RESILIENCE AND TRANSPORTATION ASSET MANAGEMENT
A Practical Approach

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Will *Old Creek Bridge* survive a flooding event to allow evacuation of the city?
Outline of the Presentation

- Overview of Transportation Asset Management (TAM)
- Resilience and TAM
- Data for Resilience Studies
- A Practical Framework for Resilience Studies
- Case Studies
- Knowledge Beyond Condition
- Closing Remarks
Resilience of Infrastructure

Resilience:

“the ability for an infrastructure asset (e.g. a bridge) to maintain a level of robustness during or after an extreme event, and to return itself to a desired level of performance within the shortest possible time to minimize the impact on the community.”
Risk and Resilience studies are integral parts of modern “whole-life” TAM practice.

Traditionally asset management did not consider the increasing effects of external and environmental forces.
Challenges, Needs, and Solutions

**CHALLENGES**
- Aging Infrastructure
- More Frequent Natural Disasters*
- Climate Change Effects, Sea Level Rise, etc.**
- Compromised Response, Service Interruption, Infrastructure Loss/Damage

**NEEDS**
- Identify vulnerabilities in the network
- Prioritize long-range plans to address vulnerabilities
- Improve resiliency of the network

**SOLUTIONS**
- Risk and Resilience Evaluations
- Optimization of Short- and Long-term Plans

Risk-Based Asset Management is the Viable Solution!
Resiliency and Infrastructure Management

- Agency policies and strategies
- Hazards and vulnerabilities
- Criticality of assets
- Robustness and redundancy of the network
- Preparedness of the agency
- Past disruptive events
- Climate change effects

Risk Management + Project Prioritization + Long-Range Planning

Improve Network Resiliency
Data Required for Resilience Evaluation

- Resilience evaluations may not pose significant effort and cost to agencies:
  - Most data is available in agency databases.
  - Some data may need to be obtained from other agencies, stakeholders, or expert elicitation.

- Intelligent TAM practice should develop protocols for efficient data collection.

![Resilience Data Sources Diagram]

- Agency Policies
- Agency Practices
- Local Resources
- Climate Change Effects
- Inventory Data
- Hazard Maps
- GIS Maps
- Asset Condition
Applicability to Infrastructure Assets

- Resilience evaluation can:
  - Be applied to an individual or network of assets
  - Encompass multiple asset types
  - Include multiple potential hazards (flood, hurricane, tornado, etc.)
  - Incorporate effects of climate change
A Practical Resilience Measurement Framework

- Factors that affect resilience:
  - Performance of the asset
  - Loss of performance during the disruptive event
  - Preparedness of the agency
  - Importance and complexity of the asset
  - Recovery time
  - Severity of hazard

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Operational (100% Restored)

Vulnerability, Hazard, Criticality of Asset

One Year

Recovery

Complexity of Asset, Preparedness of the Agency, Severity of the Hazard

Preparedness

Recovery Process

Post-Recovery

Phase 1 - Assessment

Phase 2 - Short-Term

Phase 3 - Intermediate

Phase 4 - Long-Term
## Select Hazards, Vulnerabilities, Factors

<table>
<thead>
<tr>
<th>Hazards Considered</th>
<th>Hazard Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Scour;</td>
<td>Outside of a 500 yr flood plain</td>
</tr>
<tr>
<td>Debris and ice;</td>
<td>Seismic Design Category A (Low probability of earthquake leading to)</td>
</tr>
<tr>
<td>Vessel Collision;</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vulnerabilities Considered</th>
<th>Vulnerability Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Founded on deep foundations or bedrock</td>
</tr>
<tr>
<td></td>
<td>No history and no evidence of scour/settlement</td>
</tr>
</tbody>
</table>

### Bridge Importance Factor

<table>
<thead>
<tr>
<th>Bridge Importance Factor</th>
<th>0.75</th>
<th>1.0</th>
<th>1.25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bridge is located on local routes</td>
<td>Bridge is located on National Highway System (NHS) or State routes</td>
<td>Bridge is located on Evacuation Routes, Critical infrastructure, STRAHNET, or National Network for Trucks</td>
</tr>
<tr>
<td></td>
<td>Replacement cost less than 5% of total agency budget</td>
<td>Replacement cost more than 5% and less than 25% of agency budget</td>
<td>Replacement cost more than 25% of agency budget</td>
</tr>
<tr>
<td></td>
<td>Bridge does not carry utility lines</td>
<td>Bridge carries utility lines such as fiber optics, communication lines, or other low-risk utilities (Co-Location)</td>
<td>Bridge carries utility lines such as electricity, gas, or other high risk utilities (Co-Location)</td>
</tr>
<tr>
<td></td>
<td>ADT less than 10,000</td>
<td>ADT less than 10,000</td>
<td>ADT more than 50,000</td>
</tr>
<tr>
<td></td>
<td>Detour length less than 3 miles OR Level of Service on detour is A or B</td>
<td>Detour length less than 3 miles OR Level of Service on detour is A or B</td>
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</tr>
</tbody>
</table>
US-90 Bridge over Biloxi Bay, MS\(^{(a)}\)

- The original US-90 Biloxi Bay Bridge structures suffered extensive damage during Hurricane Katrina because of shifting of bridge segments due to storm surge.

\(^{(a)}\) This example is for the purpose of demonstrating the concept only. Certain assumptions had to be made due to unavailability of the data. Working with the agency, more accurate data can be obtained, and thus a more accurate analysis can be performed.

\(^{(b)}\) Bing Maps  \(^{(c)}\) bigeyeinthesky.com, Edward S. Frank  \(^{(d)}\) Padgett et al., “Bridge Damage and Repair Costs from Hurricane Katrina”, 2008
US-90 Bridge over Biloxi Bay, MS

- Highest hazard: flood and hurricane storm surge
- Highest vulnerability: low clearance, a simply supported system, and friction bearings
- Mississippi Coast: hurricane-susceptible zone
  - Potential: Severe hazard with Regional effects
- Multi-span bridge: complex construction increases recovery time.

Friction Bearings (a)

Simple supported design and lack of lateral restraint led to lateral movement of spans (a)

(a) Robertson et al., “Coastal bridge performance during Hurricane Katrina”, 2007
(b) Chen, “A Lesson From Hurricane Katrina”, 2006
Resilience Measure

- Validation of Resilience Calculations*
  - Spans shifted due to wave action as a result of low under-clearance.
  - Validates the highest vulnerabilities identified as part of the study.

- Example Recommendation**
  - Altering the simply supported construction
  - Replacing the friction bearings with elastomeric bearings with sufficient uplift and transverse movement restraints
  - Reduce vulnerabilities.

* Details of this analysis are eliminated for the sake of brevity.

** working with the engineering department to reduce vulnerability
Case Study B – High Resiliency

- 2 span continuous steel girder with concrete slab bridge.
- Carries an urban principal arterial route with ADT of 16,000 and ADTT of about 1,000.
- Spans over an interstate highway. Vertical under-clearance 16’-5”.

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NBI Condition Data

7 Superstructure: Good Condition
7 Substructure: Good Condition
6 Deck: Satisfactory Condition
5 Structure: Somewhat better than minimum
4 Deck Geometry: Meets minimum tolerable limits to be left in place as is
Case Study B – High Resiliency

- Located in Seismic Design Category B with record of moderate earthquake.
- Over a roadway with ADTT more than 5,000.
- Located on evacuation route, long detour length, carries low risk utility line.
- More than 50 yrs since major repair, fatigue details cat C and D.

- Potential hazard: **Low hazard with Regional** effects
Knowledge Beyond Condition

**CHEN, “A Lesson From Hurricane Katrina”, 2006**
Stakeholder Engagement is Key

**DATA**
- Inventory
- Condition
- Capacity
- Cost

**INFORMATION**
- Risk Profiles
- Trends
- Performance Measures

**KNOWLEDGE**
- Mitigation Strategies & Recovery
- Prioritized LRN

**DECISION**
- What?
- When?
- How Much?
- Where?

CDM SMITH

OWNER

OTEC 2016
Reporting and Visualization of Results

- GIS-based dashboards
- Customized reports can be developed based on agency needs
Notes about Resilience

- Resilience also affects the **community and economy**
- **Collaboration** between stakeholders makes the effort more effective.
- Infrastructure systems have internal and external **dependencies**
- Recovery should be done based on **criticality of assets**

Interdependencies of infrastructure systems (transportation and gas line).

Criticality of an asset in emergency response should be considered.
Summary

- Risk and Resilience Evaluations provide knowledge beyond inventory or condition assessment
  - Informed and data-driven decision making
  - Optimize and prioritize short- and long-term plans

- Assessments should be agency specific

- Policies, practices, experiences, and institutional knowledge of the agency serve as key inputs to the studies

- Collaboration among all infrastructure stakeholders is important
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Thank You.