Risk and Resilience – Colorado DOT Case Study

AASHTO Committee on Transportation System Security and Resilience (CTSSR)
& Subcommittee on Risk Management

July 12, 2018
Project Life Cycle - Risk and Resilience

- **Planning**: Evaluate *physical* and *operational* threats during the planning stage (PEL)
- **Design**: Use Resilience in Project Selection
- **Construction**: Use Resilience in Benefit Cost Analysis of Alternatives
- **Operations, Maintenance, Asset Mgmt**: Use Resilience to Prioritize
August 2016: I-70 Risk and Resilience Pilot
- Completed November 2017
I-70 Risk and Resilience Pilot

- Analysis of risk potential and assessment of system resilience of I-70 from Kansas to Utah
- Proactive look at optimal investments we can make now, in advance of future events, to improve system resilience
- Builds on 7-step RAMCAP (Risk Analysis & Mgmt for Critical Asset Protection) process utilized in flood recovery effort
I-70 ASSETS

- Bridge
- Bridge Approach
- Roadway Prism
- Post-Tensioned Concrete Slab
- National Bridge Inventory (NBI) Culverts
- Minor Culverts
- Walls
- ITS/VMS
- Traffic Control Centers
- Tunnels

I-70 THREATS

- Avalanche
- Flood (scour)
- Flood (overtopping, debris)
- Fire (wildland)
- Landslide
- Rockslide
- High Wind
- Tornados
- Bridge Strikes
Risk ($\$) = C \times V \times T

R = \text{Risk}. \text{ Potential loss due to analyzed event, } \$
C = \text{Consequence}. \text{ Outcome of an event occurrence, } \$
V = \text{Vulnerability}. \text{ Given event has occurred, probability of that estimated consequences will be realized, } \%
T = \text{Threat}. \text{ Likelihood event will occur, } \%
I-70 Pilot Results

**User Risk**
- Value of Time
- Vehicle Running Costs

**Owner Risk**
- Asset Replace in Kind

---

**ANNUAL RISK SUMMARY BY THREAT**

**TOTAL RISK I-70**

- **Flood**
  - User Risk: $117,857,395
  - Owner Risk: $1,334,101

- **Rockfall**
  - User Risk: $35,781,405
  - Owner Risk: $3,835,682

- **Avalanche**
  - User Risk: $8,516,684
  - Owner Risk: $216,093

- **Landslide**
  - User Risk: $2,161,863
  - Owner Risk: $723,814

- **High Wind & Related Weather**
  - User Risk: $8,475
  - Owner Risk: $310

- **Bridge Vehicle Strike**
  - User Risk: $6,901
  - Owner Risk: $15,853

- **Total System Risk**
  - User Risk: $164,324,248
  - Owner Risk: $6,135,544
I-70 Pilot Results

ANNUAL TOTAL RISK BY CORRIDOR SEGMENT

SEGMENT CRITICALITY SCORE

CORRIDOR TOTAL ANNUAL RISK: $170.5 M
NEXT STEPS: I-70 Results Prioritization

- 5% of assets (about 70 assets of ~1,200) contribute to 76% of risk on I-70
- Prioritize Maintenance, Operations, Capital Improvements (Benefit-Cost)
NEXT STEPS: Standards Development

GOAL
• Develop standardized approach for conducting transportation risk and resilience assessments in Colorado
• Establish methodology, parameters and default values to use

BENEFITS
• Consistent assessments regardless of location, geography, facility type, team conducting the study, etc.

TIMELINE
• Kickoff at end of July, 2018; 24 months project
Risk and Resilience in Planning
Risk and Resilience in Planning

• PEL (Planning and Environmental Linkages)
  Corridor level transportation planning study to identify short and long term transportation issues.

• Pilot on US 34 and SH 66 PELs in NE Colorado

• PELs can be used to document Resilience issues on the corridor
  • Physical Threats
  • Operational Issues
Incorporating Resilience – Land Use Threats

Population growth in Colorado is resulting in new development at a pace that is hard to anticipate and not always appropriately reflected within a community’s land use plan.

To better communicate with Local Agencies about the impacts of unplanned land use changes on roadway operations, CDOT has developed:

- Sensitivity analysis
- Corridor operational threats analysis (COTA)
Incorporating Resiliency – Sensitivity Analysis

Objective: Identify locations that are at higher risk to unanticipated traffic increases

Sensitivity Heat Maps

• Metrics:
  – Travel time and/or speed
  – Intersection and link capacity utilization
  – Green time/progression bandwidth efficiency

• Analyze and illustrate the selected metric under:
  – Existing Conditions
  – 2040 operations with no improvements
  – Operations under 2040 PEL recommendations
  – Unanticipated growth Scenarios
Incorporating Resiliency – Operational Threats

Existing agriculture land

Future commercial property

US 34 Planning and Environmental Linkages Study
Incorporating Resilience in PELs - Summary

- Natural threats analysis to identify shocks to the transportation system
- Operational threats analysis completed to identify manmade stressors
- Combination provides resiliency from the “big event” as well as from long term strain on the system
Thank you!
Backup
Resilience

BUYING DOWN THE RISK: Capital Improvements

<table>
<thead>
<tr>
<th>Proposed Mitigation</th>
<th>Description</th>
<th>Proposed Hydraulic Design</th>
<th>Cost of Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td>Replacement of existing culverts with Two 72” concrete pipes (1 each direction) with headwalls</td>
<td>50-yr (roadway overtopping at 100-yr event)</td>
<td>$500,000/culvert $1M/site</td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>Replacement of existing culverts with Two 8’ x 8’ CBC (1 each direction) connected with a concrete chute and improvements to private crossing above interstate</td>
<td>100-yr (NO roadway overtopping at 100-yr event)</td>
<td>$800,000/culvert $1.6M/site</td>
</tr>
</tbody>
</table>

Location: I-70, Milepost 112.9.  
Criticality: High/ High Risk ($)  
Current Culvert Design: <25 year flood  
Anticipated Flows: Up to 100-year flood
BUYING DOWN THE RISK: Capital Improvements

- Both mitigation options have similar reductions in Total Risk (92% and 97%) and B/C >1
- Less expensive, Option 1 (50-year design) preferred

<table>
<thead>
<tr>
<th>Mitigation Option</th>
<th>Reduction in Annualized Owner Risk</th>
<th>Reduction in Annualized User Risk</th>
<th>Reduction in Annualized Total Risk</th>
<th>B/C Owner Risk</th>
<th>B/C Total Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1</strong></td>
<td>$5,900 (76%)</td>
<td>$1,217,276 (92%)</td>
<td>$1,223,176 (92%)</td>
<td>0.17</td>
<td>35.6</td>
</tr>
<tr>
<td>(72” concrete pipes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Option 2</strong></td>
<td>$7,481 (76%)</td>
<td>$1,278,337 (97%)</td>
<td>$1,285,819 (97%)</td>
<td>0.14</td>
<td>23.4</td>
</tr>
<tr>
<td>(8’ x 8’ CBCs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Incorporating Resiliency – Sensitivity Analysis

Weekday PM Peak (4:30-5:30 pm)

- 2017:
  - Eastbound: 29 min
  - Westbound: 29 min

- 2040:
  - Eastbound: 48 min
  - Westbound: 57 min

Congestion Scale:
- Little or None
- Light
- Mild
- Moderate
- Heavy
- Extreme
Objective: Evaluate if land use changes in proximity to the state highway will affect the population and/or employment density numbers from the projected use
  – Most vulnerable intersections are identified using the sensitivity analysis
  – Intersection Capacity Utilization is calculated for each
  – Analysis completed using data already generated during a PEL

Benefits:
- Enhance communication between CDOT and local agencies to better understand operational risks to a corridor
- Identify intersections where there is potential for a change in proposed land use or density
- Initiate discussions about intersection improvements that could be initiated by the local agency and include participation from developers
Integrating Resilience at CDOT

GOAL
• Integrate resilience into core DOT functions

BENEFITS
• Common understanding and definition of resilience in Department, identification of resilience integration

TIMELINE
• Kickoff in August, 2018; 12 months project
### Incorporating Resilience – Physical Threats

<table>
<thead>
<tr>
<th>THREATS</th>
<th>ASSETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avalanche</td>
<td>Bridges &amp; Approaches</td>
</tr>
<tr>
<td>Flood (scour)</td>
<td>Roadway Prism</td>
</tr>
<tr>
<td>Flood (debris)</td>
<td>Post Tension Concrete Slabs</td>
</tr>
<tr>
<td>Fire</td>
<td>Tunnels</td>
</tr>
<tr>
<td>Landslide</td>
<td>Culverts</td>
</tr>
<tr>
<td>Rockfall</td>
<td>Walls</td>
</tr>
<tr>
<td>High Wind</td>
<td>ITS Devices</td>
</tr>
<tr>
<td>Tornado</td>
<td>Traffic Management Center</td>
</tr>
<tr>
<td>Bridge Strike</td>
<td>Traffic Control</td>
</tr>
<tr>
<td>Railroad Crossings</td>
<td></td>
</tr>
<tr>
<td>Utilities</td>
<td></td>
</tr>
<tr>
<td>Visibility</td>
<td></td>
</tr>
<tr>
<td>Cyber</td>
<td></td>
</tr>
<tr>
<td>Other man-made Threats</td>
<td></td>
</tr>
</tbody>
</table>

1. Identify **threats**
2. Identify **assets** that overlap with each threat
3. Create a "**risk area**" map to locate all the assets against the predicted locations of threats along the corridor
4. Determine **user costs**
5. Determine **infrastructure costs**
6. Identify **consequences**
7. Determine the **vulnerability** of the asset to each threat
8. Evaluate the **risk**
10. Determine the **criticality** of the roadway segment
11. **Prioritize** assets
12. Provide resilient **recommendations**
Incorporating Resiliency Into CDOT

Project Life Cycle

Risk and Resiliency

Evaluating natural and land use threats during the planning stage

Risk and Resiliency
Benefit to Cost Analysis

Emergency Management
Planning and Environmental Linkages (PELs) are studies CDOT uses to identify and link transportation issues and environmental concerns to prioritize future projects.
Incorporating Resilience – Physical Threats

THREATS
- Avalanche
- Flood (scour)
- Flood (debris)
- Fire
- Landslide
- Rockfall
- High Wind
- Tornado
- Bridge Strike
- Railroad Crossings
- Utilities
- Visibility
- Cyber
- Other man-made Threats

ASSETS
- Bridges & Approaches
- Roadway Prism
- Post Tension Concrete Slabs
- Tunnels
- Culverts
- Walls
- ITS Devices
- Traffic Management Center
- Traffic Control

TASKS
- IDENTIFY THREATS AND CDOT ASSETS
  - Identify applicable threats and hazards along project corridor
  - Determine location of assets that exist in the corridor
  - Evaluate if the asset is independent or a part of an impacted system of threats
  - Deliverable: Map of threats and assets

- DOCUMENT VULNERABILITY AND CONSEQUENCE
  - What do we already know about the asset (age, condition, to standard, proximity)?
  - Identify high level infrastructure and user costs
  - Determine expected effects from each threat
  - Deliverable: PEL Risk Assessment Matrix

- ASSESS RISK
  - Determine likelihood of occurrence
  - Understand risk profile within the corridor
  - Prioritize resiliency improvements

- RESILIENT RECOMMENDATIONS
  - Recommend ROW preservation or system related opportunities for resiliency
  - Integrate with PEL implementation
Incorporating Resiliency – Physical Threats

1. Identify threats
2. Identify assets that overlap with each threat
3. Create a "risk area" map to locate all the assets against the predicted locations of threats along the corridor
4. Determine user costs
5. Determine infrastructure costs
6. Identify consequences
7. Determine the vulnerability of the asset to each threat
8. Evaluate the risk
9. Determine the criticality of the roadway segment
10. Prioritize assets
11. Provide resilient recommendations