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

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Topics

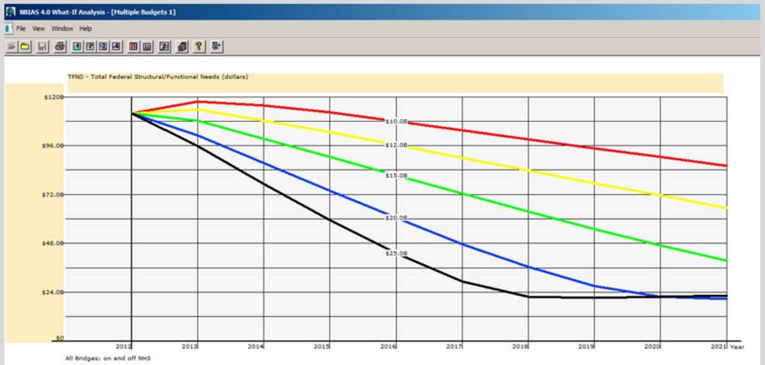
- NBIAS Overview
- Prior NBIAS Modeling Approach
- NBIAS 5.0 Modeling Enhancements
- Future Directions for NBIAS
- Conclusions

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?

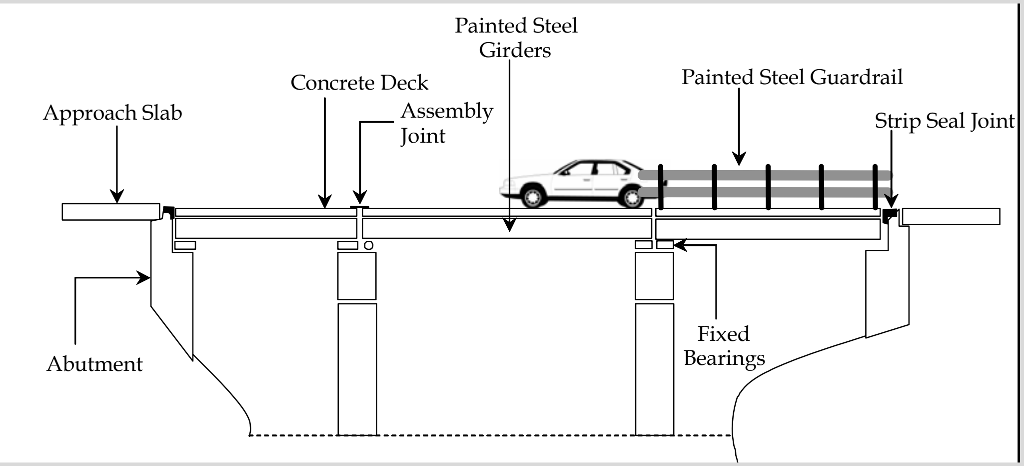
NBIAS Key Features

- 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



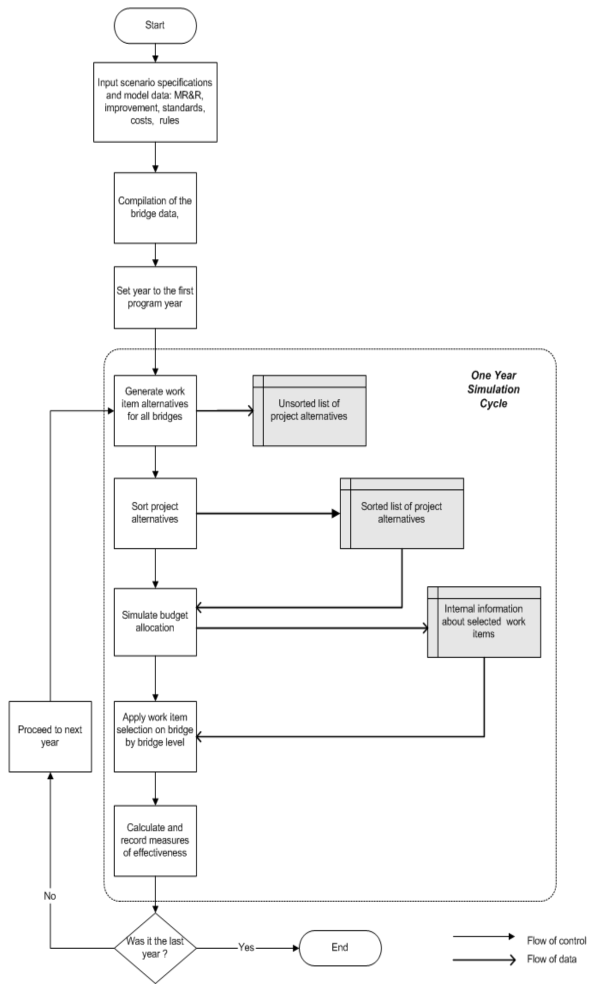
NBIAS Data

- 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

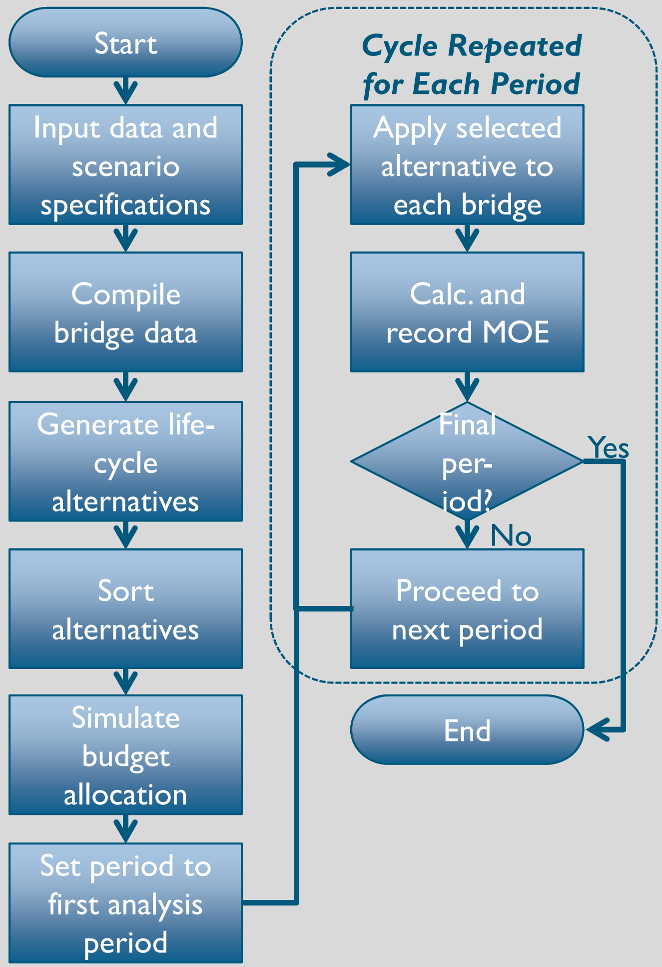
Alt.	Action by Period 1	2	3	4	5	6	7	8	9	10
1	DN	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
2	DN	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
3	DN	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
4	DN	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
5	DN	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R
6	DN	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R
7	DN	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R
8	DN	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R
9	DN	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R
10	DN	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve
11	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
12	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
13	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
14	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R
15	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R	MR&R
16	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R	MR&R
17	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R	MR&R
18	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R	MR&R
19	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve	MR&R
20	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	Improve
21	Improve	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R	MR&R

Revised MR&R Policy

State	Action	Probability of Transition to State 1	2	3	4	Fail	Unit Cost ($)	Long-Term Cost ($)	Optimal?
1	Do Nothing	92%	8%	0%	0%	0%	0.00	87.84	Y
2	Do Nothing	0%	98%	2%	0%	0%	0.00	161.48	Y
	Clean & Patch	86%	14%	0%	0%	0%	584.25	677.31	
3	Do Nothing	0%	0%	87%	13%	0%	0.00	984.32	
	Clean & Patch	53%	38%	10%	0%	0%	725.77	910.05	Y
4	Do Nothing	0%	0%	0%	87%	13%	0.00	2,127.88	
	Rehabilitate	33%	41%	17%	9%	0%	1,620.42	2,026.86	Y
	Replace	100%	0%	0%	0%	0%	3,953.51	4,035.60	

State	Action	Probability of Transition to State 1	2	3	4	Fail	Unit Cost ($)	Long-Term Cost ($)	Optimal?
1	Do Nothing	65%	28%	7%	1%	0%	0.00	435.74	Y
2	Do Nothing	0%	55%	33%	10%	2%	0.00	813.42	Y
	Clean & Patch	86%	14%	0%	0%	0%	584.25	933.12	
3	Do Nothing	0%	0%	50%	37%	13%	0.00	1,432.17	
	Clean & Patch	53%	38%	10%	0%	0%	725.77	1,191.06	Y
4	Do Nothing	0%	0%	0%	48%	52%	0.00	2,372.81	
	Rehabilitate	33%	41%	17%	9%	0%	1,620.42	2,259.49	Y
	Replace	100%	0%	0%	0%	0%	3,953.51	4,264.17	

Revised Program Simulation

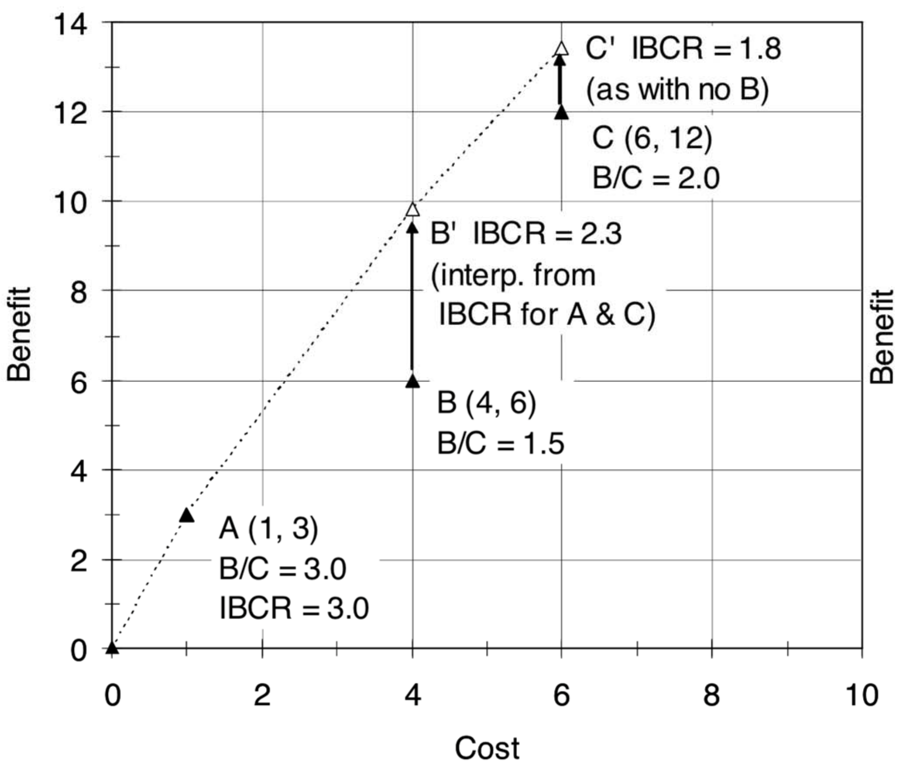


Revised IBCR Approach

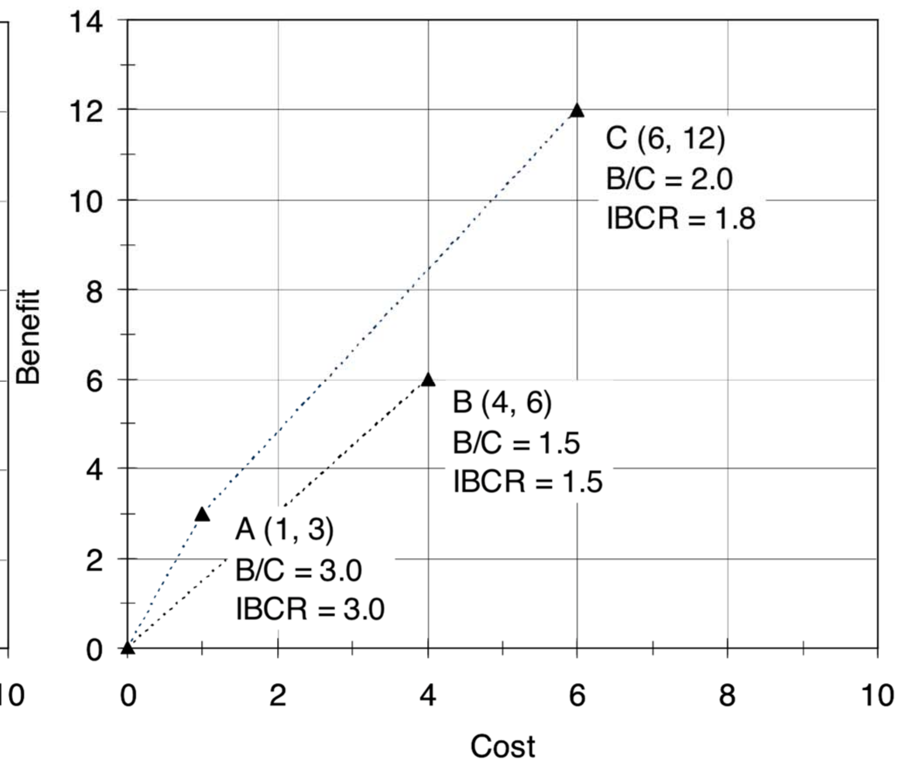
- "Classic" IBCR approach
  - Designed for single budget constraint
  - Assumes increasing benefit with increasing costs
  - Alternatives are either discarded or their benefits are adjusted to satisfy the assumptions
  - Once multiple budget constraints are introduced the approach may result in discarding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



Revised Approach



Source: Robert, Gurenich and Thompson (2008)

spy pond partners, llc

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

Conclusions

- 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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