



AASHTOWare BrM 5.2.3

Deterioration and LCCA

April 26, 2017

Mesa, Arizona

- [Contact](#)
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

BrM Help Desk

AASHTOWareBridge.com

BrM@Bentley.com

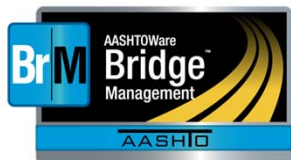
JIRA tickets:

bridgeware.atlassian.net

Josh Johnson, PE

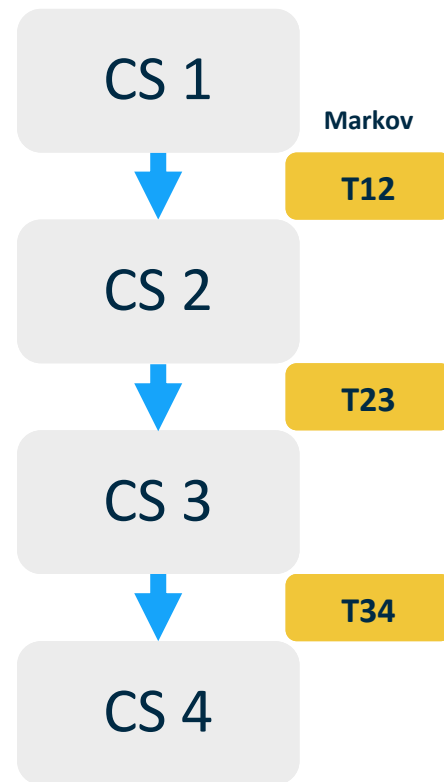
TAM Lead Engineer

Joshua.Johnson@Bentley.com



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration



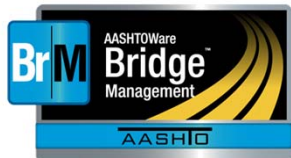
- Estimates the annual transition of elements between four discrete condition states:
 - CS1 – Good
 - CS2 – Fair
 - CS3 – Poor
 - CS4 – Severe
- Given that 100% of the element is in Condition State 1 today, in how many years will only half of that element remain in the Condition State 1?

- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration

Annual Forecasts of Element Conditions					
Year	State1	State2	State3	State4	Health
0	1.000	0.000	0.000	0.000	100.0
1	0.980	0.020	0.000	0.000	99.3
2	0.961	0.038	0.001	0.000	98.7
3	0.942	0.055	0.002	0.000	98.0
4	0.924	0.071	0.005	0.000	97.3
5	0.906	0.086	0.007	0.001	96.5
6	0.888	0.100	0.010	0.002	95.8
7	0.871	0.113	0.013	0.003	95.0
8	0.853	0.125	0.017	0.005	94.2
9	0.837	0.136	0.020	0.007	93.4
10	0.820	0.146	0.024	0.010	92.6
11	0.804	0.156	0.027	0.013	91.7

Deterioration modeling is applied individually for each bridge element



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration

Overall health of the bridge is evaluated by the bridge health index:

$$H.I. = \frac{\sum_e q_e w_e H I_e}{\sum_e q_e w_e}, \text{ where}$$

$$H I_e - \text{element's health index} = CS_1 + \frac{2}{3} CS_2 + \frac{1}{3} CS_3$$

q_e - element's total quantity

w_e - relative weight



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

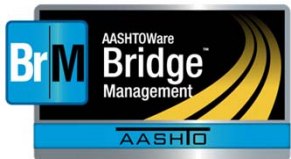
Element Deterioration

Deterioration models are a combination of:

- Weibull Survival Function
- Markovian Process

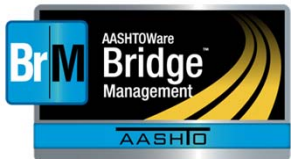
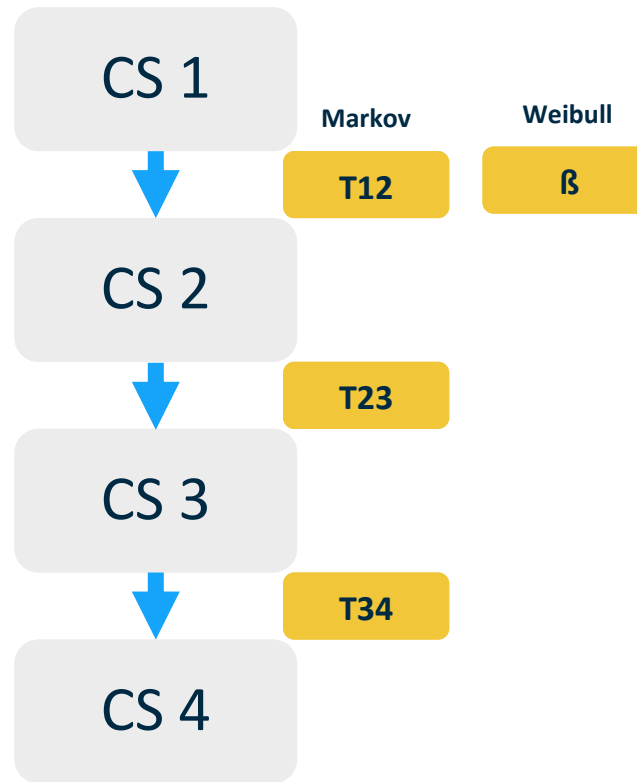
The Weibull Function models **only** CS1 to CS2 transition
(i.e. the onset of deterioration).

The Markovian Process models the rest of transitions (CS2 to CS3 and CS3 to CS4).



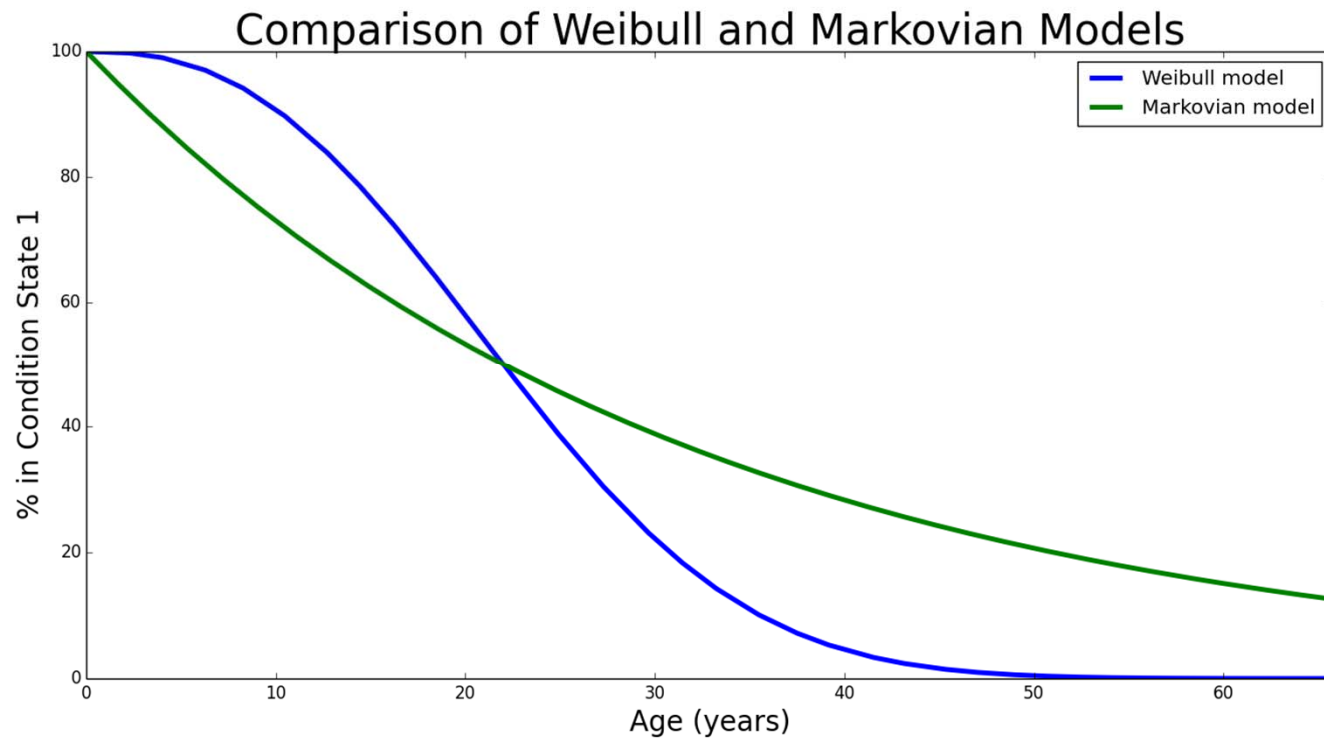
- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

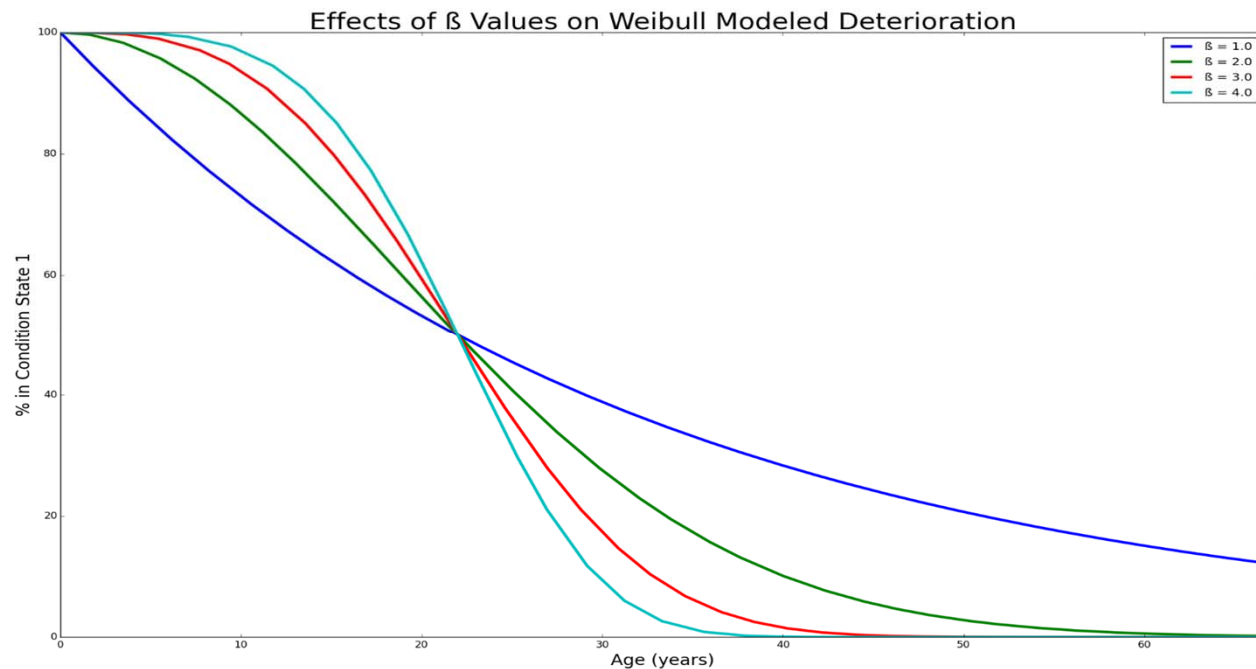
Element Deterioration



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

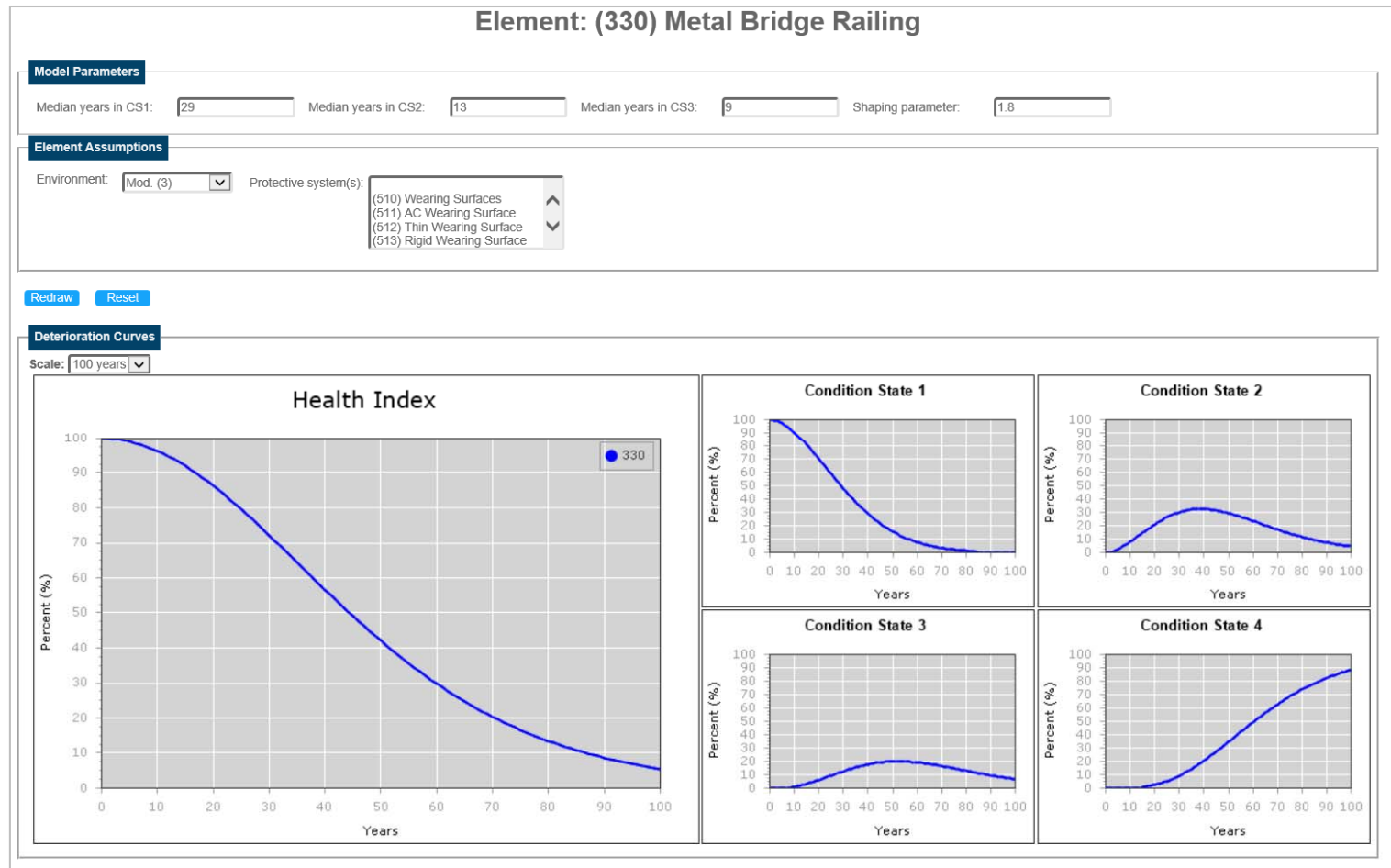
Element Deterioration

- Affects *only* CS1 to CS2 transition.
- A shaping parameter (β) controls the shape of the curve.
- $\beta = 1$ is equivalent to Markov model
- Slower deterioration rates in the early stage (based on β values)



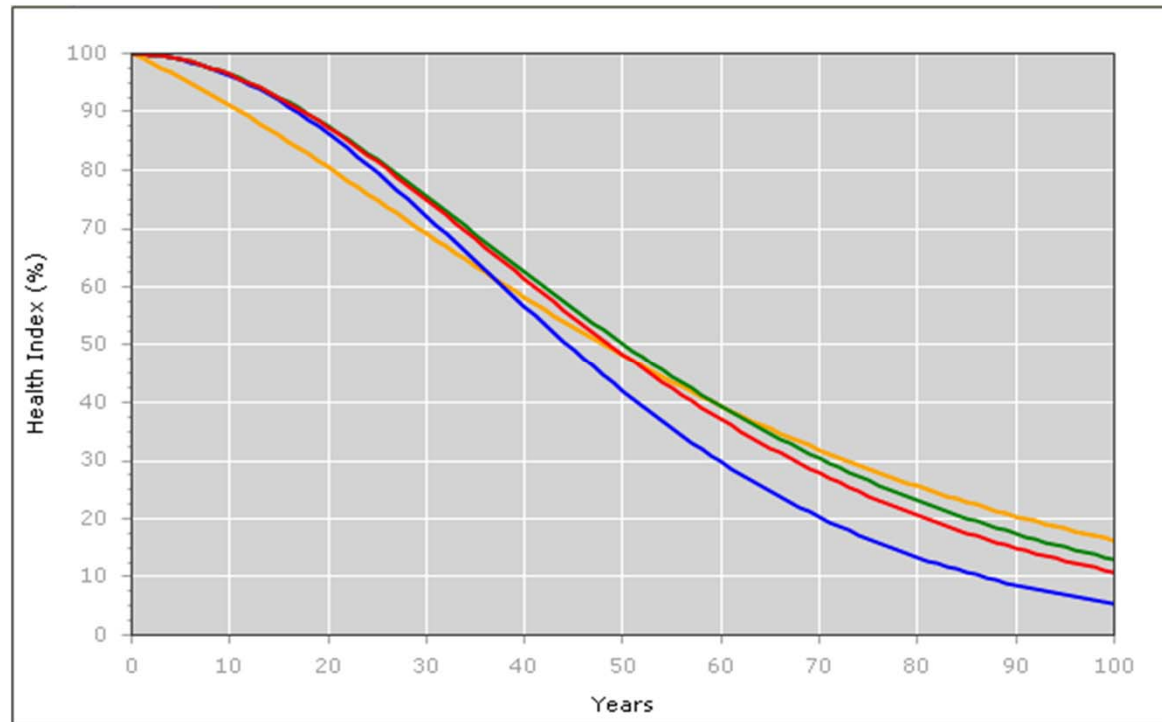
- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration

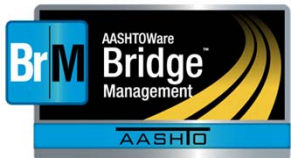


- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration



- Markovian model only (T1: 29, T2: 13, T3: 9, β : 1)
- Weibull + Markovian model (T1: 29, T2: 13, T3: 9, β : 1.8)
- Increasing T2 by 50% (T1: 29, T2: 20, T3: 9, β : 1.8)
- Increasing both T2 and T3 by 50% (T1: 29, T2: 20, T3: 14, β : 1.8)



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration

- **Protective Systems**
 - Designed to slow element deterioration.
 - An element may contain several protective systems

USER, PONTIS Element Spec

Deterioration Modeling

Model: [View Graphs](#)

Model Parameters

Median years in CS1: Shaping parameter:

Median years in CS2: Formula:

Median years in CS3:

Protection Factors

Max. protection parameter:

CS1: CS2:

CS3: CS4:

DATA DICT. | X 523 Waterproof Membrane

CHECKED OUT BRIDGES | X 531 Cathodic Prot.

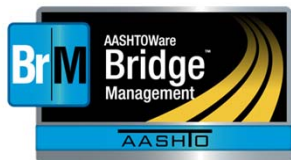
LOGGING | X 900 Abandoned Structure

NAVIGATION & FIELD SECURITY | X 910 Railroad structure

Max. protection parameter:

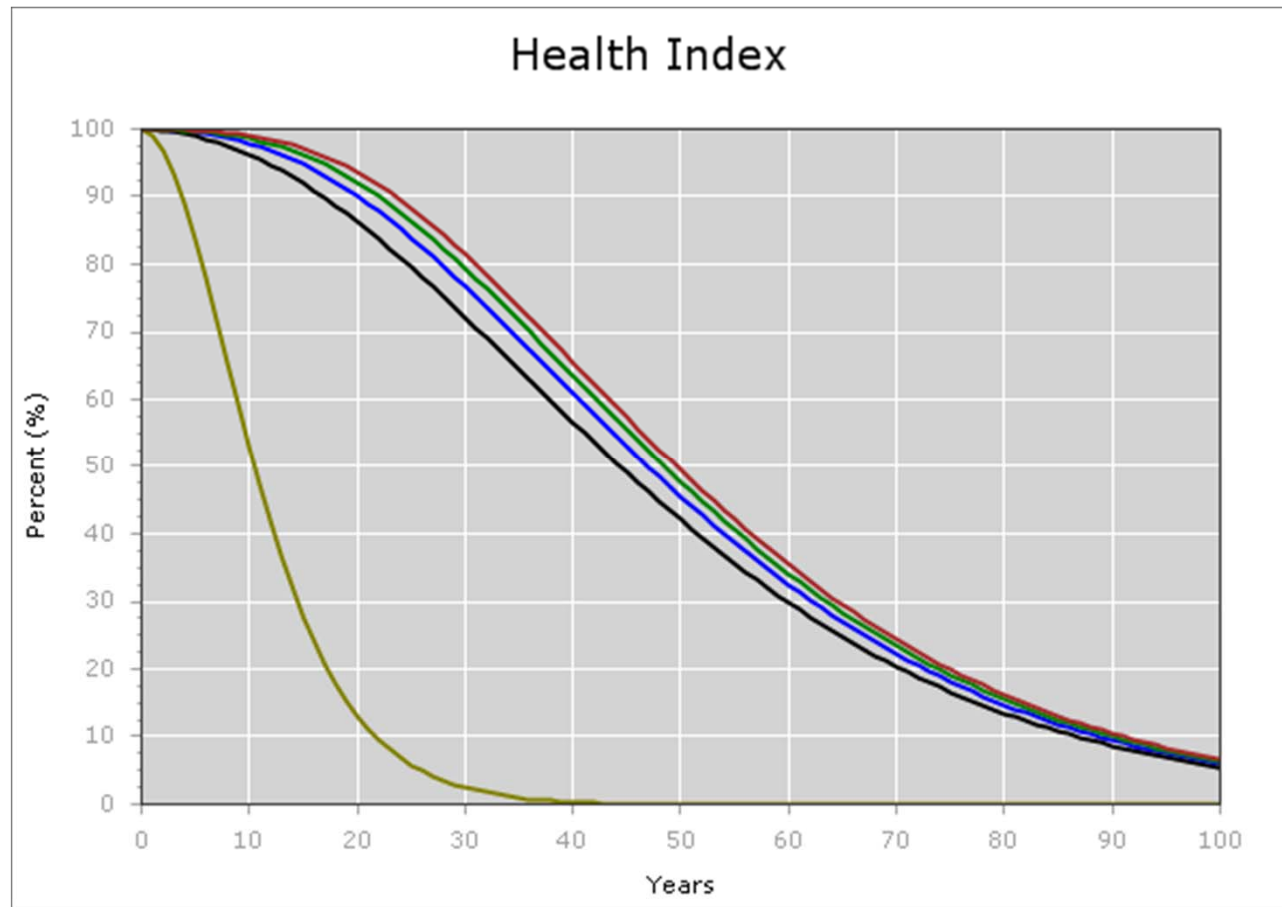
CS1: CS2:

CS3: CS4:



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration



330 – Metal Bridge Rail

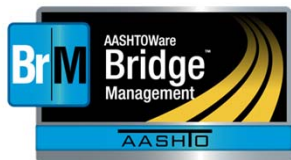
515 – Steel Protective Coating

$pp_e^+ : 1.0$ (no protection)

$pp_e^+ : 1.5$

$pp_e^+ : 2.0$

$pp_e^+ : 2.5$

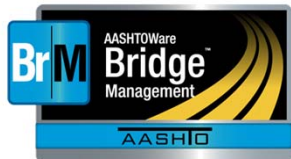


- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration

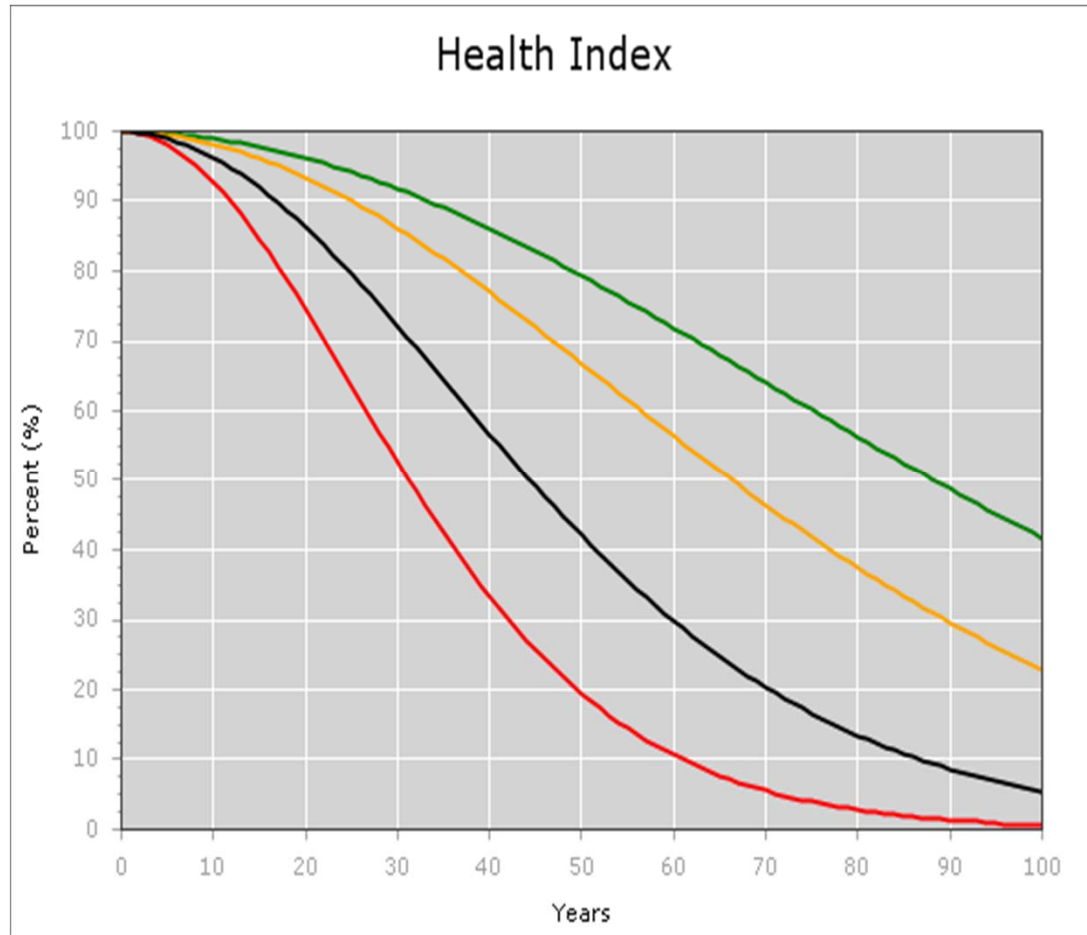
Environmental Factors

- Specified as modifiers that multiply the default transition times of elements.
- Environment factors:
 - Benign: 2
 - Low: 1.5
 - Moderate: 1
 - Severe: 0.7



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Element Deterioration

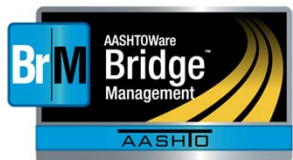


Ben(1): 2.0

Low(2): 1.5

Mod(3): 1.0

Sev(4): 0.7



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

NBI/Component Deterioration

Estimates the future ratings of NBI components:

- Deck
- Superstructure
- Substructure
- Culvert

Implementation approaches:

- Converting forecasted element ratings to NBI ratings
- Make use of element level deterioration
- Using dedicated NBI deterioration models
- Assign a number of years for a bridge to spend in each NBI rating



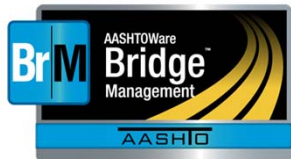
- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

NBI/Component Deterioration

NBI Direct Deterioration

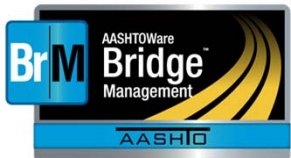
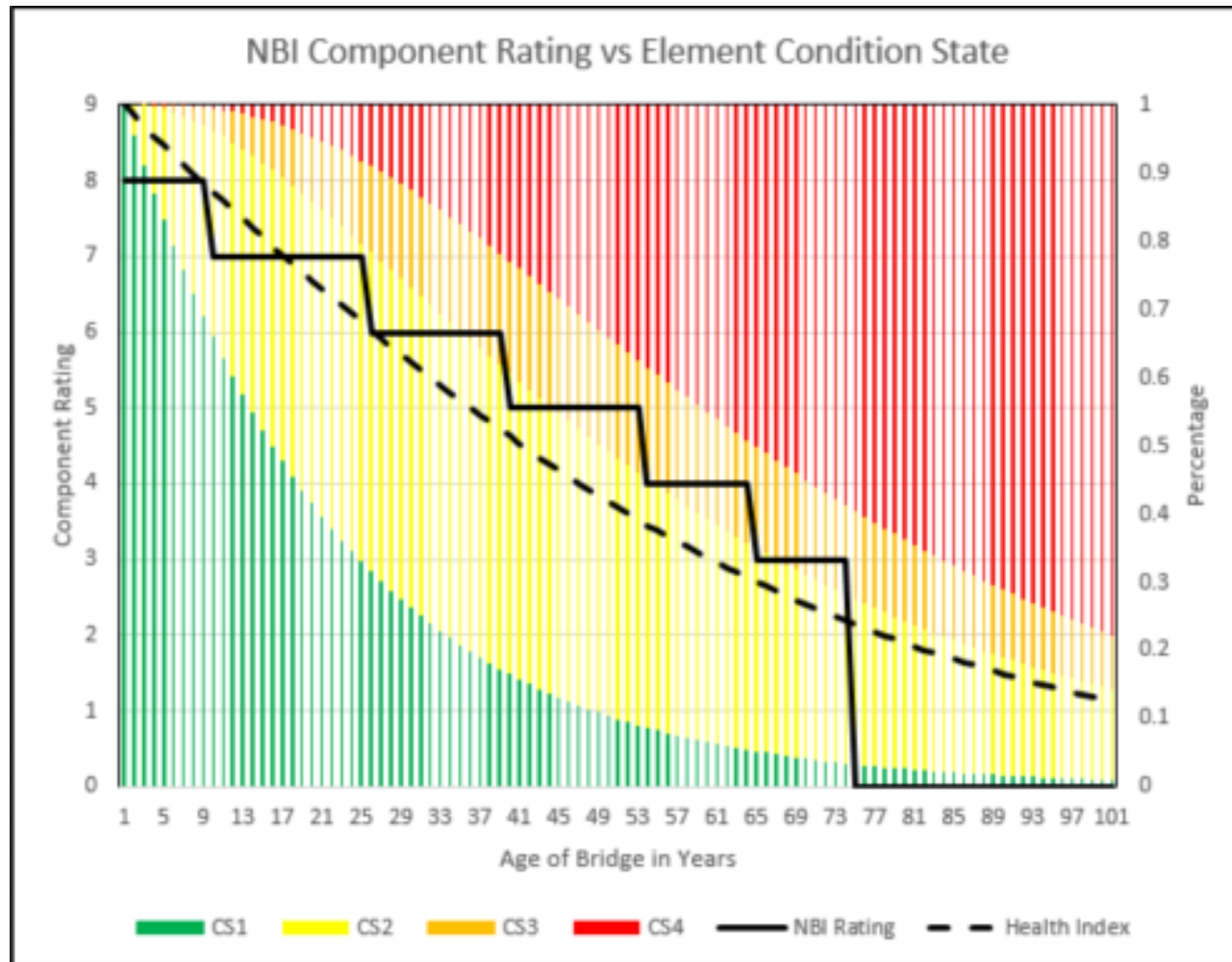
Admin > Modeling Config > NBI Deterioration Models

Components		Component Specification											
<table border="1"> <thead> <tr> <th>Component Name</th> <th></th> </tr> </thead> <tbody> <tr> <td>Deck</td> <td><input checked="" type="checkbox"/></td> </tr> <tr> <td>Superstructure</td> <td><input type="checkbox"/></td> </tr> <tr> <td>Substructure</td> <td><input type="checkbox"/></td> </tr> <tr> <td>Culvert</td> <td><input type="checkbox"/></td> </tr> </tbody> </table>		Component Name		Deck	<input checked="" type="checkbox"/>	Superstructure	<input type="checkbox"/>	Substructure	<input type="checkbox"/>	Culvert	<input type="checkbox"/>	Name: <input type="text" value="Deck"/> Description: <input type="text"/> Category: <input type="text" value="Decks/Slabs"/> Table Name: <input type="text" value="inspevnt"/> Column Name: <input type="text"/> Min NBI Value: <input type="text" value="1"/> Max NBI Value: <input type="text" value="9"/>	
Component Name													
Deck	<input checked="" type="checkbox"/>												
Superstructure	<input type="checkbox"/>												
Substructure	<input type="checkbox"/>												
Culvert	<input type="checkbox"/>												
		Component Deterioration Modeling											
		<input checked="" type="checkbox"/> Model											
		Model Parameters											
		NBI Transition Time in Years 9 : <input type="text" value="2"/>											
		NBI Transition Time in Years 8 : <input type="text" value="3"/>											
		NBI Transition Time in Years 7 : <input type="text" value="15"/>											
		NBI Transition Time in Years 6 : <input type="text" value="10"/>											
		NBI Transition Time in Years 5 : <input type="text" value="10"/>											
		NBI Transition Time in Years 4 : <input type="text" value="5"/>											
		NBI Transition Time in Years 3 : <input type="text" value="2.6"/>											
		NBI Transition Time in Years 2 : <input type="text" value="0"/>											
		NBI Transition Time in Years 1 : <input type="text" value="0"/>											



NBI/Component Deterioration

- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA



- Contact
- Element Deterioration
- NBI/Component Deterioration
- **NBI Conversion**
- LCCA

NBI/Component Deterioration

NBI Conversion

Admin > Modeling Config > NBI Conversion Profiles

NBI Profiles

NBI Profile Name	
<input checked="" type="checkbox"/>	BrM Default - Copy
<input type="checkbox"/>	FHWA Profile
<input checked="" type="checkbox"/>	BrM Default

Profile Details:

Name:

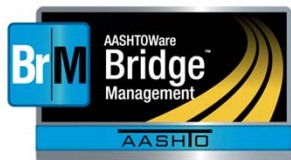
Profile enabled

Generic Upper Limits

Group enabled

Method of CS average:

NBI	Enabled	CS1 %	CS2 %	CS3 %	CS4 %
9	<input checked="" type="checkbox"/>	100	1	1	1
8	<input checked="" type="checkbox"/>		5	5	1
7	<input checked="" type="checkbox"/>		20	5	2
6	<input checked="" type="checkbox"/>			10	3
5	<input checked="" type="checkbox"/>			20	5
4	<input checked="" type="checkbox"/>				15
3	<input checked="" type="checkbox"/>				100
2	<input type="checkbox"/>				
1	<input type="checkbox"/>				

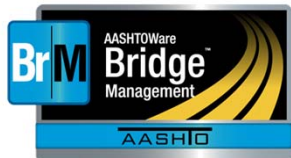


- Contact
- Element Deterioration
- NBI/Component Deterioration
- **NBI Conversion**
- LCCA

NBI/Component Deterioration

NBI Conversion Group by Unit

Deck	ELEMKEY	Element Name	Unit	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4
	Unit	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4	Health Index	NBI Conversion
Superstructure	sq.ft	5000	0	1300	700	7000	71.4%	0.0%	18.6%	10.0%	77.6	
	ft											
	each											
	Average						71.4%	0.0%	18.6%	10.0%	77.6	5
Substructure	Unit	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4	Health Index	NBI Conversion
	sq.ft											
	ft	150	10	0	0	160	93.8%	6.3%	0.0%	0.0%	97.9	
	each	28	1	1	0	30	93.3%	3.3%	3.3%	0.0%	96.7	
	Average						93.5%	4.8%	1.7%	0.0%	97.3	6
Substructure	Unit	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4	Health Index	NBI Conversion
	sq.ft											
	ft	230	25	0	0	255	90.2%	9.8%	0.0%	0.0%	96.7	
	each	8	4	0	0	12	66.7%	33.3%	0.0%	0.0%	88.9	
	Average						78.4%	21.6%	0.0%	0.0%	92.8	6



- Contact
- Element Deterioration
- NBI/Component Deterioration
- **NBI Conversion**
- LCCA

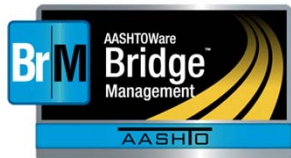
NBI/Component Deterioration

NBI Conversion Relative Weight

Deck	ELEMKEY	Element Name	Unit	Element Weight	Weight Override	Used Weight	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4	Health Index	NBI Conversion
	12	Re Concrete Deck	sq.ft	6		6	5000	0	0	0	5000	100.0%	0.0%	0.0%	0.0%	100.0	8
38	Re Concrete Slab	sq.ft	9		9	0	0	1300	700	2000	0.0%	0.0%	65.0%	35.0%	21.7	3	
Component Weighted Averages:						2000.00	0.00	780.00	420.00	3200.00	62.5%	0.0%	24.4%	13.1%	70.6	4	

Superstructure	ELEMKEY	Element Name	Unit	Element Weight	Weight Override	Used Weight	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4	Health Index	NBI Conversion
	110	Re Conc Opn Girder/Beam	ft	10		10	150	10	0	0	160	93.8%	6.3%	0.0%	0.0%	97.9	7
161	Stl Pin Pin/Han both	each	20		20	28	1	1	0	30	93.3%	3.3%	3.3%	0.0%	96.7	6	
Component Weighted Averages:						68.67	4.00	0.67	0.00	73.33	93.6%	5.5%	0.9%	0.0%	97.6	7	

Substructure	ELEMKEY	Element Name	Unit	Element Weight	Weight Override	Used Weight	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4	Health Index	NBI Conversion
	205	Re Conc Column	each	15		15	8	4	0	0	12	66.7%	33.3%	0.0%	0.0%	88.9	6
210	Re Conc Pier Wall	ft	8		8	80	0	0	0	80	100.0%	0.0%	0.0%	0.0%	100.0	8	
215	Re Conc Abutment	ft	8		8	150	25	0	0	175	85.7%	14.3%	0.0%	0.0%	95.2	7	
Component Weighted Averages:						63.23	8.39	0.00	0.00	71.61	88.3%	11.7%	0.0%	0.0%	96.1	7	



- Contact
- Element Deterioration
- NBI/Component Deterioration
- **NBI Conversion**
- LCCA

NBI/Component Deterioration

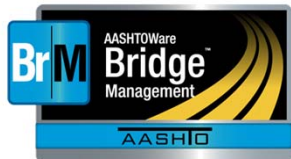
NBI Conversion Calibration

Network NBI Rating distributions

Bridge Filter:

Component:

	Latest Inspection Reported	Latest Inspection Converted	Current	+5 Years	+10 Years
NBI Rating 9	4	6	0	0	0
NBI Rating 8	2	2	6	0	0
NBI Rating 7	2	1	3	9	8
NBI Rating 6	6	7	6	4	4
NBI Rating 5	4	0	1	3	2
NBI Rating 4	8	10	9	9	10
NBI Rating 3	1	1	2	2	3
NBI Rating 2	0	0	0	0	0
NBI Rating 1	0	0	0	0	0



- Contact
- Element
Deterioration
- NBI/Component
Deterioration
- NBI Conversion
- LCCA

Life Cycle Cost Analysis (LCCA)

- **Short-Term analysis: 5 years**

- Considers project alternatives in a short-term program
- Example:
- Bridge Rehab, Deck Rehab, etc.

- **Long-Term analysis: 75**

- Considers what happens to the bridge after the program.
- Applies preservation policies



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Life Cycle Cost Analysis (LCCA)

Preservation Policies

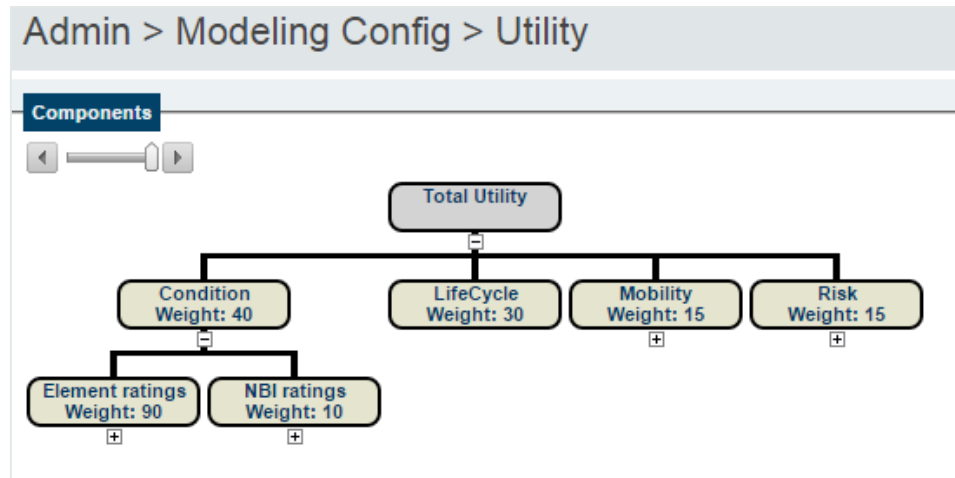
Component	Conditions	Action
Admin > Modeling Config > LCCA Policy Rules		
Rule Editor		
Policy: Culvert policy	Rule: Rehab Culvert	Create New
Rule Details		
Name: Rehab Culvert	Resulting Action: Rehab Culvert - Network	
Summary		
(Health Index of Category 'Culvert' Must Be Less Than Or Equal To Number Value 70 AND Health Index of Category 'Culvert' Must Be Greater Than Number Value 50 AND Repeat every 30 or more years)		
Rule Builder		
Add Condition Add Group		
Type: Category Health Index	Type: Number Value	
Field: Culvert As Number	Must Be: Less Than or Equal To	Number Value: 70 Remove Condition
AND		
Type: Category Health Index	Type: Number Value	
Field: Culvert As Number	Must Be: Greater Than	Number Value: 50 Remove Condition
AND		
Type: Repeat (in years)		
Repeat every: 30 or more years.	Remove Condition	



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- LCCA

Life Cycle Cost Analysis (LCCA)

Utility



$$LCC_{Utility} = \left(1 - \frac{LCC}{2 \times \text{replacement cost}} \right) \times 100$$

$$LCC = ST + LT - \text{Residual}$$

$$\text{Residual} = \left(\frac{\text{Remaining Service Life}}{\text{Service Life}} \right) \times \text{Replacement Cost}$$



- Contact
- Element Deterioration
- NBI/Component Deterioration
- NBI Conversion
- **LCCA**

Life Cycle Cost Analysis (LCCA)

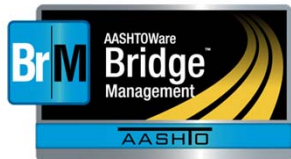
Updated Utility – Rehab Project

Index	Date	Year	Action Name	Orig. Cost	NPV Cost	Prior Action H.I.	After Action H.I.
1	2016	0	Bridge-Rehab	\$260,570	\$260,570	71.01	77.08
2	2021	5	Paint-General, Thin Bonded Overlay	\$45,844	\$37,681	67.63	73.14
3	2036	20	Beams Rehab, Concrete Deck Overlay	\$176,863	\$80,718	51.48	65.73
4	2048	32	Beams Rehab, Deck-Replace	\$292,525	\$83,386	53.37	85.50
5	2059	43	Beams Rehab	\$18,861	\$3,493	68.56	71.50
6	2064	48	Substructure-Rehab	\$21,984	\$3,346	63.41	64.10
7	2069	53	Beams Rehab	\$17,747	\$2,220	56.32	59.00
8	2079	63	Beams Rehab	\$17,768	\$1,502	45.74	48.42
9	2080	64	Bridge-Replacement	\$1,625,000	\$132,044	47.29	100.00
10	2093	77	Paint-General	\$13,176	\$643	78.87	79.64
Remaining Life:				52 years			
Residual:				\$1,242,647	\$53,911		
Total Life-Cycle Cost:				\$551,691			

$$LCC = ST + LT - R = \$260,570 + \$345,032 - \$53,911 = \$551,691$$

$$LCC_{Utility} = \left(1 - \frac{\$551,691}{2 \times \$1,625,000} \right) \times 100 = \mathbf{83.02}$$

$$Benefit = 83.02 - 75.83 = \mathbf{7.19}$$





BrM Help Desk

AASHTOWareBridge.com

BrM@Bentley.com

JIRA tickets:

bridgeware.atlassian.net

Josh Johnson, PE

TAM Lead Engineer

Joshua.Johnson@Bentley.com