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

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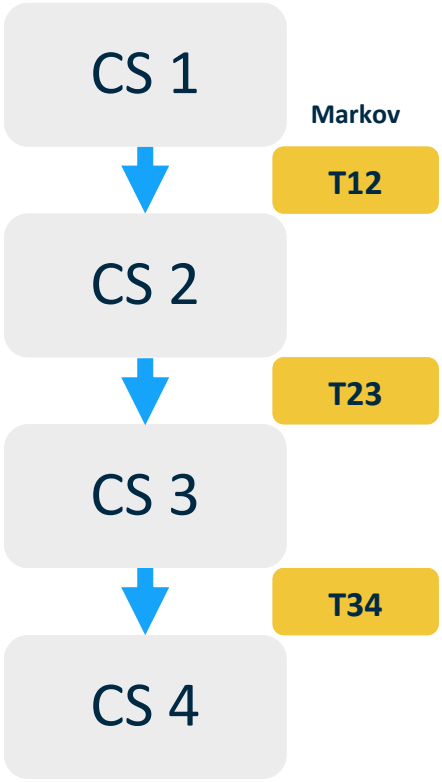
Element Deterioration



- 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?

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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

Element Deterioration

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

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

HI_e - element's health index = $CS_1 + \frac{2}{3} CS2 + \frac{1}{3} CS3$

q_e - element's total quantity

w_e - relative weight

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).

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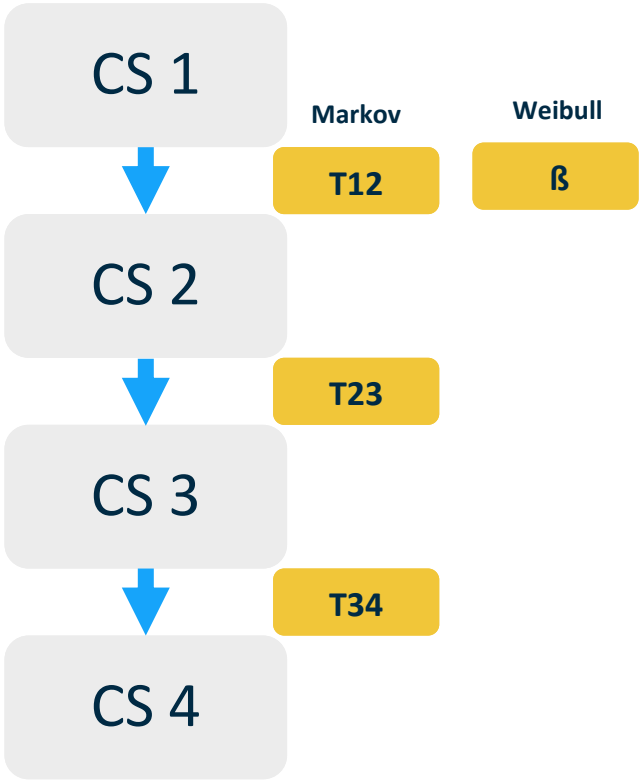
Element Deterioration



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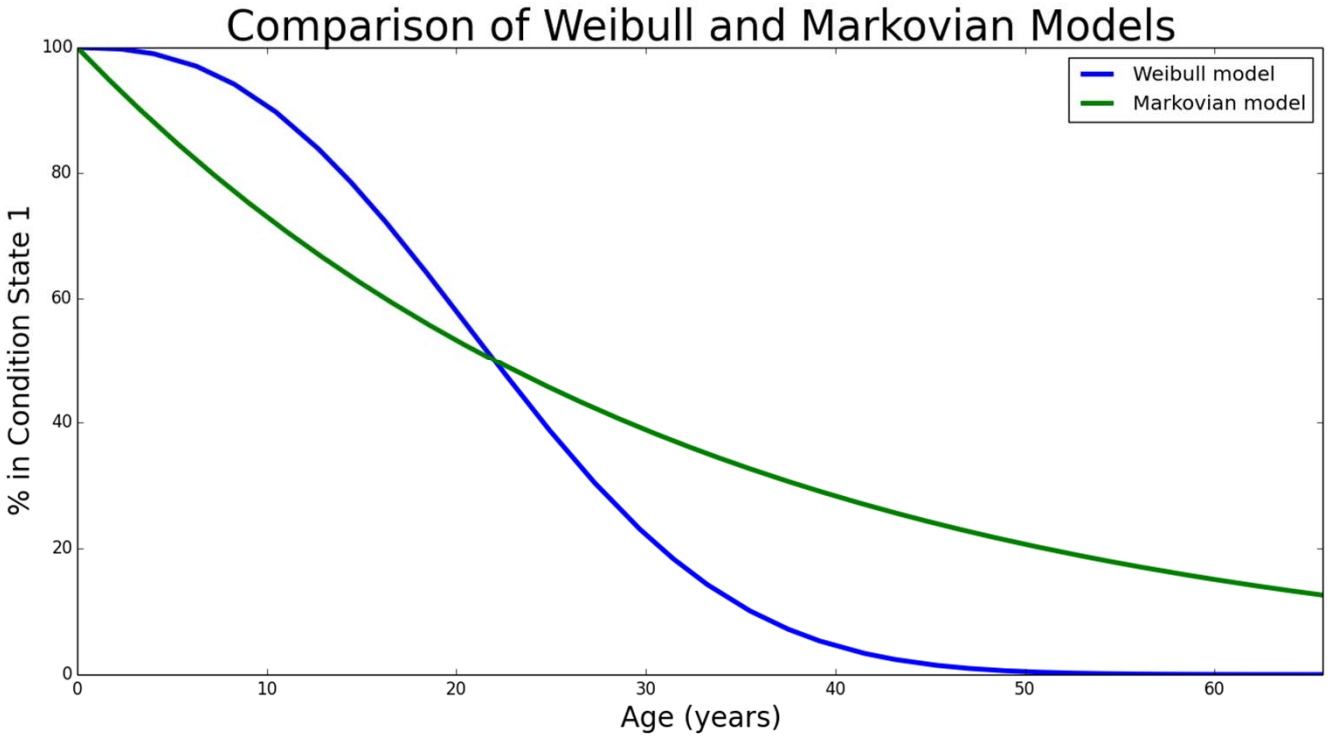
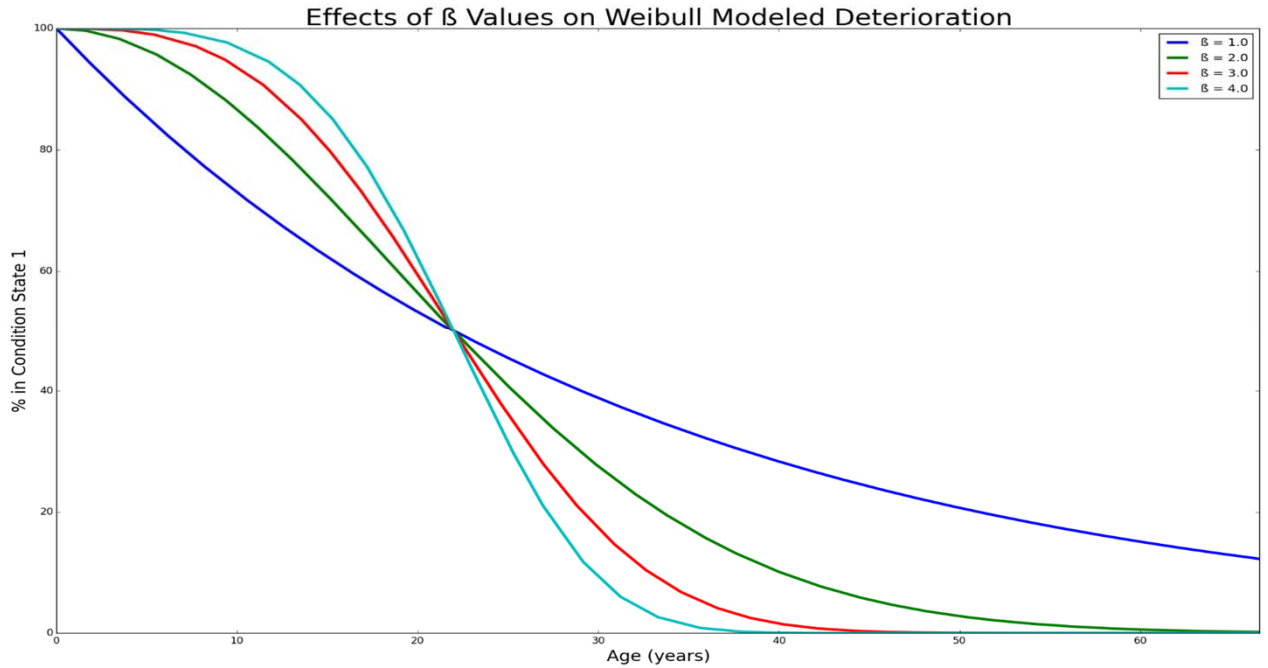
Element Deterioration



Element Deterioration

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



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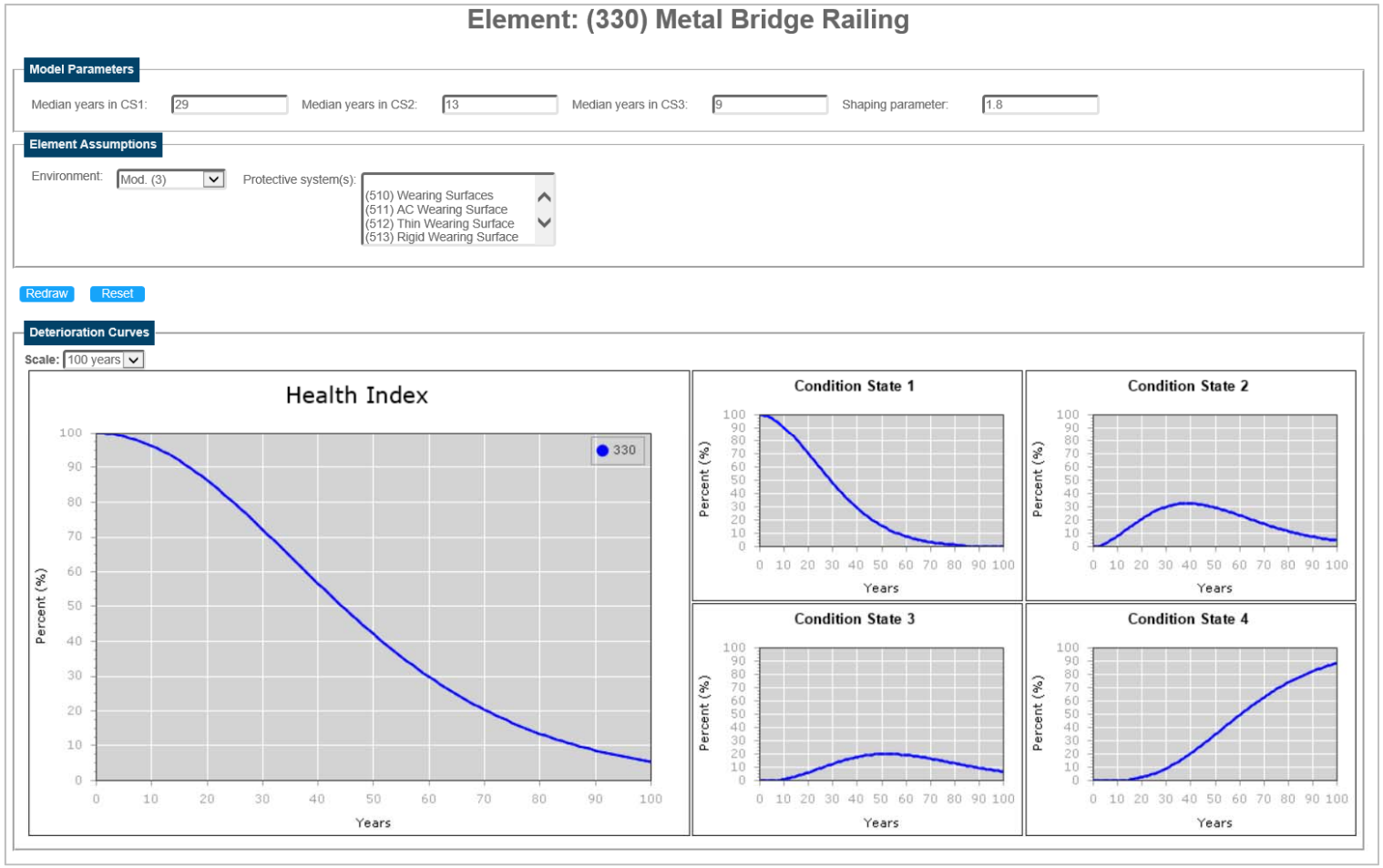
Element Deterioration



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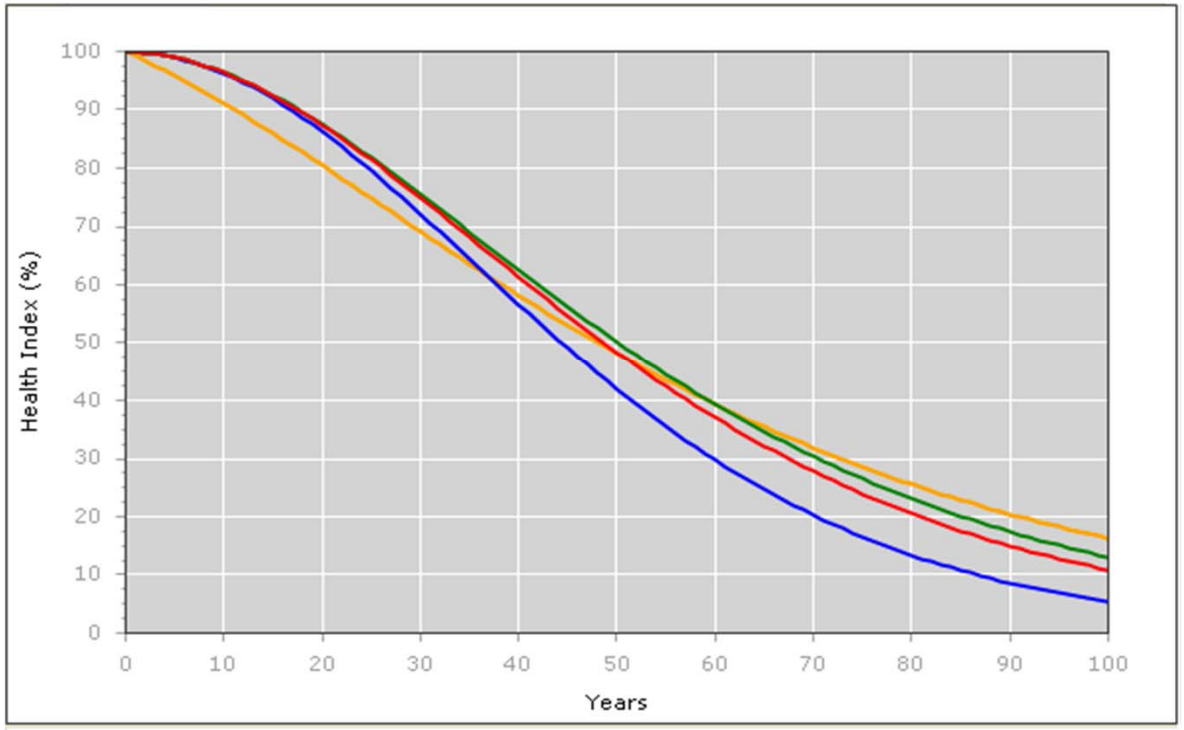
Element Deterioration



- 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)

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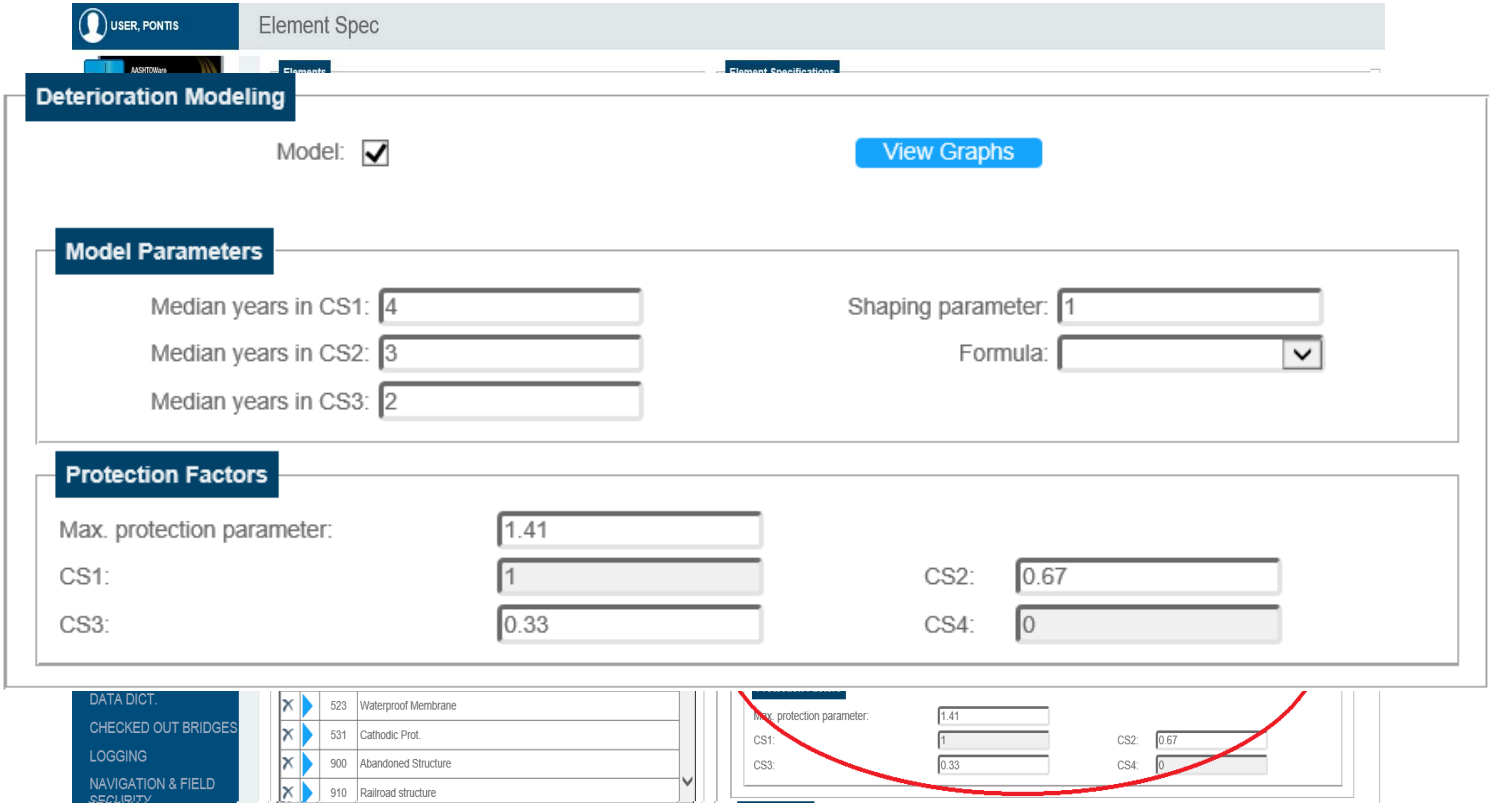
Element Deterioration

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



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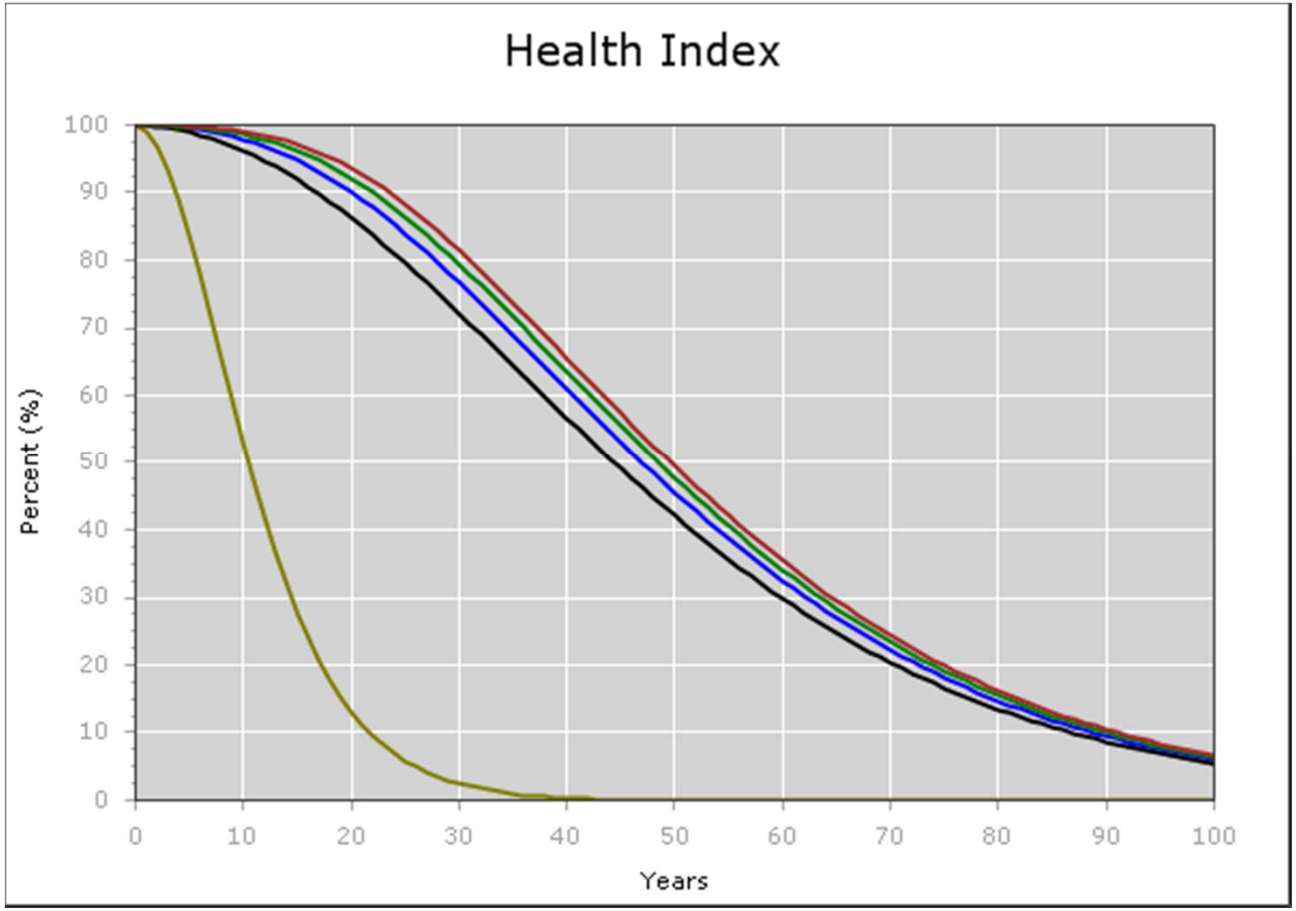
Element Deterioration



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

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

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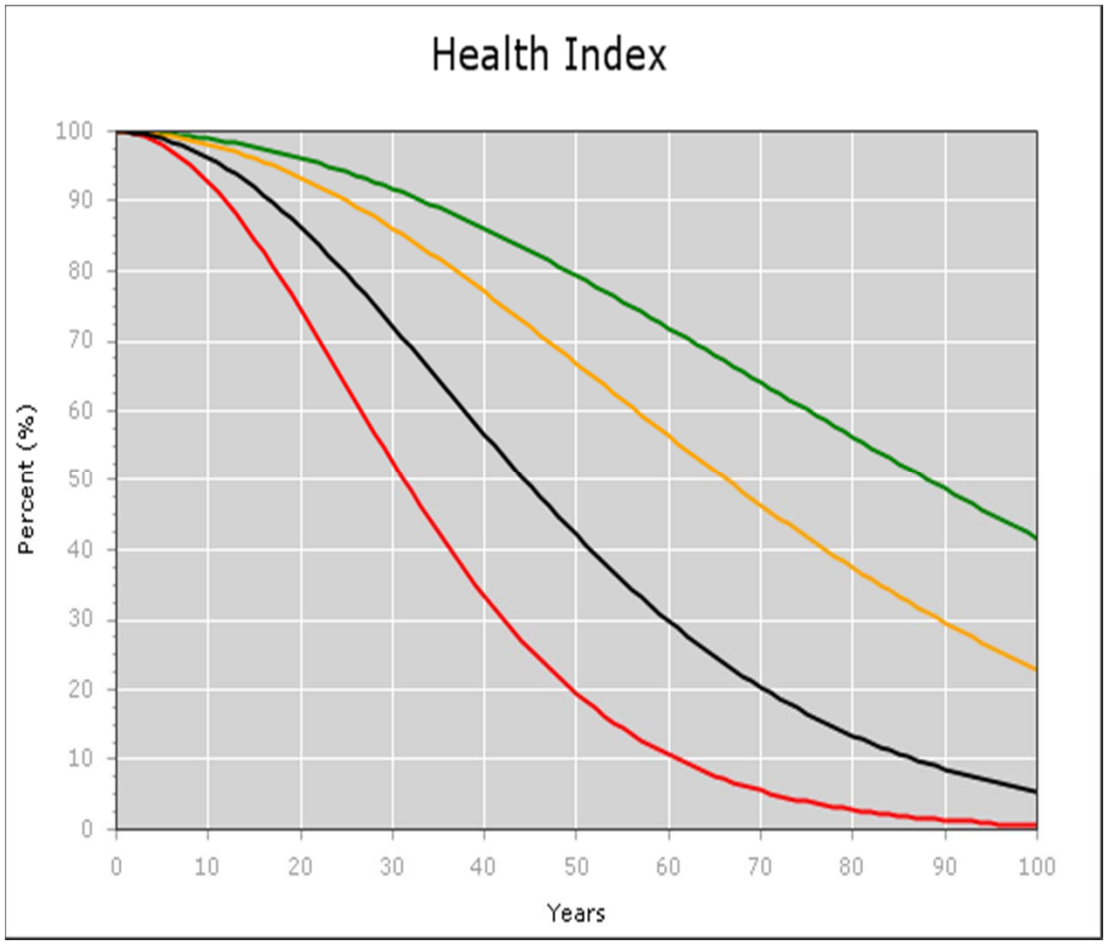
Element Deterioration



Ben(1): 2.0
Low(2): 1.5
Mod(3): 1.0
Sev(4): 0.7

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

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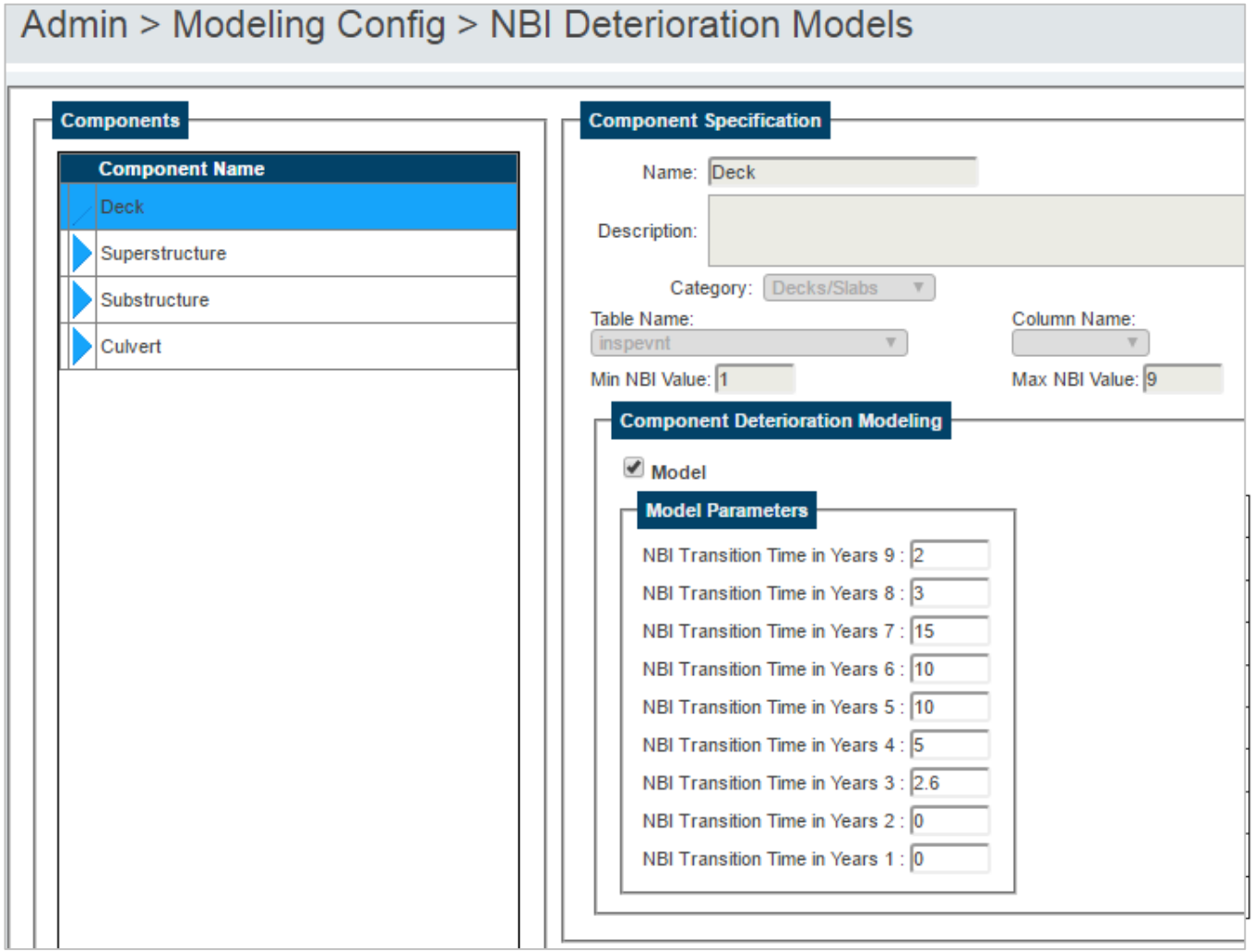
NBI/Component Deterioration

NBI Direct Deterioration



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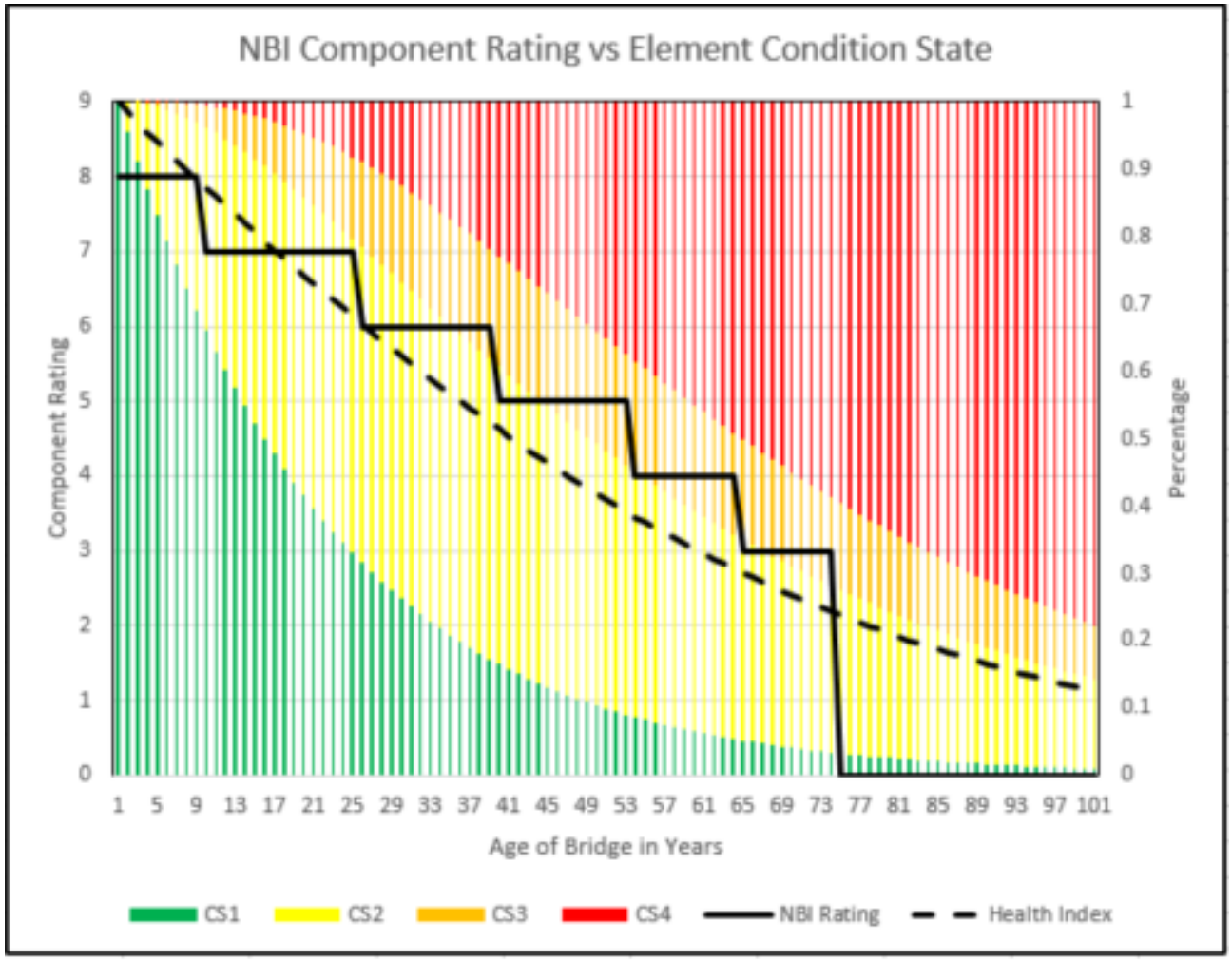
NBI/Component Deterioration



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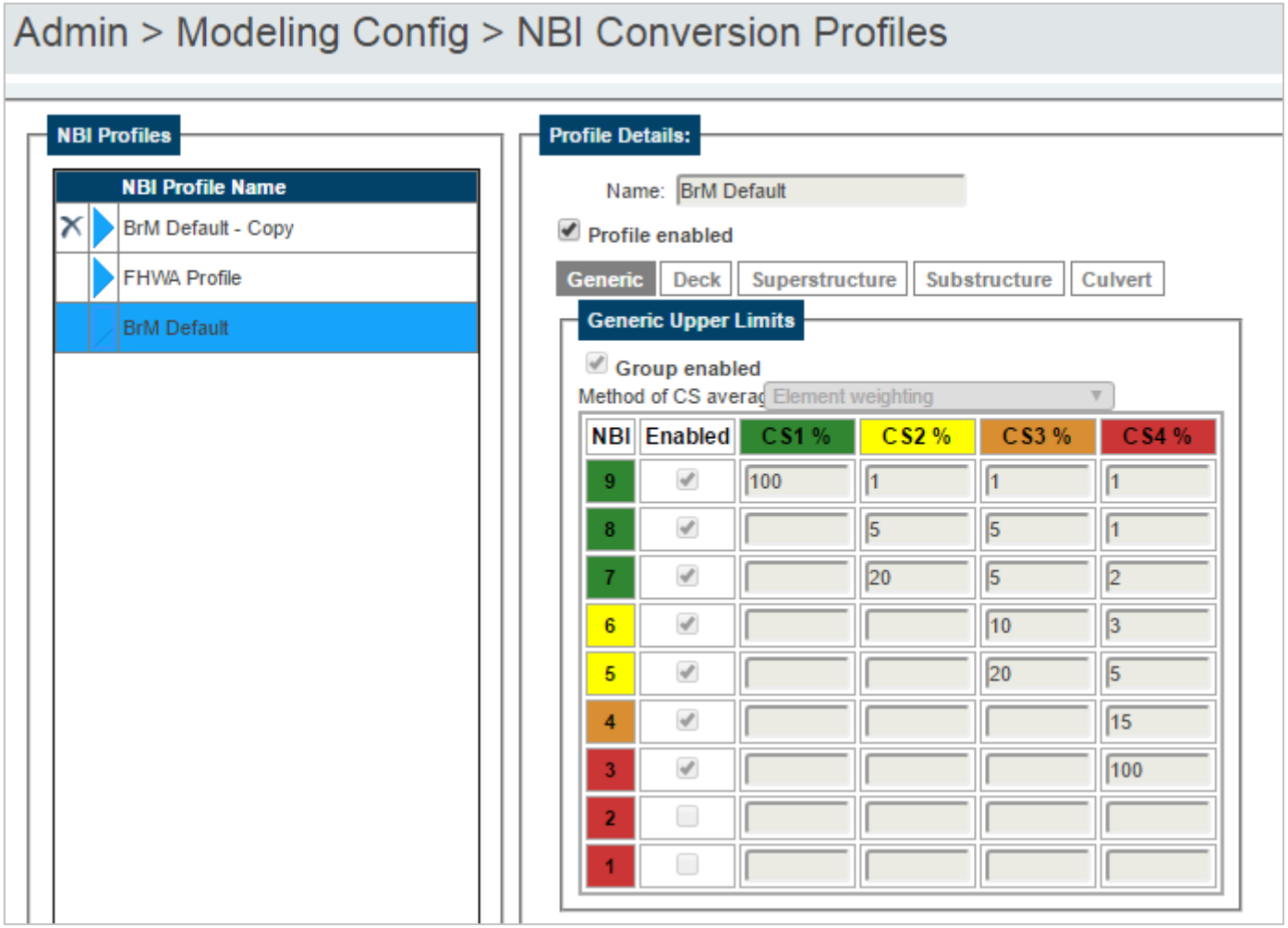
NBI/Component Deterioration

NBI Conversion



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NBI/Component Deterioration

NBI Conversion

Group by Unit

	ELEMKEY	Element Name	Unit	Qty. 1	Qty. 2	Qty. 3	Qty. 4	Total Qty.	Pct. 1	Pct. 2	Pct. 3	Pct. 4
Deck												

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	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**

Superstructure

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**

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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**

Superstructur	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**

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NBI/Component Deterioration

NBI Conversion Calibration

Network NBI Rating distributions

Bridge Filter: Entire Network ▼ Re-estimate results

Component: Bridge-Level ▼

	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

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

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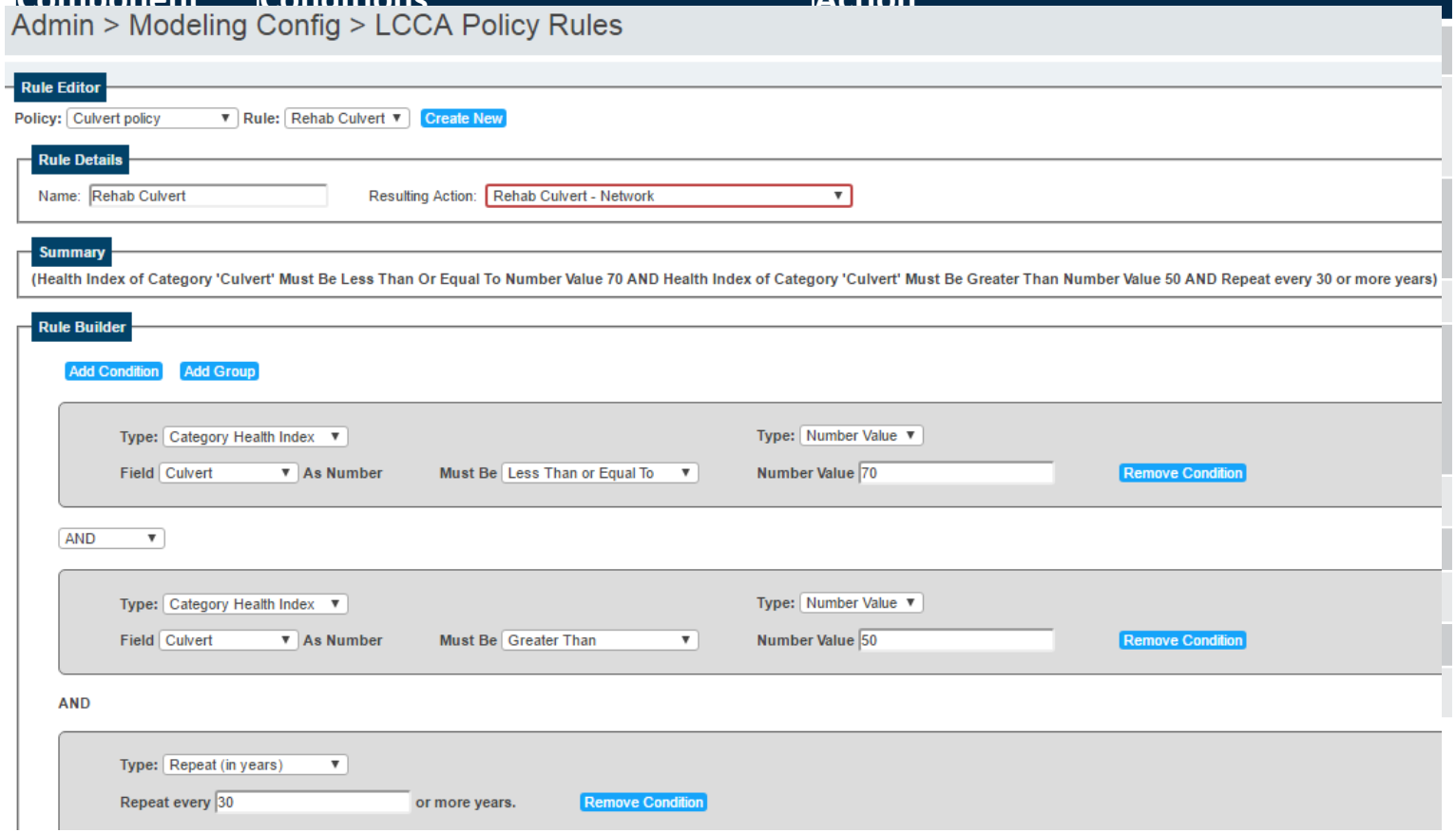
Life Cycle Cost Analysis (LCCA)

Preservation Policies

Component	Conditions	Action



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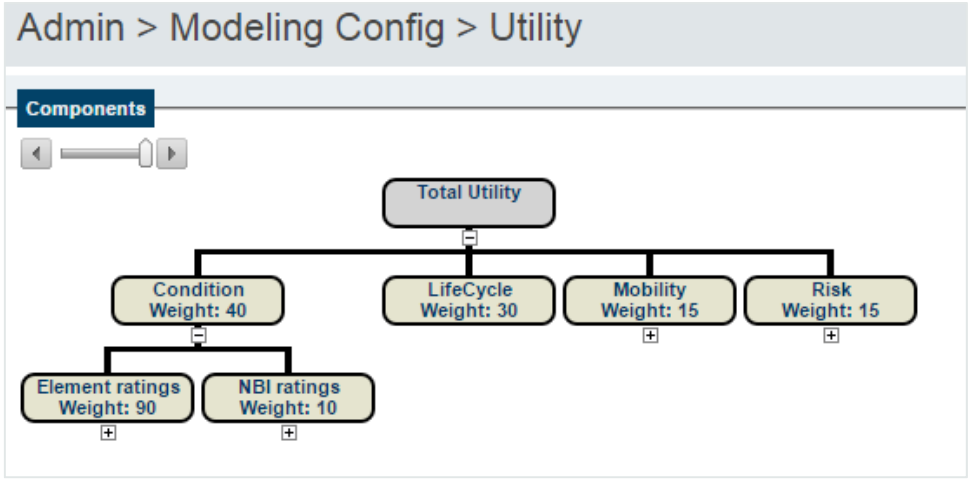
Life Cycle Cost Analysis (LCCA)

Utility



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

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

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

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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		

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

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

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

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