Screening & Retrofit Prioritization of Truss Bridges

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Screening of Truss Bridges

- Identify Inventory of “N” Bridges
  - SC Trusses
  - Essential Bridges
  - Compile group: \( G = \{B_1, \ldots, B_N\} \)

- Compilation of Basic Information (for each bridge)
  - Structural characteristics
  - Soil conditions & site hazard
  - Performance level desired
  - Importance of link in network

Prioritization of SC Truss Bridges

- Pertinent Factors
  - Function of bridge as a symbol to community
  - Importance
  - Physical condition
  - Serviceability
  - Service life category
Prioritization for Seismic Retrofit

**Prioritization Basis**

- $G = \{B_1, \ldots, B_N\}$  Group of $N$ bridges in a region
- $M = $ Resources allocated for rehabilitation of $N$ bridges

Prioritization Index: $P = \{P_1, \ldots, P_N\}$

**Various Methods**
- Subjective
- Computational

Prioritization Algorithms

**Method of Indices:**

$$P = P(R, I, NSO)$$

- $R = $ Rank (function of seismic vulnerability)
- $I = $ Importance (function of ADT, cost, etc.)
- $NSO = $ Non-seismic & Other Factors

**Method of Expected Damage:**

$$P = P(R, H_{LOSS}, NSO)$$

- $R = $ Rank (function of direct loss due to damage)
- $H_{LOSS} = $ Indirect Loss
- $NSO = $ Non-seismic & Other Factors
Method of Indices

\[ P = P(R,I,NSO) = \alpha_1 R + \alpha_2 I + \alpha_3 NSO \]

\[ \alpha_i = \text{relative weight; } \sum \alpha_i = 1.0 \]

Non-Seismic & Other Factors

\[ V = \max \{ V_1, V_2 \} \]

Vulnerability Index reflecting susceptibility to connection & bearing failure:

0 : low-to-moderate  
6 : moderate-to-high

V2 = \sum w_i V_{2,i}

Vulnerability Index based on structural and foundation sub-systems susceptibility:

0 : low-to-moderate  
6 : moderate-to-high

Rank

\[ P = \alpha_1 R + \alpha_2 I + \alpha_3 NSO \]

E = 10 F_v S_1 ; \quad F_v = \text{site coefficient} \quad S_1 = Sa (T=1sec)

V = \max \{ V_1, V_2 \}

Bridge Inspection

- Observation
- Existing Data Base / Expert Input
- Analysis

V_2 = \sum w_i V_{2,i}
Vulnerability

Bridge over Trinity River, Near Livingston, Texas February 04

Importance Factor

\[ P = \alpha_1 R + \alpha_2 I + \alpha_3 \text{NSO} \]

- \( r_1 = 0.8 \) - County Arterial
- \( r_2 = 0.5 \) - County Hwy
- \( r_3 = 0.2 \) - Local Access

- \( d_1, d_2 = \) detour distances
- \( r_1 (d_1/d_{ref}) \) and \( r_2 (d_2/d_{ref}) \)

Utility factor:
- \( 1 \) if utilities carried by bridge
- \( 0 \) if no utilities on bridge

Costs scale factors:
- \( \alpha_1 \) and \( \alpha_2 \)

- Costs = \( \text{ADT} / \text{ADT}_{ref} \)
Non-Seismic & Other Factors

\[ P = \alpha_1 R + \alpha_2 I + \alpha_3 \text{NSO} \]

- does not lend itself to direct enumeration
- owner agency criteria
- assumed on relative basis

\[ \alpha_{i} = \text{relative weight; } \sum \alpha_{i} = 1.0 \]

Priority Index, Method of Indices

\[ P = P(R,I,\text{NSO}) \]

\[ = \alpha_1 R + \alpha_2 I + \alpha_3 \text{NSO} \]

\( R, I, \text{NSO} = [0, \ldots, 100] \)

\[ \alpha_{i} = \text{relative weight; } \sum \alpha_{i} = 1.0 \]

\[ e.g. \quad \begin{array}{c|c|c|c} R & I & \text{NSO} & \sum \alpha_{i} = 2.25 \alpha_{o} \\ \hline \alpha_1 = 1/2.25 \alpha_{o} & \alpha_2 = 1/4 \alpha_{o} & \alpha_3 = 1/4 \alpha_{o} & \end{array} \]

\[ \alpha_{o} = 1/2.25 \]

\[ [0 - 100] \]
Method of Expected Damage

\[ P = P(R, H_{LSS}, NSO) = \alpha_1 R + \alpha_2 H_{LSS} + \alpha_3 NSO \]

\( R, H_{LSS}, NSO = [0, \ldots, 100] \)

\( \alpha_i = \text{relative weight; } \sum \alpha_i = 1.0 \)

\[ P \Rightarrow [0 - 100] \]

Rank

\[ P = \alpha_1 R + \alpha_2 H_{LSS} + \alpha_3 NSO \]

\( R (B_{LSS}) = \frac{100 B_{LSS}}{\max (B_{LSS} \text{ of group})} \)

\( B_{LSS} = U \times RCR_T \)

Total repair cost ratio; function of 5 damage states:
- DS1 = No Damage
- DS2 = Slight Damage
- DS3 = Moderate Damage
- DS4 = Extensive Damage
- DS5 = Collapse
Rank (cont’d)

\[ RCR_T = \sum_i RCR_i P[DS_i | Sa(1)] \rightarrow \text{Total repair cost ratio} \]

\[ Sa(1) = Sa \text{ at 1-sec period} \]

\[ RCR_i = \text{Repair cost of Damage State } "i", DS_i \]

\[ P[DS_i | Sa(1)] = \text{Probability of DS}_i \text{ occurrence, for a give } Sa(1) \]

\[ = \frac{1}{1 + \{Sa(1) /A_i\}^{-1.7 / \beta_c}} \]

\[ A_i = \text{Median spectral acceleration to cause damage state } "i" \]

\[ \beta_c = \text{randomness & uncertainty parameter } = 0.6 \text{ recommended} \]

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**Damage State** | **Damage Type** | **A\(_i\) (g)**
---|---|---
1 | None | 0.10
2 | Slight | 0.15
3 | Moderate | 0.40
4 | Extensive | 0.60
5 | Collapse | 1.0

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**Fragility Curves**

Example
Rank (cont’d)

- **Fragility Curves**
  - Load paths and potential damage mechanisms
  - Limit states to characterize 5 damage states (DSi)

\[ R = 100 \frac{B_{LOSS}}{\max \{ B_{LOSS} \text{ for group } \}} \]

**Indirect Loss**

\[ P = \alpha_1 R + \alpha_2 H_{LOSS} + \alpha_3 \text{NSO} \]

- Indirect Loss Factor
  - does not lend itself to direct enumeration
  - owner agency criteria
  - assumed on relative basis
Non-Seismic and Other Factors

\[ P = \alpha_1 R + \alpha_2 H_{\text{LOSS}} + \alpha_3 \text{NSO} \]

Non-Seismic & Other Factors
- does not lend itself to direct enumeration
- owner agency criteria
- assumed on relative basis

Priority Index, Method of Expected Damage

\[ P = P(R, H_{\text{LOSS}}, \text{NSO}) \]
\[ = \alpha_1 R + \alpha_2 H_{\text{LOSS}} + \alpha_3 \text{NSO} \]

\( R, H_{\text{LOSS}}, \text{NSO} = [0, \ldots, 100] \)
\( \alpha_i = \text{relative weight; } \Sigma \alpha_i = 1.0 \)

\[ \left\{ \begin{array}{l}
\alpha_1 = 1 \\
\alpha_2 = 1/2 \alpha_0 \\
\alpha_3 = 1/3 \alpha_0 \\
\Sigma \alpha_i = 1.83 \alpha_0 \\
\alpha_0 = 1/1.83
\end{array} \right. \]

\[ P \mapsto [0 - 100] \]
### Example 1: Method of Indices

Group of 10 bridges:  $\alpha_o = 0.444$;  
$\alpha_1 = 1$, $\alpha_2 = 0.444$  
$\alpha_3 = 1/4$, $\alpha_4 = 0.111$  

<table>
<thead>
<tr>
<th>Bridge</th>
<th>R</th>
<th>I</th>
<th>NSO</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>75</td>
<td>85</td>
<td>20</td>
<td>73</td>
</tr>
<tr>
<td>B2</td>
<td>90</td>
<td>45</td>
<td>75</td>
<td>68</td>
</tr>
<tr>
<td>B3</td>
<td>40</td>
<td>25</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>B4</td>
<td>100</td>
<td>90</td>
<td>75</td>
<td>93</td>
</tr>
<tr>
<td>B5</td>
<td>80</td>
<td>100</td>
<td>50</td>
<td>86</td>
</tr>
<tr>
<td>B6</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>42</td>
</tr>
<tr>
<td>B7</td>
<td>25</td>
<td>75</td>
<td>10</td>
<td>46</td>
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<tr>
<td>B8</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>B9</td>
<td>80</td>
<td>10</td>
<td>75</td>
<td>48</td>
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<tr>
<td>B10</td>
<td>50</td>
<td>90</td>
<td>20</td>
<td>64</td>
</tr>
</tbody>
</table>

### Example 2: Method of Expected Damage

Group of 10 bridges:  $\alpha_o = 0.545$;  
$\alpha_1 = 1$, $\alpha_2 = 0.545$  
$\alpha_3 = 1/2$, $\alpha_4 = 0.273$  
$\alpha_5 = 1/3$, $\alpha_6 = 0.182$  

<table>
<thead>
<tr>
<th>Bridge</th>
<th>R</th>
<th>HLOSS</th>
<th>NSO</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
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<td>50</td>
<td>10</td>
<td>29</td>
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<tr>
<td>B2</td>
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<td>45</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>B3</td>
<td>100</td>
<td>90</td>
<td>50</td>
<td>88</td>
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<tr>
<td>B4</td>
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<td>90</td>
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<td>43</td>
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<tr>
<td>B5</td>
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<td>95</td>
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<tr>
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<td>50</td>
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<td>41</td>
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<tr>
<td>B7</td>
<td>75</td>
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<td>61</td>
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<tr>
<td>B10</td>
<td>85</td>
<td>45</td>
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