ATTENDEE POSTERS COMPILATION
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
- Florida 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

Steven Olmedo, 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, systems, and services continues to remain a critical consideration and an endless retrofitting 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 complicated the long term delivery of these complex transportation systems. At the 2015 Transportation Research Board (TRB) Annual Meeting, Session 197: Mainstreaming 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 models for risk assessment and life cycle cost analysis, and appropriate adaptation strategies. This multiple part challenge necessitated a new approach to Incorporate such current and future risks. As part of the 2016 Annual Meeting ADOT submitted a paper representing the core of this new approach – a Resilience Program and an ADOT United States Geological Survey Framework paper that were respectively recognized as a best paper by the TRB Special Task Force on Climate Change and Energy in the spirit of contributing forward thinking research to assist society’s long term benefit and engineering-based asset adaptation process – a new paradigm to Transportation, Extreme Weather, and Climate Change Adaptation into Infrastructure planning and design. This paper presents the ongoing efforts to date of benefits from preeminent researchers in the two integral, and practice ready, remaining parts – probabilistic modeling for engineering design and infrastructure system life cycle outcomes for extreme weather and climate change in a transportation engineering setting.

Arizona DOT Resilience Program
Transportation infrastructure is a complex system of assets required to deliver a myriad of services and functions. The expansion of risk development for extreme weather management and climate change adaptation has resulted in a journey of a few of today’s complex transportation systems. In order to develop an innovative approach, the first step was to create a system process that allowed for a shift from a deterministic process design of the immediate and/or frequency based, (expected) risk of failure, and hazard probability and programs budgeting focus – i.e. extreme events not considered – to a probabilistic analysis approach that inputs additional data, variables, and considerations not previously considered. In 2015 and 2016 ADOT focused on linking scientific evidence-driven data capture with the design engineering processes through the development of a partnership with the United States Geological Society (USGS). Extensive 2 D and 3D engine modeling undertaking.

(CEA-TA) – A Structured Sequence

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

2015 FHWA Pilot Project - The study examined baseline (historical) and potential future extreme weather conditions, focusing on temperature and precipitation variables. Two future analysis periods were selected: 2021 to 2050 (referred to subsequently as 2040, the median year), which reflects the transition of ongoing long Shand planning efforts, and 2065 to 2095 (2080), roughly associated with the expected design lifetime of some critical infrastructure type, such as bridges. To provide a long term baseline against which to compare the projections, the team also examined temperature and precipitation observations from 1990 through 1999. The report was issued by FHWA in the spring of 2016.

Develop economic analysis process - Justification

Optimize operation and maintenance of an increasingly aging stock, which is subjected to evolving loads (e.g. both load 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 framework for the assessment/design of management investment/and management of assets. Employed once a determination has assessed a repair/rehabilitation/replacement scenario.

Define limits of simultaneous that incorporates latest science/engineering

Extreme weather events - such as severe wind, storm surge, changes in precipitation, higher temperatures, and others are potential vectors of infrastructure failure and should be taken into consideration in infrastructure economic analysis and asset management models.

Systematically record locations and resistance efforts GISTAMP - Risk Management

Civil infrastructure systems are among the largest local, state and Federal investments, and these infrastructure systems are critical to our nation’s economic and environmental and social outcomes. Yet longstanding underinvestment in infrastructure has resulted in the poor condition of much of U.S. infrastructure, with an estimated $3.6 trillion of investment needed by 2020. New methods for benefit cost analysis, return on investment studies, and major rehabilitation timeline analyses are needed that incorporate probabilistic approaches, and minimize risk to long-term viability. The results of CEA-TA provides that method.

Infrastructure owners and managers have long been concerned with their facilities’ ability to withstand extreme weather conditions. Engineers, for planning and design, increasingly require information on future conditions, the impacts of climate change on such conditions, and the potential risks to infrastructure assets. The challenge is to use advanced tools, models, and concepts to incorporate these projections into design and project design. The ability of infrastructure owners and managers to incorporate probabilistic models for infrastructure design, and life cycle cost analysis, and appropriate adaptation strategies is critical to the long term benefit of the nation’s transportation infrastructure. This paper presents the ongoing efforts to date of benefits from preeminent researchers in the two integral, and practice ready, remaining parts – probabilistic modeling for engineering design and infrastructure system life cycle outcomes for extreme weather and climate change in a transportation engineering setting.

A Climate Engineering Assessment for Transportation Assets (CEA-TA) - A Structured Sequence

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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.
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’ 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.

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.

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.

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.
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 Croope, Ph.D., ENV SP, Planning  
Brian Urbanek, 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.
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
Broading 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.

Bryan Haines bhaines@dot.ga.gov

#WORKINGFORYOU

WWW.DOT.GA.GOV

GDOT Georgia Department of Transportation
HOOT 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 HOOT 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 rockfall 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.
Idaho Transportation Department (ITD)

RESILIENCE

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 travelling 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 – Gotcha 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 cyber security 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

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

The I-55 Lake Shore Drive interchange was recognized for its creative use of a temporary bridge to accommodate inbound I-55 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 threats and hazards and determined how to plan for future projects with built-in mitigation strategies.

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, all while ensuring their safety and the safety of the traveling public.

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."
KEEING KANSAS MOVING

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 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.

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 Resilience 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

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(859) 257-7504 / Ben.J.Blandford@uky.edu

MORE INFORMATION:


In 2017 Kentucky Resilience Assessment Program.
Louisiana: Growing in our Resilience

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

EMERGENCY RESPONSE

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

RESILIENCE INNOVATION

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

RESILIENCE INNOVATION

- Study to identify vulnerable coastal bridges and create Storm Surge and Wave Atlas
- Establish 100-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

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 100-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.

Shawn Wilson, Ph.D., Secretary
Vince Latino, Assistant Secretary for Operations

www.dotd.la.gov
877-452-3683
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 disallowing 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 (ie: storm surge, slope failures) and incremental (SLR) threats.
- Expanding risk assessment to inland highways
MARYLAND DEPARTMENT OF TRANSPORTATION

What are we proud of?

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.

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.

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.
**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 model, 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, parkways, 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
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.”
Recognizing Success in Resilience-Related Work, “3 Things My DOT is Proud Of”

Research
- “Flash Flood Vulnerability and Adaptation Assessment Pilot Project” (2014)
- Incorporate resilience into Transportation Asset Management and Bridge Replacement and Improvement Management systems (ongoing)

Collaboration
- MN - participate in state climate change, climate adaptation and air quality groups to collaborate with other state agencies to minimize impacts and increase resilience.
- 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 and drought tolerant seed mixtures to use on roadsides and stormwater ponds

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

Connect research to practice
Engage more staff in resilience conversations

Resilience at MnDOT: Design, construct, operate, and maintain infrastructure to be resilient to the changing climate

Summary of the Report of the Interagency Climate Adaptation Team
May 2017

Adapting to Climate Change in Minnesota

Our climate is changing
Climate change is already occurring in Minnesota and its impacts are affecting our state’s environment, economy, and communities.

Over the last several decades, the state has experienced substantial warming during winter and at night, with increased precipitation throughout the year, often from larger and more frequent heavy rainfall events.

In the years and decades ahead, winter warming and increased extreme weather will continue to be Minnesota’s two leading symptoms of climate change.

How we’re adapting
Minnesota is taking many steps to increase climate adaptation in our state, including a wide range of planning, assessment, and implementation efforts.

This report summarizes ongoing adaptation activities in selected Minnesota state agencies, including the Departments of Agriculture, Commerce, Health, Military Affairs, Natural Resources, Homeland Security and Emergency Management, and Transportation, as well as the Environmental Quality Board, Pollution Control Agency, Board of Water and Soil Resources, and Metropolitan Council.

Planning for the future
State agencies have developed five statewide climate adaptation initiatives to help advance Minnesota’s progress in climate adaptation.

The Interagency Climate Adaptation Team has also identified six priority recommendations for needed action in climate adaptation by state governments. These focus on reducing the extreme precipitation, health of vulnerable populations, preparing ecosystems, strengthening agricultural water management, managing climate impacts in populated centers, and better using climate data.

Tim Sexton, Chief Sustainability Officer
http://www.dot.state.mn.us/sustainability/
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.

https://www.mdt.mt.gov/  Contact email: lryan@mt.gov  Phone (406) 444-6821
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.

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.

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.
“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
Recognizing Success in Resilience-Related Work

What Are We Doing in New Hampshire?

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
Resiliency is NDDOT’s plan to preserve and enhance our transportation assets.

North Dakota Department of Transportation
Resiliency - The North Dakota Way

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

NDResponse 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
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503-986-3425
SAFETY
Resilient in getting our employees and the users of the transportation facilities home

INNOVATION
Resilient in quickly and effectively maintaining our transportation system

EDUCATION
Resilient in advancing career development for all employees

Road to Resilience
Overcoming past challenges & experiences with innovative solutions

AREAS TO IMPROVE
• Keeping up with society’s trends and technology’s capabilities
• Innovating and improving design/construction techniques:
  - 3D modeling
  - Drones
  - Alternative Delivery

IMPROVE Act

MemFix4

Department of Transportation

Tennessee Department of Transportation

TDOT Reconnect

GTA
“3 Things TDOT is Proud Of”
1) Assessing the Vulnerability of Tennessee Transportation Assets to Extreme Weather (2015 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-ˈzil-yən(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 Deggis P.E.
Grit in Action - Points of Pride

Our rapid response, communication and innovation were all evident in our response to Hurricane Harvey in 2017.

Massive Emergency Response

When Hurricane Harvey hit Texas on Aug. 25, we mobilized a massive response involving more than 5,000 employees. At the height of the storm, more than 2,000 state road segments were closed as TxDOT crew members and equipment addressed the disastrous impacts across 50 Texas counties. Our effort lasted almost another year as we removed more than 31 million cubic feet of debris, enough to fill 100,000 dump trucks.

Committed to Continuous Improvement

Even one death on our system is unacceptable. We are committed to designing the safest system possible as a shared responsibility with Texas drivers. Our safety campaigns educate drivers in every corner of the state and our engineers work diligently to design a system that is more forgiving of driver error. Our internal focus on safety has made a difference, and we want to do the same on our system.

Texas Department of Transportation | www.txdot.gov

Contact: Michael Lee, Director, Engineering and Safety Operations
UDOT Achievements in Risk-Based Asset Management
Keeping Utah Moving

Things We Do Well

1. Asset Management
   - To keep Utah moving, UDOT's strategy has three main goals: (1) zero fatalities, (2) enhance infrastructure, and (3) profit. UDOT's achievements in asset management are evident in the following three examples, which are key indicators of success:
     - UDOT has completed a national report on assessment for the I-15 corridor and is beginning a second pilot for US 80.
   - The success of the second pilot is to augment the corridor planning program with added attention given to threats from natural hazards and health hazards.
     - In 2013, UDOT launched a risk-based statewide safety effort for all rural UDOT roads to create a comprehensive database of highway assets located throughout Utah.
     - UDOT's efforts in risk-based asset management have been recognized with various awards and recognitions, including the National Highway Laboratory (NHTL) Award for Excellence in Asset Management.
   - UDOT has implemented a risk-based asset management program that prioritizes investments in critical infrastructure based on risk levels and asset deterioration.

2. Performance Management
   - The American Society of Civil Engineers (ASCE) 2017 report gave Utah a grade of B minus for infrastructure, highlighting the need for improvement in some areas.
     - UDOT's implementation of risk-based asset management has improved the overall condition of the state's roads and bridges.
   - UDOT has identified the following performance measures to meet our strategic goals:
     - Performance Condition
     - Risk Assessment
     - Asset Management
   - UDOT has been recognized with various awards and recognitions for its performance management program.
     - UDOT's risk-based asset management program is designed to prioritize investments in critical infrastructure based on risk levels and asset deterioration.

3. Risk Management
   - To ensure infrastructure remains safe and reliable, UDOT assesses the risk associated with various types of assets, including bridges, roads, and pipelines.
   - UDOT has completed a risk assessment for the I-15 corridor and is beginning a second pilot for US 80.
     - The second pilot is focused on addressing specific challenges identified during the first pilot.
   - UDOT has implemented a comprehensive approach to risk management that includes the assessment of risk levels and the development of strategies to mitigate risks.

Integrating Risk and Resilience into Corridor Planning
FHWA Extreme Weather & Durability Grant

- UDOT has identified the need for improved resilience in its asset management program, particularly in relation to extreme weather events.
- The US Department of Transportation (USDOT) has awarded UDOT a grant to develop a risk-based approach to corridor planning that incorporates extreme weather and durability considerations.
- This grant will enable UDOT to develop a comprehensive risk management strategy that considers the potential impacts of extreme weather events and natural disasters on the state's transportation infrastructure.

Areas of Improvement

- UDOT's investment in data collection and analysis has allowed the agency to identify areas for improvement in its asset management program.
- The agency has implemented a risk-based approach to prioritizing investments, which has resulted in a significant reduction in the number of high-risk assets.
- UDOT has implemented a comprehensive asset management program that prioritizes investments in critical infrastructure based on risk levels and asset deterioration.

Contacts

- For more information, please contact UDOT's asset management team at info@udot.state.ut.us.
Improving Resilience to Floods
Highways, Bridges and Culverts

Planning: Completed the Transportation Resilience Planning Tool

Programming: Resilience in the project selection and prioritization process

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

Operations: Rivers & Roads Training

Areas to Improve

- Develop Quick Response Unmanned Aerial System (UAS) Program
- Integrate Mitigation Project Planning and Funding into Agency Processes

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Todd Sears
Emergency Management Director
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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 Change 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 resiliency 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 on 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, storms, 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 roadside plant communities to evolve and mature over time, resulting in lowest lifecycle maintenance costs and maximum highway operation, environmental, and social values.

WSDOT SEEKS TO IMPROVE IN THESE AREAS:

Better coordination among jurisdictions:
- How we identify and address network and system vulnerabilities with transportation partners and communities.
- How to meet the needs of vulnerable communities, and improve evacuation plans for transit-dependent, low income, elderly, people with disabilities - wherever they live.

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.


FOR MORE INFORMATION, GO TO:
www.wsdot.wa.gov/SustainableTransportation/adapting.htm
STREAMLINED CONTRACTING
- On-Site Contractor Meetings
- Expedited Quotes and Selection
- Quick Mobilization
- County Highway Dept. Accounts

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

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

wisconsindot.gov • For more information contact: rossanne.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: Gasex; O’Bell; 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.
WATER MANAGEMENT FOR ROAD AUTHORITIES IN THE FACE OF CLIMATE CHANGE

Poster 10604
Thomas Bles, Deltares, the Netherlands
Lise Foucher, EGIS, France
Janette Bessembinder, KNMI, the Netherlands
Christian Axelsen, Danish Road Directorate, Denmark

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 System (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 extrinsic 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, hydraulic 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 economic evaluation to confirm the validity of the strategy selected at the high level.

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Hosted and organised by: AIT, austriatech, ACARE, Alice, Association of European Regions, RERAC, ERTICO, ENSIDE, FRAMA, KOMPASS

Co-organised by: Together with:
Development of a Climate Adaptation Strategy for the InnovA58 Highway in the Netherlands
Poster 10313
Myrthe Ljéstaha, Rijkswaterstaat, the Netherlands
Kees van Muiswinkel, Rijkswaterstaat, the Netherlands
Wim Leendertse, Rijkswaterstaat and the University of Groningen, the Netherlands
Thomas Bles, Deltares, 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, Rijkswaterstaat has to ensure that road networks continue their operational functions, both now and in the future. Therefore adaptation strategies are needed to develop and maintain a climate resilient infrastructure, integrated in the environment. To develop such a strategy, the ROADAPT methodology - developed in response to the ‘CEDR 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 methodologies are useful to assess vulnerability and potential measures for road infrastructure and to increase adaptive design. An area-oriented approach is needed, since climate resilience requires regionally tailored solutions.

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: in the Quick Scan workshops risks of current and future climate were identified and plotted on 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).

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 assess 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.

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 line-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

CONTACT: Wim Leendertse, +31 6 51573847, wim.leendertse@wets.nl or wileend@yahoo.com
CEDR ROADAPT and FHWA Frameworks for Vulnerability Assessment in The Netherlands and Washington State - infrastructure climate resilience
Poster 10510
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Tina Hodges, US Department of Transportation, Federal Highway Administration, Washington DC

Introduction and background
United States Federal Highway Administration (FHWA) and Rijkswaterstaat, the executive part of the Ministry of Infrastructure and Water Management in The Netherlands, work 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, InnovA58 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 waiting for infrastructure to be damaged.

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

FHWA Climate Change and Extreme Weather Vulnerability Assessment Framework
Includes three main segments: 1. Define Scope; 2. Assess Vulnerability; 3. Integrate Results into Decision-making.
The Assess Vulnerability segment is compared with the ROADAPT 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.
- CMP 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.

InnovA58 project test area – The Netherlands
The InnovA58 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 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.

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 result 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 Sensitivity Matrix 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 more manipulating of factors and weighting than the ROADAPT Vulnerability Assessment approach. This allows users of VAST to understand the sensitivity/robustness of results.
- ROADAPT 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 used knowledge from testing in the FHWA Framework update. Rijkswaterstaat uses knowledge and experience for improved implementation of the ROADAPT framework, for benefit of other projects in Netherlands.

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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 been conducted to explore how organizations develop resilience from the change of various external factors. However, some changing internal factors are also challenging 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, raising 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 retaining 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 adapt;
- The ability to maintain its function;

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

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 plans to achieve the skill-based resilience need to consider both systematic strategies and individual wishes. Researches unveiled the positive behavior, healthy workplace and employees' positive psychological capital are critical to support organizations facing critical changes. However, strategies coming from different levels can cause negative influences between agency and employees. Thus, it's 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 on potential influences on employees, which is driven by the agency's operational nature, as well as the need of employees. An example of agency's operational nature to be able to deliver the result of its mission is the use of performance assessment that can bring anxiety to employees in some cases. Thus, existing strategies will be examined for achieving skill-based intra-agency resilience.

This study explored the existing strategies developed for varied purposes. It served as an insight to develop a model for strategies of skill-based resilience through a systems thinking perspective acknowledging real world interactions. Creating a workspace with skill-based resilience culture is considered the foundation of skill-based resilience. It's powerful to mitigate the resistance against maintaining operations when adversity occurs. The second more in-depth part of the model is the skill identification and location. Strategies or this part targets both hard and soft skills. Soft skills are usually hard to capture. However, through storytelling and personnel portraying, soft skills are possible to be identified. Skill retention is a well researched topic for which there are plenty of good strategies in the literature.

Focus of this work is on the resilience skill systemic approach, capturing ways a culture of resilience can become an integral part of the skill-based resilience personnel, and the transfer and continuity of this dimension supporting the agency's resilience dimension that enables the end result of the production of a resilient infrastructure system to come to fruition. With efficient skill transferring, the agency can maintain skills with less concerns on employee turnover, as well as improve the career adaptability of employees. Besides the model, some elements, such as employee resilience, are part of concern when developing strategies for achieving skill-based resilience. Critical infrastructure such as transportation need to continuously evolve in all resilience dimensions.
RESILIENCE ASSESSMENT OF TRANSPORTATION TUNNELS

Sandeep Khetwal, Shiling Pei, Marte Gutierrez
Department of Civil and Environment Engineering, Colorado School of Mines, Golden, CO

Motivation:
Tunnels are one of the most critical infrastructures in a transportation network and they greatly undermine network resilience when they lose functionality (either entirely or partially) due to disruptive events. However, most of the tunnel owners or managers typically analyzed these functionality loss events on a case-by-case basis. There is currently a lack of systematic data collected or analyzed done to look into the overall trend and frequency of the occurrence and severity of such events. Some of the most critical questions of interest to tunnel owners are:
- In a given tunnel, what is the best and worst case scenario function loss one can expect, when a certain hazardous condition occurs?
- Are there certain tunnel type, design, or management methods that are vulnerable to such functional interruption?
- Is there a statistically significant difference in the recovery time for the same event under different circumstances?

To answer this question, one needs a systematic collection of the tunnel function loss data and based on the needs of resilience assessment, an "ideal" data collection framework to support resilience modeling.

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

Tunnel Functionality Losses: Some Major Incidents

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>Tunnel Type</th>
<th>In Service Since</th>
<th>Date of Event</th>
<th>Incident</th>
<th>Closure Time</th>
<th>Cost ($ million)</th>
<th>Damage (injury)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-95/49</td>
<td>Bi-directional</td>
<td>1975</td>
<td>1/10/2000</td>
<td>Earthquake</td>
<td>3 months</td>
<td>25</td>
<td>3 (injured)</td>
</tr>
<tr>
<td>I-90</td>
<td>Bi-directional</td>
<td>1975</td>
<td>1/10/2000</td>
<td>Vehicle</td>
<td>3 months</td>
<td>25</td>
<td>3 (injured)</td>
</tr>
<tr>
<td>I-95/49</td>
<td>Bi-directional</td>
<td>1980</td>
<td>1/10/2000</td>
<td>Earthquake</td>
<td>3 months</td>
<td>25</td>
<td>3 (injured)</td>
</tr>
</tbody>
</table>

The graph shows typical function loss event in the tunnel versus time. The case considers 1 Lane closure, in a bi-directional, 2 lane tunnel. The procedure is:
- Whole tunnel closed to set up barrier.
- One lane opened with lower speed than maximum allowable.
- Task which caused closure performed (Tasks like, washing of walls, inspections, replacements, etc.)
- Tunnel opened again to remove barrier.
- Whole tunnel opened with lower than normal speed and then transitioned to normal speed.

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 – Operation and Maintenance data, regularly updated.
- Function Data – Performance data, in normal operation and with respect to an event. Resilience metric is derived from this data.

Concept & Future work:
- Functionality Q5 from simulation
- Resilience metric Q5
- Functionality Q5 from simulation

Data collection framework to support tunnel resilience assessment

Resilience in Tunnel Infrastructure:
- Resilience study for transportation tunnels is in its nascent stage.
- There are a few research 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 quantifiable data, determining improvement in tunnel's resilience, given a design or management change.

Tunnel Functionality:
- Simple metric – Defines state of tunnel operation. Ease of recording
- Functionality Q – Ratio of Traffic Capacity open to public to maximum traffic capacity
- Metric Considered – Tunnel lanes closure & Speed Limit

\[
Q(t) = \frac{\text{Reduced speed limit}}{\text{Normal speed limit}}
\]

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