsdot.wa.gov/SustainableTransportation/adapting.htm
PARTNERSHIPS
- TIME Program
- FHWA Emergency Relief
- County Highway Departments
- WI Indigenous Tribes
- WI Dept of Natural Resources
- WisDOT Region Staff
- WI Emergency Management
- FEMA
- Consultants and Contractors

TECHNOLOGY
- Remote Monitoring
- In-field iPads and WiFi
- 511 Wisconsin: Traffic Management Center
- Bathometric and Sonar Surveys
- Drone Photography
- Social Media

STREAMLINED CONTRACTING
- On-Site Contractor Meetings
- Expedited Quotes and Selection
- Quick Mobilization
- County Highway Dept. Accounts

FUTURE IMPROVEMENTS
- Identify At-Risk Structures
- Improve Statewide Guidance
- Improve Monitoring and Technology
- Flood Plain Surveys
- Bridge Strengthening Program

wiscosindot.gov • For more information contact: rosanne.meer@dot.wi.gov
SOLVING TOMORROW’S PROBLEMS TODAY

Successes
Winter Weather – Connected Vehicles; variable speed limits; dynamic messaging; road weather information systems; winter research team; snow fence; commercial vehicle operators portal; and WYDOT authorized travel.

Land Slides/Rock Fall – in-house investigation capabilities; ATV drill rigs; inclinometer program; vibrating-wire piezometer groundwater monitoring; rockfall hazard rating team; statewide rockfall hazard rating inventory; EPS Geofoam lightweight fill applications; couple shear pile applications; and northwest states communication network.

Avalanche Control – Gases; O’Bells; snow supporting structures; Aviguard; two full-time avalanche technicians; NIXLE notification system; and Gov Delivery notification.

Opportunities
Winter Weather – Increased truck parking; commercial connectivity; freight movement; and alternate fuel vehicles; electric and compressed natural gas.

Future technology implementation – autonomous applications; smart cities; cyber threats; integration of information; and legal challenges.

DOT.STATE.WY.US
WATER MANAGEMENT FOR ROAD AUTHORITIES IN THE FACE OF CLIMATE CHANGE

Poster 10604
Thomas Bies, Deltares, the Netherlands
Lise Foucher, EGIS, France
Janette Bossemendier, KNMI, the Netherlands
Christian Axelsen, Danish Road Directorate, Denmark
Roderick Corbally, ROAD-IS, Ireland
John Paul Rooney, ROAD-IS, Ireland
Mark Tucker, ROAD-IS, Ireland

ABSTRACT
European National Road Authorities (NRAs) have recognized for a long time that climate change will have a significant effect on their assets and operations. Especially, water management assets will be affected. The damage caused by floods and rain to infrastructure assets amounts to €600 million annually, making it by far the dominant weather impact already in the current climate, let alone in the future when it is expected that likelihood and intensity of intense rainfall will increase. Many challenges exist in addressing intense rainfall events into proper design and maintenance of water management systems. These challenges exist both in the field of climate science itself as well as in the translation of climate projections into proper design and maintenance of water management systems. This paper presents results of the WATCH project (Water management in the face of climate Change) that was commissioned under the CEDR 2015 call Climate Change: From Desk to Road. It addresses climate change, socio-economic evaluation, and sustainable drainage systems.

RESULTS
Results of the project are:
- Comprehensive manual on how to determine the resilience of drainage systems and the consequences for inspection and maintenance as well as for the design and assessment of alternatives. In this manual, all below mentioned other outputs culminate.
- Guidelines to correctly interpret and apply relevant information extracted from climate projections, to be used in road drainage maintenance and design.
- Climate analogues tool for rainfall extremes in Europe.
- Protocol for adapting Sustainable Drainage Systems (SuDS) systems for climate change, with applications for roads across Europe.
- Guidelines for a socio-economic analysis of adaptation and maintenance approaches for water management for optimized decision making properties of NRAs. Socio-economic evaluations are seen as an essential, and often lacking, tool for implementation of climate change adaptation measures.

MANUAL
The manual aims at assessing current and future resilience of NRAs water management facilities, ensuring optimal design, maintenance planning and asset management. The approach considers two levels of analysis (high and detailed level) including risk assessment, socio-economic evaluation protocol and definition of measures and strategies.

On the high level, the analysis is performed for sub-groups of assets in order to identify the best adaptation strategy for those sub-groups (classification based on existing site factors, infrastructure intrinsic factors, consequences and hazard level). The goal of this "screening" level is to prioritize the assets that should be further studied in the detailed level.

On the detailed level, an analysis is carried out for each type of assets following 4 main steps: asset inventory, hydrological calculations, hydraulic analysis of the asset and asset risk evaluation. The adaptation strategy from the high level is translated into design options, up to the individual asset. Design and maintenance choices are compared using a socio-economic evaluation for specific assets. The final socio-economic evaluation, aggregated at the project level, should then be compared to the initial socio-economic evaluation to confirm the validity of the strategy selected at the high level.

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Hosted and organised by: 
Austrian Ministry for Transport, Innovation and Technology 
AIT, Austrian Institute of Technology 
austriatech
Development of a Climate Adaptation Strategy for the InnovA58 Highway in the Netherlands

Poster 10313
Myrthe Leijstra, Rijkswaterstaat, the Netherlands
Kees van Muijwinkel, Rijkswaterstaat, the Netherlands
Wim Leendertse, Rijkswaterstaat and the University of Groningen, the Netherlands
Thomas Blees, Deltarec, the Netherlands

ABSTRACT
Climate change induced extreme weather events may affect the functionality of (federal) highways and therefore pose a risk for safety and traffic flow. As the asset manager of the main road system in the Netherlands, the Rijkswaterstaat has to ensure that road networks continue their operational function, both now and in the future. Therefore, adaptation strategies are needed to develop and maintain climate resilient infrastructure, integrated in the environment. To develop such a strategy, the ROADAPT methodology developed in response to the "CLIP call 2012: Road owners adapting to climate change" and Dynamic Adaptation Policy Pathways were tested on a planned Dutch highway project, InnovA58. We conclude by stating that both methods are useful to assess vulnerability and potential measures for road infrastructure, and to increase adaptive design. An area-orientated approach is needed, since climate resilience requires regionally tailored solutions.

CASE STUDY
- The InnovA58, highway, the Netherlands, is used as a test case. The project area experiences heavy downpours, which are increasing as the climate changes, resulting in localized flooding and need for enhanced stormwater management. The project is currently in the planning phase, and construction is expected to begin in 2020.
- A process has been designed to access risks, vulnerability and possible measures for the InnovA58 highway and the close environment (see table 1), using the ROADAPT methodology and Dynamic Adaptation Policy Pathways.

Proven steps Actions taken
Define problem - two workshops
- To determine climate threats for the ASB of the highway and surrounding environment
- To determine key risks and potential measures
Vulnerability Assessment - GIS method for mapping distinctive vulnerable points in the area
Socio-economic impacts - Two methods: Cost-Benefit Analysis, Cost-Benefit Analysis
Adaptation Strategy - Dynamic Adaptation Policy Pathways to determine an adaptation strategy

RESULTS
The application of the ROADAPT and the Dynamic Adaptation Policy Pathways methodologies on the InnovA58 has led to output that resulted in an adaptation strategy for the highway. The output consists of:
- Risk matrices: the Quick Scan workshops risks of current and future climate were identified and prioritized in risk matrices.
- Selection of top risks: top risks were derived from the risk matrices and potential measures identified (see fig. 1).
- Vulnerability maps: the ROADAPT Vulnerability Assessment led to GIS maps, presenting the most vulnerable locations of the InnovA58 project (see fig. 2).
- Impact Assessment: the ROADAPT Socio-economic Impact Assessment was carried out to assess which measures are potentially viable.
- Adaptation Strategy: potentially viable measures have been plotted to establish an adaptation strategy for the InnovA58 (see table 2).

CONCLUSION
- The ROADAPT method provides a clear tool for generating and assessing risks, consequences and possible measures.
- In addition, the Dynamic Adaptation Policy Pathways provide insight into which measures can be combined into an adaptation strategy.
- However, the methodologies are dependent on the input of local knowledge and the ROADAPT method is area-oriented, rather than area-oriented.
- Therefore, to be able to make an integral assessment of climate resilience of the road and its environment, a process that incorporates an area-oriented approach is absolutely needed. Such an area-oriented approach should be adaptive in itself, since future climate conditions and effectiveness of measures is uncertain.

www.traconference.eu
CEDR ROADAPI and FHWA Frameworks for Vulnerability Assessment in The Netherlands and Washington State - infrastructure climate resilience

Poster 10510

Kees van Muiswinkel, Rijkswaterstaat, Rijswijk, The Netherlands
Simon Page, Washington State Department of Transportation, Olympia, Washington
Amy Follmer, US Department of Transportation, Volpe Center, Cambridge, Massachusetts
Mike Woning, Deltres, Delft, The Netherlands
Tina Hodges, US Department of Transportation, Federal Highway Administration, Washington DC

Introduction and background

The United States Federal Highway Administration (FHWA) and Rijkswaterstaat, the executive arm of the Ministry of Infrastructure and Water Management in The Netherlands, worked together on the topic of infrastructure climate resilience. Implementation of climate change resilience tools, developed in the United States and Europe, was tested on infrastructure projects in both countries. InnovAS8 in The Netherlands and SR167 in Washington State.

Using these tools is anticipated to result in cost savings, as proactively planning for climate change is generally cheaper than reacting to infrastructure damage.

Climate change adaptation frameworks for road infrastructure

ROADAPI: climate change adaptation framework for road infrastructure, sponsored by the Conference of European Directors of Roads (CEDR).

FHWA Climate and Extreme Weather Vulnerability Assessment Framework: 1. Identify key vulnerabilities; 2. Define scope; 3. Assess Vulnerability; 4. Integrate results into decision-making.

The Assess Vulnerability segment is compared with the ROADAPI Vulnerability Assessment tool, and contains three tools:

- Sensitivity Matrix to determine how assets like roads, bridges and railways may be negatively affected by extreme weather situations.
- CMIP Climate Data Processing Tool calculates local temperature and precipitation projections for transportation planners.
- Vulnerability Assessment Scoring (VAST) Tool supports analysis and ranking of multiple assets.

InnovAS8 project test area – The Netherlands

The InnovAS8 project expands an existing highway in the southern part of the Netherlands from two lanes in each direction to three lanes in each direction.

The project area experiences heavy downpours, which are increasing due to the climate changes, resulting in localized flooding and need for enhanced stormwater management. The project is currently in the planning phase and construction is expected to begin in 2020.

SR167 project test area – Washington State

The SR167 Project will complete a critical missing link to Interstate 5 near Tacoma, in Washington State. The project includes 10 km of new construction and five new interchanges. It traverses a floodplain of a minor tidal creek affected by sea-level rise and is within the floodplain of a major river impacted by sea-level rise, channel aggradation due to glacial retreat, and increased peak flows. The project area is experiencing increases in heavy downpours and continued urbanization that results in localized flooding. The project is currently in the design process. WSDOT expects to begin construction in 2019.

Results of comparison of frameworks

- The frameworks have similar approaches and results in comparable outcomes.
- Each framework has specific qualities and applicability.
- Results of methods are indicative, checking results based on expert judgment is of great importance.
- FHWA VAST tool is useful to road managers with less experience in and knowledge of sensitivity to extreme weather and climate change of assets.
- FHWA VAST tool allows for more manipulation of factors and weighting than the ROADAPI Vulnerability Assessment approach. This allows users of VAST to understand the sensitivity/robustness of results.
- ROADAPI framework lends itself to sharing information to the public / lay users. FHWA tools are spreadsheet-based and thus less accessible to a wide audience.

Conclusion

- These excellent frameworks can be used and customized by users to effectively identify extreme weather and climate change vulnerabilities, prioritize vulnerabilities, and develop adaptation strategies.
- The main benefit of using the tools is that they help users determine the most vulnerable locations in an objective manner. This takes away any personal bias or over-representation of well-known locations or assets.
- Testing frameworks in different countries and contexts is of great value.
- Comparison helps future users understand strengths and weaknesses of frameworks to be able to best apply them in projects.
- FHWA has a great knowledge from testing in the FHWA Framework Update. Rijkswaterstaat uses knowledge and expertise for improved implementation of the ROADAPI framework for benefit of other projects in The Netherlands.
Intra-Agency Skill Based Approach to Build a Resilient Work Force in State DOTs

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1University of Delaware, 2Delaware Department of Transportation, 3Oklahoma State University, 4Beijing Liaotong University

In an ever-changing environment, resilience is one of the most critical characteristics for an organization to survive and thrive. In the last two decades, studies have established how organizations survive from the chance of various external factors. However, some changing internal factors also challenge the resilience of organizations.

The employee aging, retirement, and their physical and mental condition, associated with other internal issues, such as the lack of skill, succession strategy, ailing the cost of agencies to maintain their organization continuity and development. Additionally, when leadership and management changes, their rich experiences and comprehensive understanding of the structure, precious resources are lost. This usually leads to operational instability. Thus, developing a systematic method to retain the skill-based resources for improving transportation agencies’ resilience is important.

What is Intra-Agency Skill-Based Resilience

In different fields, resilience was defined through various perspectives. However, there were a few common definitions that most approaches included:

- The speed of recovering from disturbance
- The magnitude of adversity that an entity can absorb
- The ability to maintain its function

As a critical aspect of organizational resilience, intra-agency skill-based resilience is defined as the ability of government agency, such as a State Department of Transportation, to tolerate skill-related adversities and maintain its continuous operations, still producing a resilient transportation system.

Existing Management Strategy Review

Skill-based resilience is a new topic from a management perspective. There are few studies focused on this topic to review. Thus, reviewing other relevant topics across different fields is necessary. Some crucial elements in knowledge management community of practice, change management, succession management, and employee resilience are examined.

- Knowledge Management
  - Storytelling: old but efficient way to capture and share knowledge
  - Expert system and knowledge mapping
- Community of Practice
  - By developing a community of practice, an organization obtains the recognition of learning form and sharing knowledge with them.
- Change Management
  - Change management helps organizations to adapt to the ever-changing environment by changing more spontaneously
- Succession Management
  - Succession management strategies can help all members to adapt to future roles.

Intra-Agency Skill-Based Resilience

The intra-agency skill-based resilience has two dimensions that impact the production of a resilient infrastructure system – agency’s resilience and employee’s resilience. An agency plan to achieve skill-based resilience needs to consider both systematic strategies and individual actions. Researchers unveiled the positive behavior, healthy workplace, and employees’ positive psychological capital is critical to support organizations facing significant challenges. More importantly, strategies coming from different levels can cause negative influences between agency and employee. Therefore, it is necessary to discuss strategies from both perspectives to reach the equilibrium point.

The agency’s dimension focuses on the organizational planning and management and its ultimate mission. The other dimension targets in potential influencing factors: productivity, which is driven by the agency’s operational nature, as well as the need of employees. An example of agency’s operational nature is the ability to deliver the result of its mission and use the performance assessment that brings energy to employees in some cases. Thus, existing strategies will be examined for achieving skill-based intra-agency resilience.

Delaware Resilient and Sustainable Communities League
RESILIENCE ASSESSMENT OF TRANSPORTATION TUNNELS
Sanjeev Khetwal, Shiling Fei, Marte Gutierrez
Department of Civil and Environment Engineering Colorado School of Mines, Golden, CO

Motivation:
Tunnel systems are one of the most critical links in a transportation network and they greatly undermine network resilience when they lose functionality (either abruptly or partially) due to disruptive events. However, most of the tunnel owners or managers typically analyze these functionality loss events on a case-by-case basis. Consequently, a lack of systematic data collection or analysis tools to look into the overall trend for the occurrence and severity of such events. Some of the most critical questions of interest to tunnel owners are:
- In any given tunnel, what is the link and worst-case scenario function loss one can expect, when all scenarios happen simultaneously?
- Are there certain tunnel types, design or management methods that are more sensitive to such functional interruptions?
- Is there a statistically significant difference in the recovery time for the same event under different circumstances?

Objective:
1. Developing data collection framework in order to correlate tunnel functionality/performance with existing tunnel parameters.
2. Improvement of existing tunnel infrastructure, using a data-driven approach, by strategizing the distribution of funds for repair and upgrade.
3. Development of Probabilistic Model for tunnel function loss to complement the lack of available data.
4. The ultimate result of the previous objectives will be improvement in the design of tunnels, based on performance measures and existing underground transportation infrastructure.

Tunnel Functionality/Losses: Some Major Incidents

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Location</th>
<th>Year/Date</th>
<th>Incident</th>
<th>Casualty</th>
<th>Event Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunker Hill, CA</td>
<td>2016/5/24</td>
<td>Vandalism</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>O'Hare, IL</td>
<td>2017/1/17</td>
<td>Security</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Boston, MA</td>
<td>2018/7/4</td>
<td>Bombing</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>New York, NY</td>
<td>2019/9/11</td>
<td>Terrorist</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Resilience in Tunnel Infrastructure:
- Resilience study to transportation tunnels is to its nascent stage.
- Therefore a few resiliency studies related to tunnels, mainly about specific hazards, like fire and flooding.
- A general quantitative assessment of the tunnel based on functionality loss is not available.
- There is a lack of quantitative data, determining improvement in tunnel resilience, given a design or management change.

Tunnel Functionality:
- Simple metric - Delivers data after tunnel operation. Ease of scoring.
- Functionality Q = -100% of Traffic Capacity - 100% of Traffic Capacity
- Metric Considerations - Tunnel lane closure & Speed Limit

Data Collection Framework:
- This study proposes to collect the tunnel data according to the framework shown below. The data can be broadly divided into Static, Dynamic and Function Data.
- Static - Tunnel data which does not generally change with time except when tunnel is upgraded.
- Dynamic - Operational Maintenance data, regularly updated.
- Function Data - Performance data in normal operation and after respective events. Resilience metrics are derived from this data.

Concept & Future work:
- Development of a comprehensive database of tunnel incidents.
- Development of a predictive model for tunnel function loss.
- Development of a decision support system for tunnel maintenance.

Transportation Tunnel Complex Infrastructure:
- Geotechnical - Geological profile, Support System, Drainage.
- Structural - Geometry, Liner Type, E&M, electrical system.
- Electro-Mechanical - Ventilation, Lighting, Power Supply, Cables, Control Rooms, etc.
- Safety - Cross Passages, Fire Suppression Signs, Sensors, and Alarms.
- Interdependencies of Systems.

Acknowledgement:
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Compiled by the research team for
NCHRP Project 20-117, Deploying Transportation
Resilience Practices in State DOTs.