MULTI-OBJECTIVE OPTIMIZATION FOR LONG-TERM NETWORK-LEVEL RENEWAL PLANNING OF BRIDGES IN IOWA: PHASE II PROGRESS REPORT
IDS Program Objectives

- Comprehensive analysis of Iowa bridge inventory and condition data.
- Development of deterioration models to predict bridge performance based on historical Iowa NBI data.
- Development of a risk-based prioritization model to rank bridges based on both the likelihood of failure and consequence of failure, and then assign priority indices to indicate relative urgency of preservation actions.
- Development of 20-year optimal preservation plans that maximize system-wide performance and minimize risks under a range of budget and performance target scenarios.
- Investigating trade-offs between funding levels and system-wide performance and risk levels.
# Bridge Type Groupings

<table>
<thead>
<tr>
<th>Group ID</th>
<th>Bridge type (NBI Items 43A/43B)</th>
<th>Route Type (NBI Item 5B)</th>
<th>Type of Service on bridge (NBI Item 42A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group #1</td>
<td>Continuous Steel</td>
<td>Interstate</td>
<td>Mainline Highway only</td>
</tr>
<tr>
<td>Group #2</td>
<td>Prestressed Girder</td>
<td>Interstate</td>
<td>Mainline Highway only</td>
</tr>
<tr>
<td>Group #3</td>
<td>Continuous Steel</td>
<td>Interstate</td>
<td>Overpass at Interchange</td>
</tr>
<tr>
<td>Group #4</td>
<td>Prestressed Girder</td>
<td>Interstate</td>
<td>Overpass at Interchange</td>
</tr>
<tr>
<td>Group #5</td>
<td>Continuous Slab</td>
<td>Interstate</td>
<td>Mainline/Overpass at interchange</td>
</tr>
<tr>
<td>Group #6</td>
<td>Simple span Steel</td>
<td>All Routes</td>
<td>All Types</td>
</tr>
<tr>
<td>Group #7</td>
<td>Continuous Steel</td>
<td>U.S. or State</td>
<td>All Types</td>
</tr>
<tr>
<td>Group #8</td>
<td>Prestressed Girder</td>
<td>U.S. or State</td>
<td>All Types</td>
</tr>
<tr>
<td>Group #9</td>
<td>Simple Span Slab</td>
<td>All Routes</td>
<td>All Types</td>
</tr>
<tr>
<td>Group #10</td>
<td>Continuous Slab</td>
<td>U.S. or State</td>
<td>All Types</td>
</tr>
<tr>
<td>Group #11</td>
<td>Two Girder Steel</td>
<td>All Routes</td>
<td>All Types</td>
</tr>
<tr>
<td>Group #12</td>
<td>Continuous/Simple Span Steel</td>
<td>County or City</td>
<td>All Type</td>
</tr>
<tr>
<td>Group #13</td>
<td>Prestressed Girder</td>
<td>County or City</td>
<td>All Types</td>
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</tbody>
</table>
Bridge Evaluation

- 6 different preservation methods using 16 different scenarios
  - Concrete Overlay
  - Deck Repair
  - Deck Replacement
  - Bridge Replacement
  - Bridge Widening
  - Prestressed Beam End Repair
<table>
<thead>
<tr>
<th>Method</th>
<th>Unit Cost</th>
<th>Maximum Total Budget</th>
<th>Condition Improvement</th>
<th>Material (Item 43A)</th>
<th>Deck Condition (Item 58)</th>
<th>Superstructure Condition (Item 59)</th>
<th>Substructure Condition (Item 60)</th>
<th>Operating Rating (Item 61)</th>
<th>Wearing Surface (Item 108A)</th>
<th>Deck Protection (Item 108C)</th>
<th>Deck Geometry (Item 68)</th>
<th>Condition Index - S1 Agency Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Slump Concrete Overlay</td>
<td>$50/sq. ft.</td>
<td>15%</td>
<td>3 point increase in Deck with a maximum deck condition rating of 7, increase superstructure and substructure by 1 point with a maximum condition rating of 7.</td>
<td>1,2,3,4,5</td>
<td>4.5</td>
<td>&gt;3</td>
<td>&gt;3</td>
<td>&gt;32.4 tons</td>
<td>4</td>
<td>0.1,2</td>
<td>&gt;3</td>
<td>&gt;30</td>
</tr>
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<td>15%</td>
<td>3 point increase in Deck with a maximum deck condition rating of 7, increase superstructure and substructure by 1 point with a maximum condition rating of 7.</td>
<td>1,2,3,4,5</td>
<td>4,5,6</td>
<td>&gt;5</td>
<td>&gt;5</td>
<td>&gt;32.4 tons</td>
<td>1</td>
<td>0</td>
<td>&gt;3</td>
<td>&gt;30</td>
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<td>5</td>
<td>&gt;4</td>
<td>&gt;4</td>
<td>&gt;32.4 tons</td>
<td>1</td>
<td>1.2</td>
<td>&gt;3</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Deck Replacement (Interstate)</td>
<td>$115/sq. ft.</td>
<td>25%</td>
<td>Deck to condition 8, Superstructure to condition 7, Substructure to condition 7</td>
<td>1,2,3,4,5</td>
<td>&lt;=5</td>
<td>&gt;=5</td>
<td>&gt;=5</td>
<td>&gt;32.4 tons</td>
<td>1, 4</td>
<td>0.1,2</td>
<td>&gt;4</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Deck Replacement (Non-Interstate)</td>
<td>$115/sq. ft.</td>
<td>25%</td>
<td>Deck to condition 8, Superstructure to condition 7, Substructure to condition 7</td>
<td>1,2,3,4,5</td>
<td>&lt;=5</td>
<td>&gt;=5</td>
<td>&gt;=5</td>
<td>&gt;32.4 tons</td>
<td>1, 4</td>
<td>0.1,2</td>
<td>&gt;3</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Deck Repair</td>
<td>$25/sq. ft.</td>
<td>1%</td>
<td>2 points increase in Deck</td>
<td>1,2,3,4,5</td>
<td>4.5</td>
<td>&gt;4</td>
<td>&gt;4</td>
<td>any</td>
<td>4</td>
<td>0.1</td>
<td>any</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Bridge Replacement (non-Interstate)</td>
<td>$325/sq. ft.</td>
<td>75%</td>
<td>New</td>
<td>1,2,3,4,5</td>
<td>&lt;6</td>
<td>&lt;6</td>
<td>&lt;6</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>&lt;35</td>
</tr>
<tr>
<td>Bridge Replacement (Interstate)</td>
<td>$275/sq. ft.</td>
<td>75%</td>
<td>New</td>
<td>1,2,3,4,5</td>
<td>&lt;6</td>
<td>&lt;6</td>
<td>&lt;6</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>&lt;35</td>
</tr>
<tr>
<td>Bridge Replacement (non-Interstate)</td>
<td>$275/sq. ft.</td>
<td>75%</td>
<td>New</td>
<td>1,2,3,4,5</td>
<td>any</td>
<td>&lt;5</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
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<td>$275/sq. ft.</td>
<td>75%</td>
<td>New</td>
<td>1,2,3,4,5</td>
<td>any</td>
<td>any</td>
<td>&lt;5</td>
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<td>1,2,3,4,5</td>
<td>&lt;5</td>
<td>&lt;=7</td>
<td>&lt;=7</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>&lt;35</td>
</tr>
<tr>
<td>Bridge Widening</td>
<td>$1000/sq. ft.</td>
<td>5%</td>
<td>2 point increase in Deck with a maximum rating of 8, Superstructure to condition 7, Substructure to condition 7</td>
<td>3,4,5</td>
<td>&gt;4</td>
<td>&gt;4</td>
<td>&gt;4</td>
<td>&gt;32.4 tons</td>
<td>any</td>
<td>any</td>
<td>2</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Prestressed Beam End Repair</td>
<td>$1500/ beam end</td>
<td>5%</td>
<td>Superstructure increase 2 points to a maximum of 7, Substructure to condition 7</td>
<td>5</td>
<td>&gt;4</td>
<td>&lt;5</td>
<td>&gt;4</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>any</td>
<td>&gt;30</td>
</tr>
</tbody>
</table>
Deterioration Factors

- Age
- ADT
- ADTT
- Length of Maximum Span
- Number of Lanes
- Deck Protection (wearing surface)
- Deck Protection (Reinforcing Steel)
- Design Load
- Skew Angle
Risk Factors

- Highway System (NHS vs. Non-NHS) - 25%
- Functional Class of Route - 30%
- Detour Length - 15%
- Type of Service Under Bridge - 5%
- ADT - 25%
Programming Budget

- Multiple budget scenarios can be assessed.
- Scenarios can have limits on individual maintenance methods.
- Targets for overall inventory condition can be based on agencies' individual criteria.
- The program output should be viewed as an overall system need or shortfall.
- The program output shows what the most efficient use of program dollars should be based on work types.
Program Scenarios

- $70 million per year
- $100 million per year
- $100-$120-$140-$160 million stepped every 5 years
- $100 million min. to $250 million max.
- No limit per year with condition index threshold of 42

Budget limit examples:

- 40% of budget for replacements
- 60% of budget for replacements
- 75% of budget for replacements
- No limit on replacements

Large Project Limits:

- Any project over $5 million
- $120 million annual limit
- No annual budget limit
- Different project criteria
IDS Program vs. Iowa Program

- IDS proposed 1632 projects over 20 years from 2014 thru 2033
- 384 of the 1632 projects are already programmed or were completed in 2011, 2012, or 2013
- 142 of the 384 are in the first 5 years of IDS’s program
- 854 of the 1632 projects have a proposed work item in our Structure Inventory and Inspection Management System
Do Nothing for 20 Years

Change in Condition Index

Change in Structurally Deficient Bridges
$70$ Mill. Annual Budget

**Change in Condition Index**

**Change in SD Bridges**

**Dollars Spent of $70$ mill. Budget Allowance**

**Dollars Spent of $120$ mill. For Large Projects**
Over a 21 Year Period
Over a 21 Year Period
Change in Condition Index

Change in Structurally Deficient Bridges

Budget Spent Annually

Large Project Budget Spent Annually

$100-$120-$140-$160 Budget Scenario

$120-$140-$160 Budget Scenario
Over a 21 Year Period
Over a 21 Year Period
$2,760,000,000 Max.
Total/Scenario
Questions?

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