Modeling of Life Cycle Alternatives in the National Bridge Investment Analysis System (NBIAS)

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Topics

- NBIAS Overview
- Prior NBIAS Modeling Approach
- NBIAS 5.0 Modeling Enhancements
- Future Directions for NBIAS
- Conclusions
NBIAS Overview

• NBIAS is the analysis system used by FHWA to predict future bridge investment needs and performance for the biennial C&P Report
• The system predicts conditions and performance of each of the >600,000 highway bridges in the NBI
• Example questions NBIAS can help answer:
  – What is the size of the maintenance, repair and rehabilitation backlog for the bridges on the National Highway System?
  – What level of spending is required annually to maintain current bridge conditions over the next 20 years?
  – What user benefits might be achieved through addressing current bridge functional improvement needs?
NBIAS Key Features

- Uses a modeling approach adapted from Pontis
- Needs considered
  - Maintenance, repair and rehabilitation (MR&R)
  - Widening existing lanes and shoulders
  - Strengthening
  - Raising
- Performs a parameterized analysis with analysis steps varying by
  - Budget
  - Cutoff benefit/cost ratio
  - Budget growth rate
- Includes a what-if analysis module for dynamically viewing analysis results
NBIAS Data

- Core data comes from the NBI
  - Bridge inventory
  - Summary conditions
- Element level data can be imported or predicted from a set of synthesis, quantity and condition (SQC) models
- Other data
  - Cost data reported to FHWA
  - Element models derived from state data
  - User cost parameters from HERS
Prior NBIAS Modeling Approach

- MR&R policy determined through Markov modeling approach
  - One year decision period
  - Similar to Pontis, though with user costs, consideration of a “do nothing” cost
- Program simulation used to simulate work and future conditions
  - Year-by-year simulation
  - Incremental benefit cost ratio (IBCR) approach used to select work given a budget
  - One overall budget constraint
Issues with the Modeling Approach

• MR&R policy
  – Element-level “optimal” MR&R policy is not always optimal
  – Assumption that needed work will be performed next year if deferred does not consider possibility of chronic deferral or potential for future bridge replacement
  – Life cycle cost minimizing approach often is to wait until an element is in its worst condition to take action – may not be realistic `or consistent with agency practice

• Program simulation
  – Single overall budget – *FHWA sought to specify budget by work type*
  – Year-by-year simulation can result in downstream unspent funds or unmet needs
NBIAS 5.0 Modeling Enhancements

• Life-cycle alternatives
  – 21 generated for each bridge
  – Each specifies action to be taken over a 5-year period
• Revised MR&R policy
  – Solved for a one-year to a five-year policy
  – Results in revised transition probabilities but no change to underlying model formulation
• Revised program simulation
  – Simulation selects project alternative for each bridge, looking across all years at once
  – Implemented revised IBC approach to accommodate a matrix of budget constraints by year and action type
## Life Cycle Alternatives

<table>
<thead>
<tr>
<th>Alt.</th>
<th>Action by Period</th>
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<tbody>
<tr>
<td></td>
<td>1</td>
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<tr>
<td>1</td>
<td>DN</td>
</tr>
<tr>
<td>2</td>
<td>DN</td>
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Revised MR&R Policy

<table>
<thead>
<tr>
<th>State</th>
<th>Action</th>
<th>Probability of Transition to State</th>
<th>Unit Cost ($)</th>
<th>Long-Term Cost ($)</th>
<th>Optimal?</th>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>1</td>
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<td>161.48</td>
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<tr>
<td></td>
<td>Clean &amp; Patch</td>
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<td>677.31</td>
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<tr>
<td>3</td>
<td>Do Nothing</td>
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<td>984.32</td>
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<tr>
<td></td>
<td>Clean &amp; Patch</td>
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<td>725.77</td>
<td>910.05</td>
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<tr>
<td>4</td>
<td>Do Nothing</td>
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<td>2,127.88</td>
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<td>2,026.86</td>
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<td>4,035.60</td>
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<table>
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<tr>
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<th>Action</th>
<th>Probability of Transition to State</th>
<th>Unit Cost ($)</th>
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<th>Optimal?</th>
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<tbody>
<tr>
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<td>1  2  3  4  Fail</td>
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<td></td>
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<tr>
<td>1</td>
<td>Do Nothing</td>
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<td>0% 55% 33% 10% 2%</td>
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<td>2,259.49</td>
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<tr>
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<td>Replace</td>
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<td>3,953.51</td>
<td>4,264.17</td>
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</table>
Revised Program Simulation

Start

Input data and scenario specifications

Compile bridge data

Generate life-cycle alternatives

Sort alternatives

Simulate budget allocation

Set period to first analysis period

Cycle Repeated for Each Period

Apply selected alternative to each bridge

Calc. and record MOE

Final period?

Yes

No

Proceed to next period

End

Final period?

Yes

No

Cycle Repeated for Each Period

Apply selected alternative to each bridge

Calc. and record MOE

Final period?

Yes

No

Proceed to next period

End
Revised IBCR Approach

• “Classic” IBCR approach
  – Designed for single budget constraint
  – Assumes increasing benefit with increasing costs
  – Alternatives are either discarded or their benefits are adjusted to satisfy the assumptions
  – Once multiple budget constraints are introduced the approach may result in discarding optimal alternatives

• Revised approach
  – Implemented approach detailed by Robert, Gurenich and Thompson and implemented in a tool for Virginia DOT in 2008
  – Retains all alternatives, grouping them into tiers
IBCR Example

INCBEN Heuristic

- A (1, 3)
  - B/C = 3.0
  - IBCR = 3.0

- B (4, 6)
  - B/C = 1.5

- C (6, 12)
  - B/C = 2.0
  - IBCR = 1.8

- B’ IBCR = 2.3
  (interp. from IBCR for A & C)

Revised Approach

- A (1, 3)
  - B/C = 3.0
  - IBCR = 3.0

- B (4, 6)
  - B/C = 1.5

- C (6, 12)
  - B/C = 2.0
  - IBCR = 1.8

Source: Robert, Gurenich and Thompson (2008)
Future Directions for NBIAS

• Continuing to support NBIAS 4.2
  – Added good/fair/poor measure described in PM2
  – Currently being used by FHWA to support the next C&P Report
• Now completing work on NBIAS 5.2
  – Transition to use of new element definitions (FHWA SNBIBE)
  – Updated transition probability models based on work performed by Paul Thompson with data compiled by Paul Jensen
  – Support for culverts
• Expect to use NBIAS 5.x after the next C&P Report and further testing of the new modeling approach
• The NBIAS 5.0 modeling enhancements offer potential for more accurate and robust modeling of bridge investment needs
• Further testing being performed to quantify changes in predicted results relative to prior versions of NBIAS
• Potential further enhancements
  – Increasing number of alternatives considered
  – Use of exact optimization rather than a heuristic approach
  – Implementing parallel processing
  – Various other modeling enhancements
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    • Paul Jensen