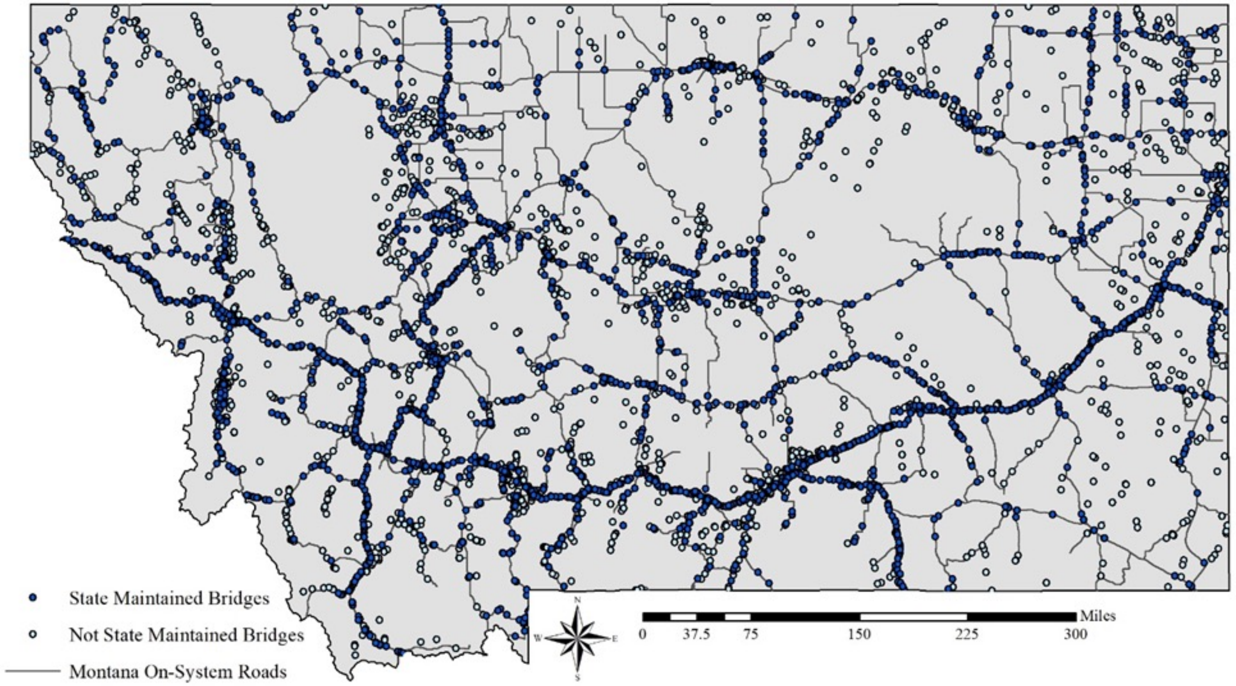
Final Presentation and Implementation Meeting

November 15, 2022

Agenda

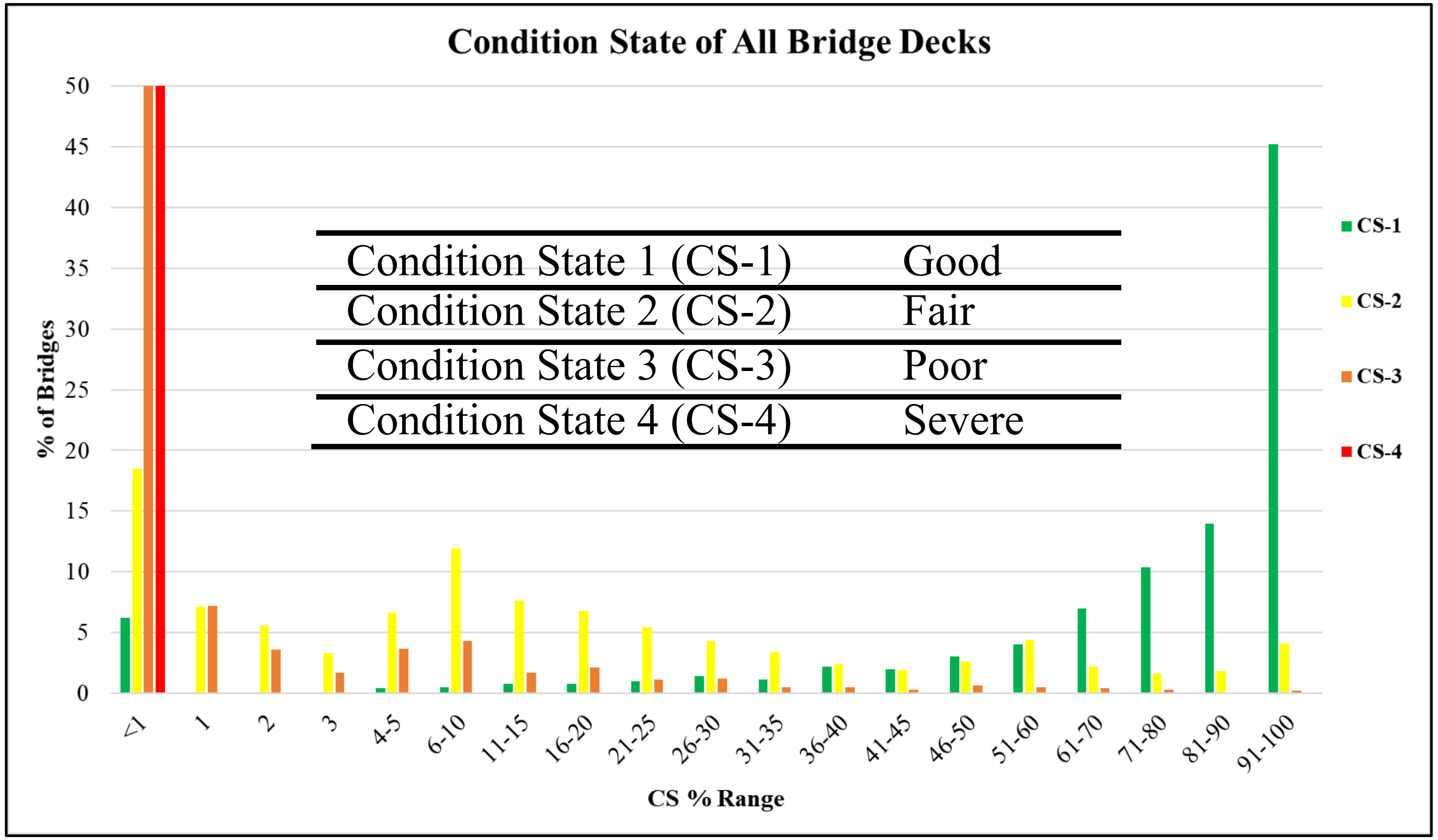
- Final Presentation
  - Approach
  - Results
  - Conclusions
- Implementation Report
  - Optimization runs
- Implementation Recommendations
- Performance Measures Report



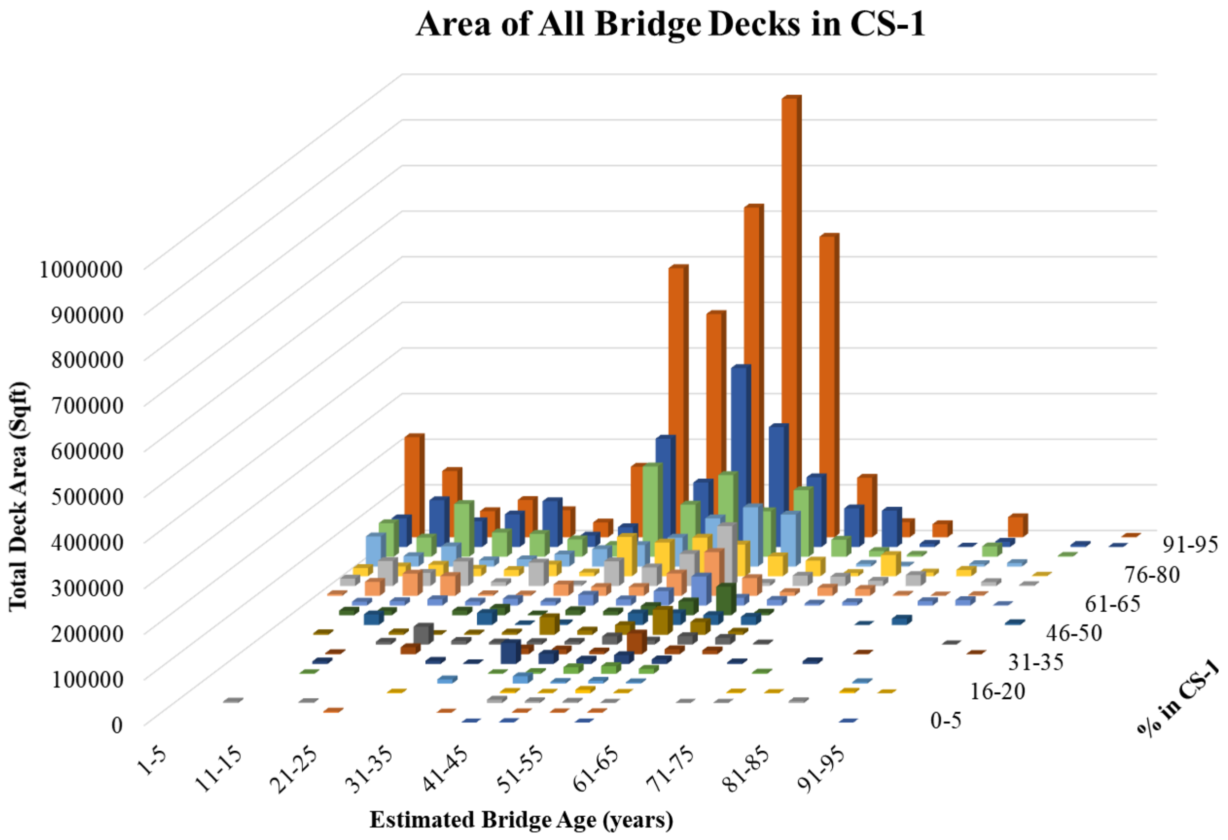
Research Approach

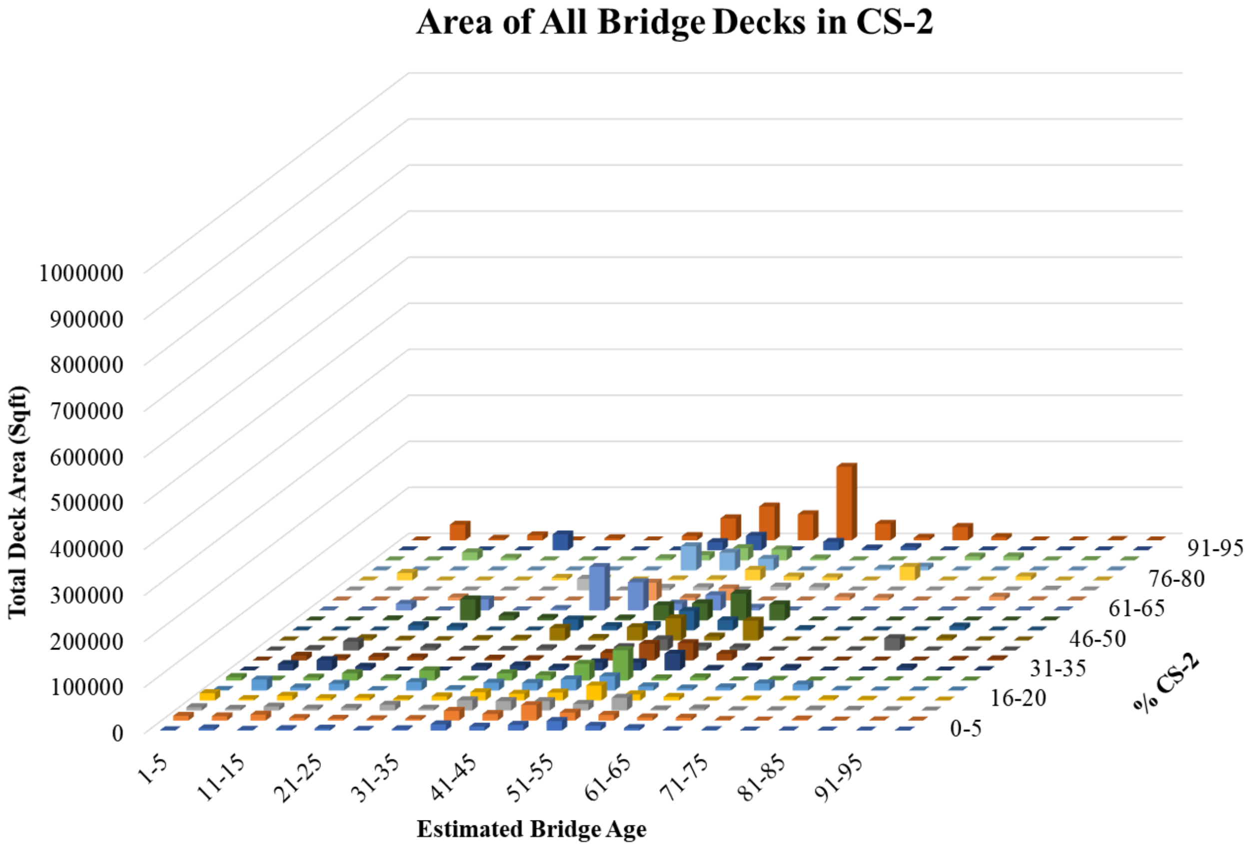
Percent of bridge decks in CS-1, 2020

- Median percentage of bridge deck area rated as CS-1 was 75%.
- Median percentages for CS-2 and CS-3 were 22% and 3%, respectively.
- Research focus was Weibull distribution for CS-1 deterioration



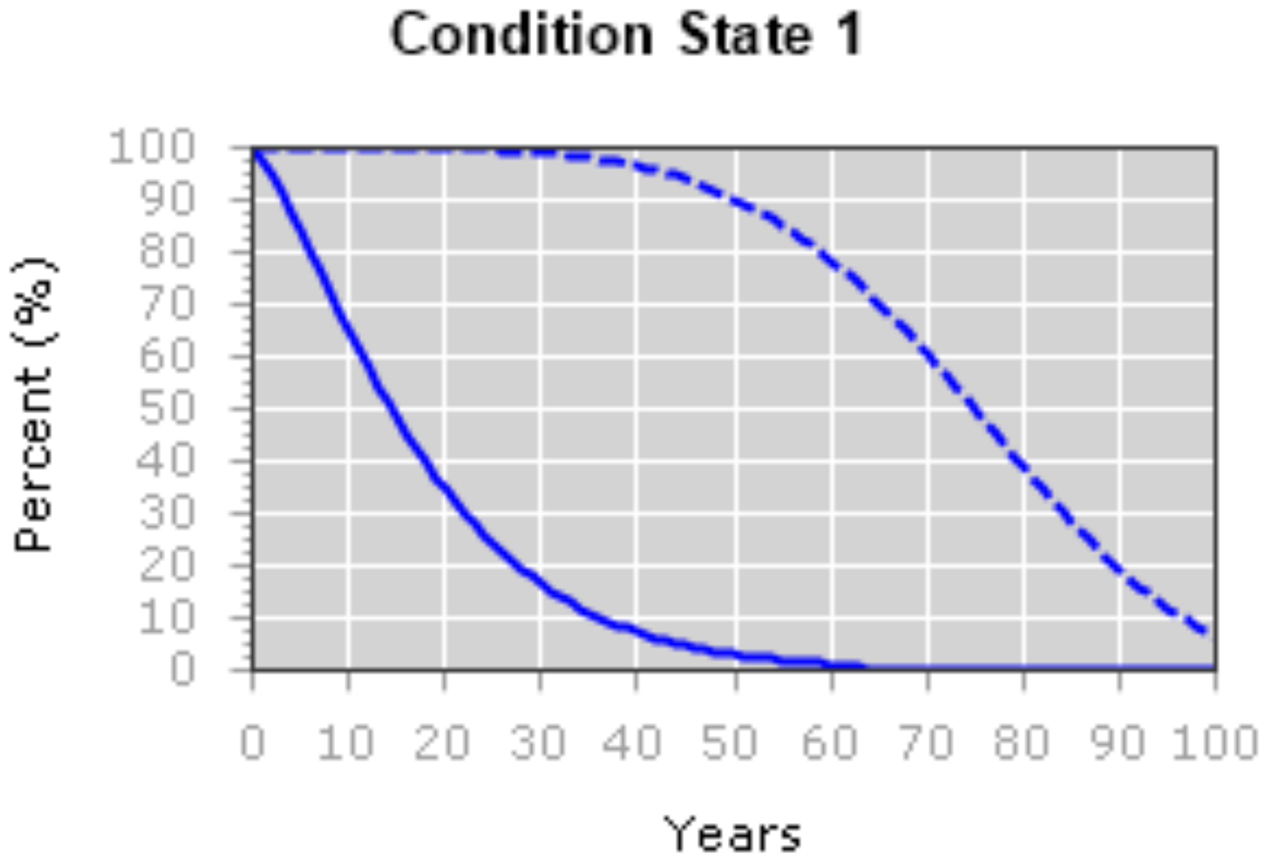
Raw data for bridge deck CS-1 and CS-2 ratings



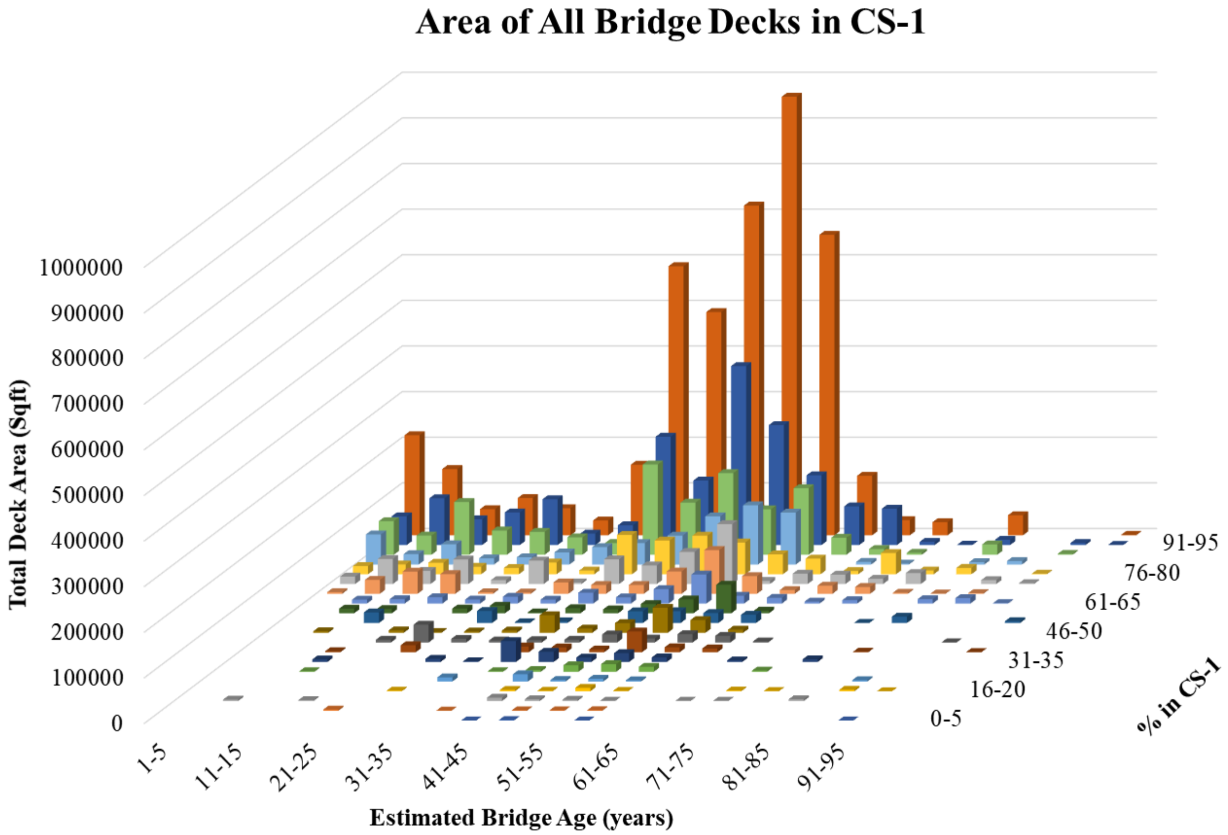


Graphical Method

- Represents all inspection data points
- May not be unreasonable for low-volume bridges
- Consistently under-estimates deterioration for elements considered compared with default values
- Ability to accelerate deterioration rates using estimated maintenance target values

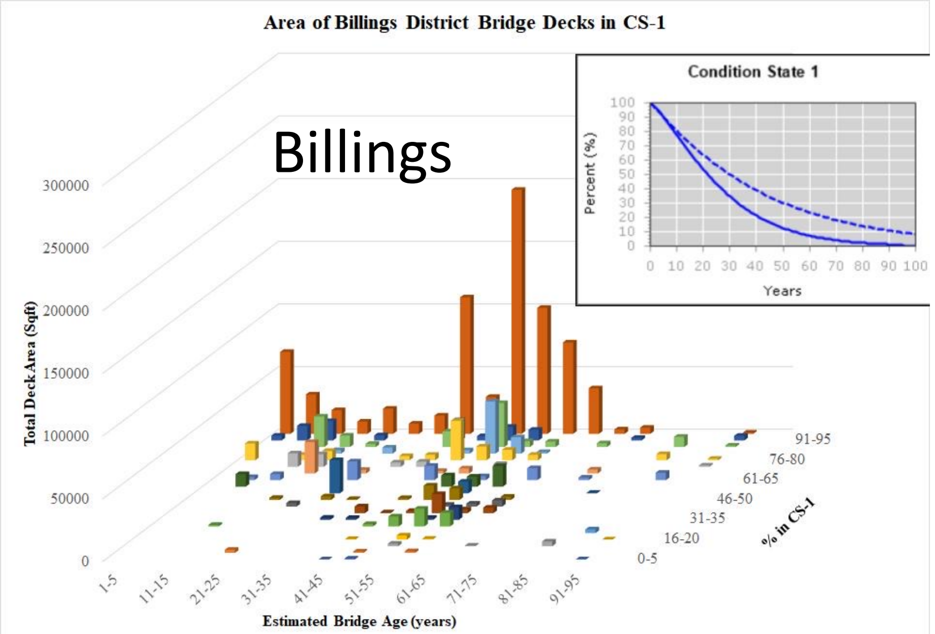


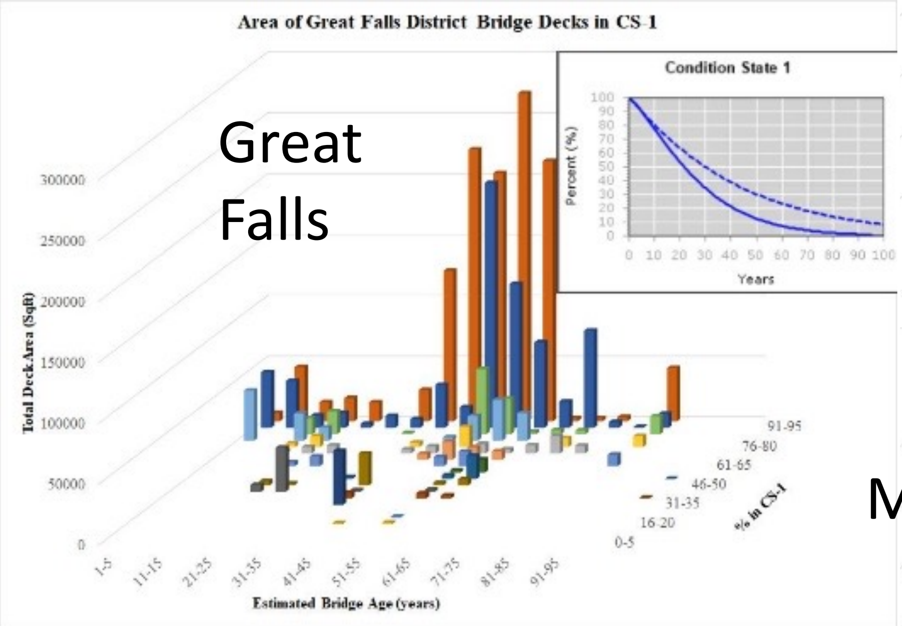
Estimated deterioration targets

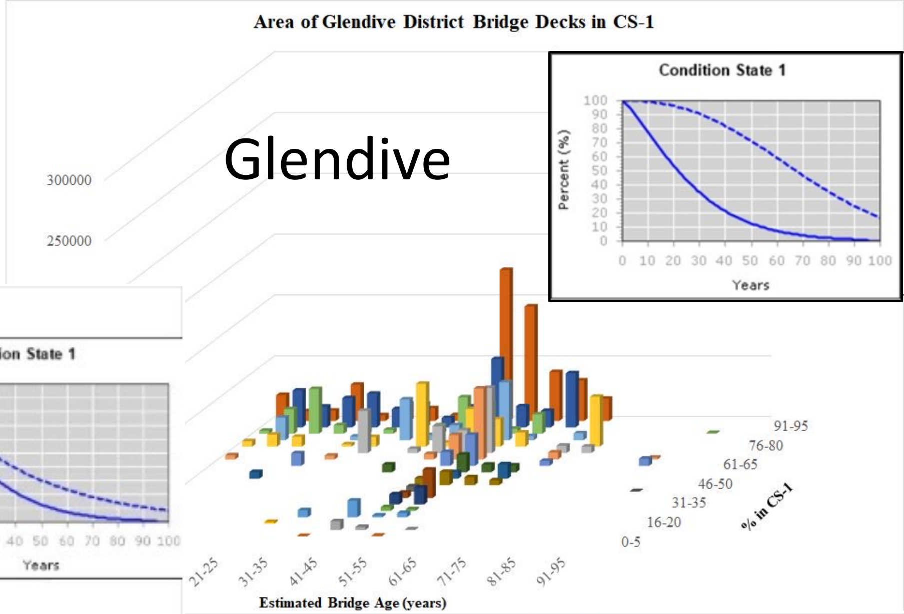


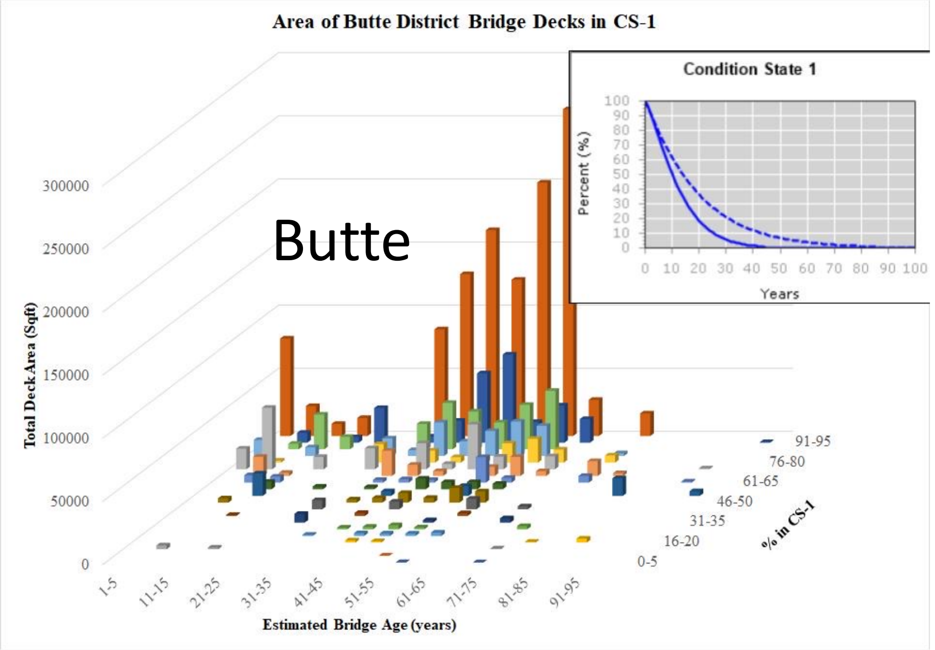
Element	CS-1 Target	Years
Reinforced Concrete Deck	97.5%	10
	90%	20
	70%	30
Steel Girder	70%	40
Prestressed Concrete Girder	95%	40
Concrete Abutment	90%	50
Steel Culverts	75%	50
Concrete Culvert	95%	30
	75%	50

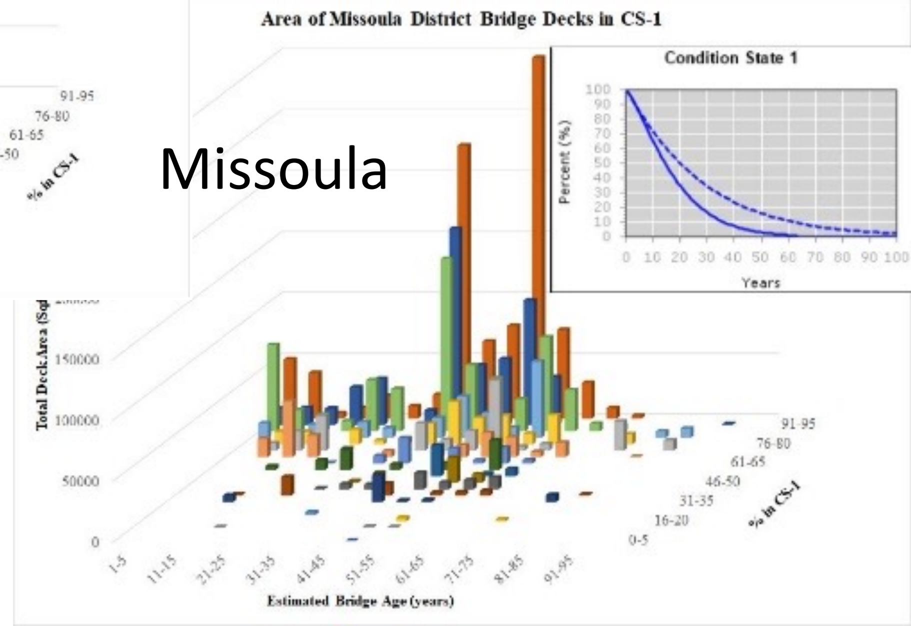
Regional Trends





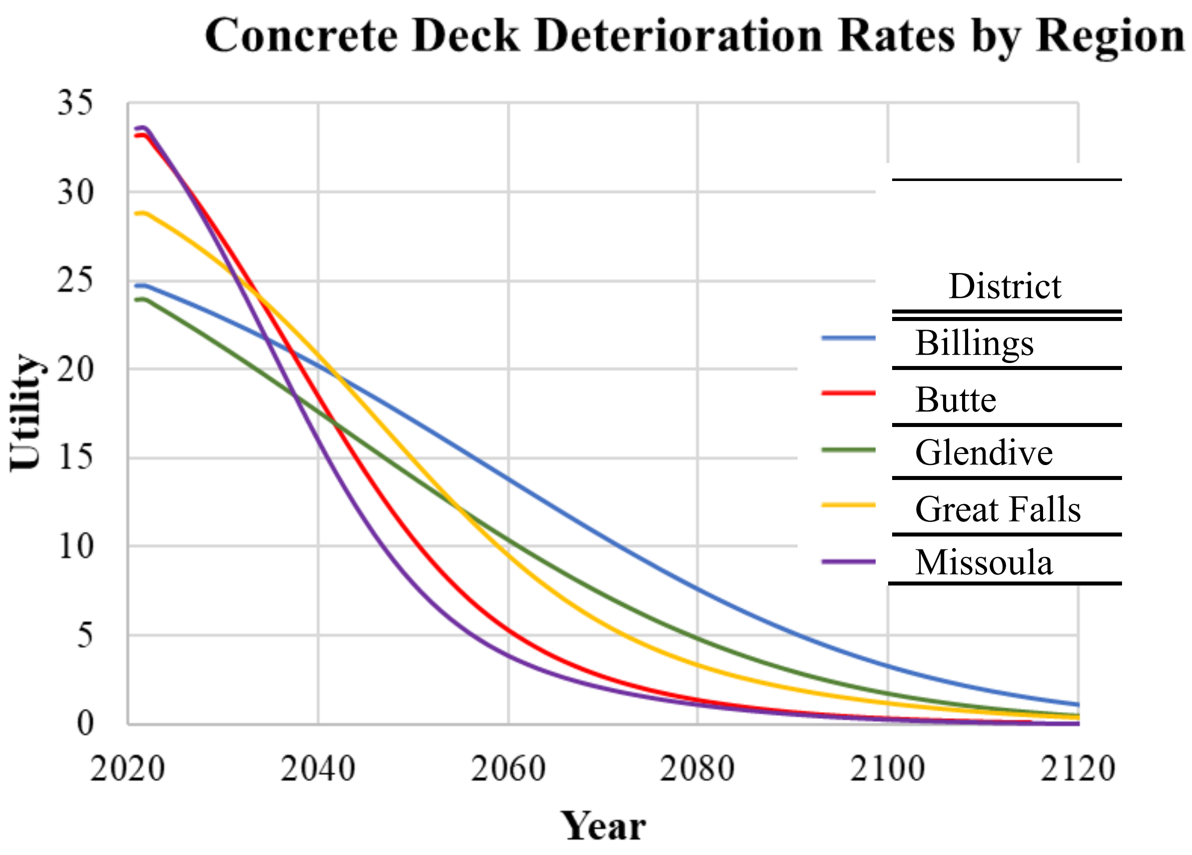






Environmental factors for concrete decks

- Shape-factors and median years in CS-1 for calculated for each maintenance district
- Utility index = customized deterioration curve that considers user-defined elements and conditio state ratings.
- Shown here are concrete deck elements and CS-1 deterioration.

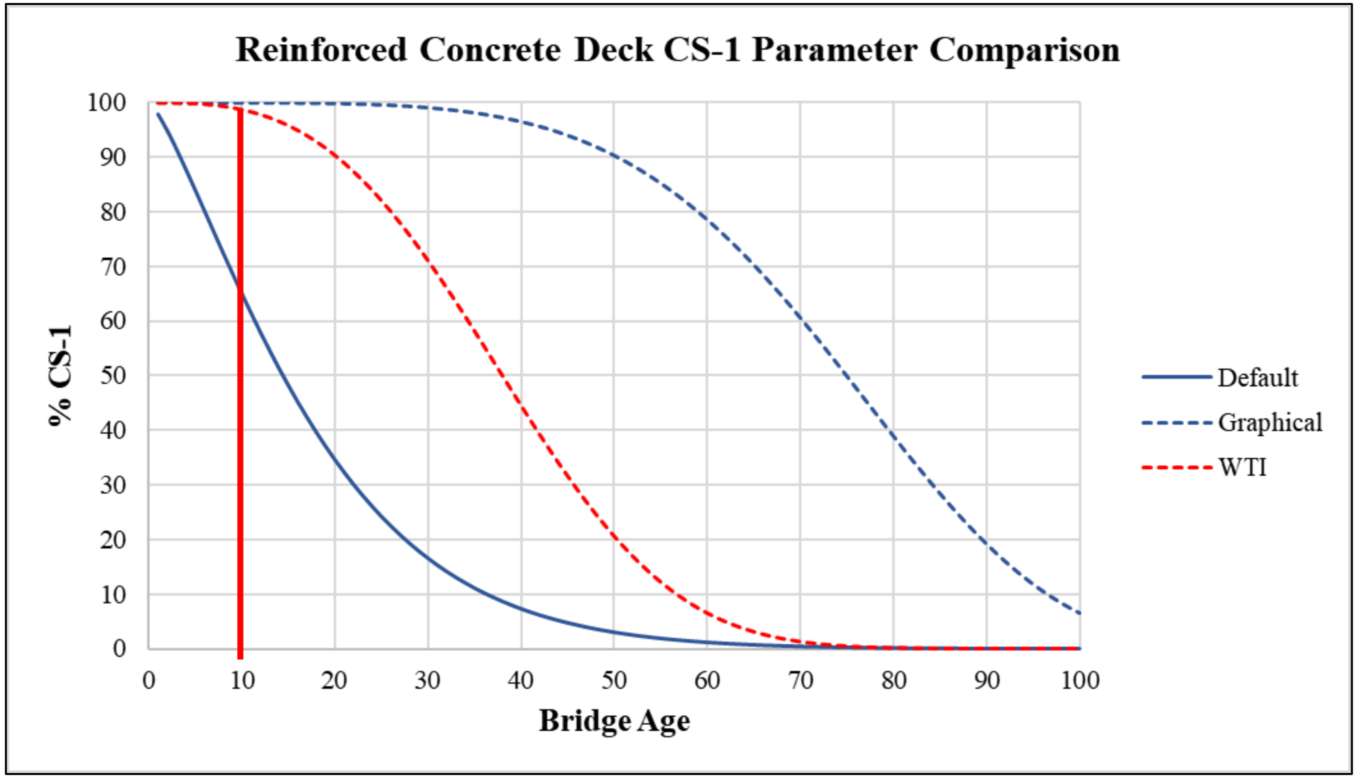


Results

Reinforced Concrete Deck

Parameter Estimates	Shape Factor	Median Years CS-1	CS-2	CS-3
BrM Default	1.3	14.4	42.0	14.9
Graphical	4.8	75	42	14.9
WTI Refinement	3.0	38	42	14.9

Element	CS-1 Target	Years
Reinforced Concrete Deck	97.5%	10
	90%	20
	70%	30



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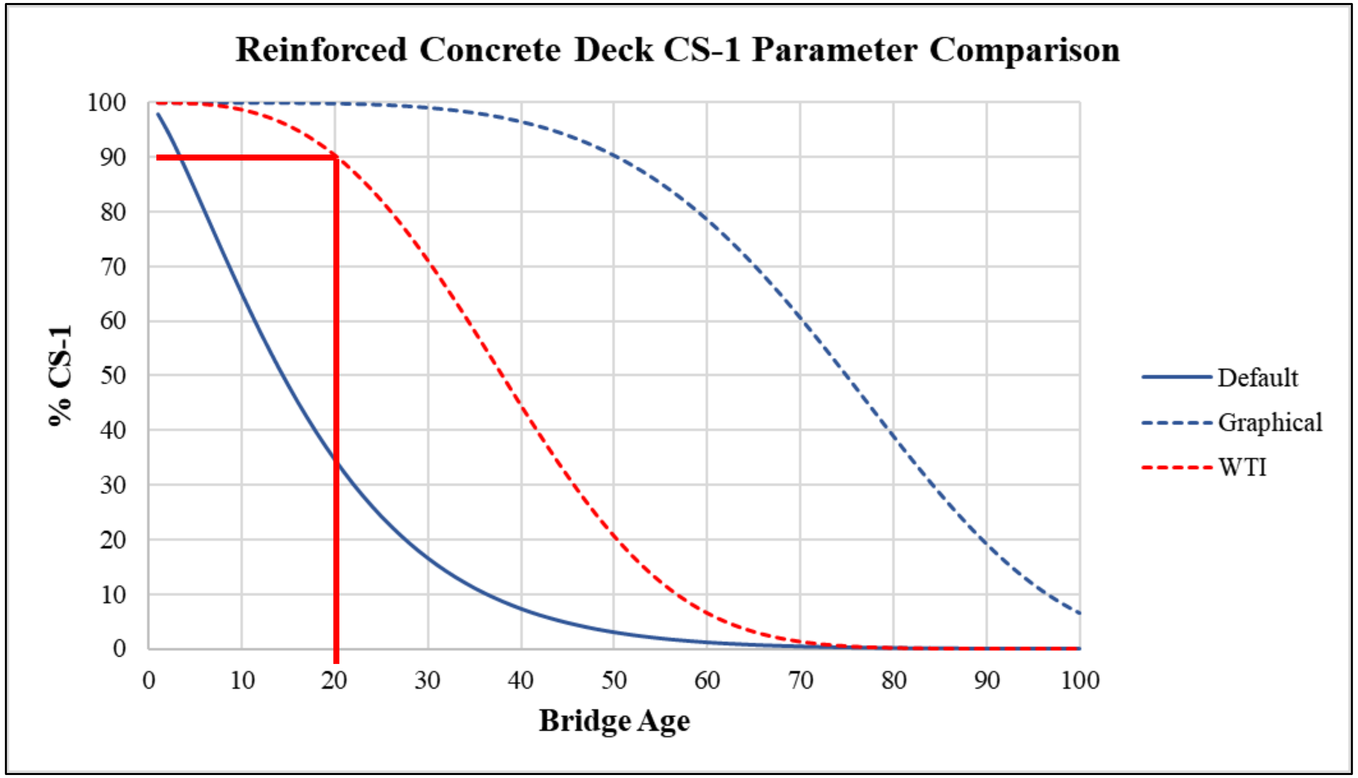

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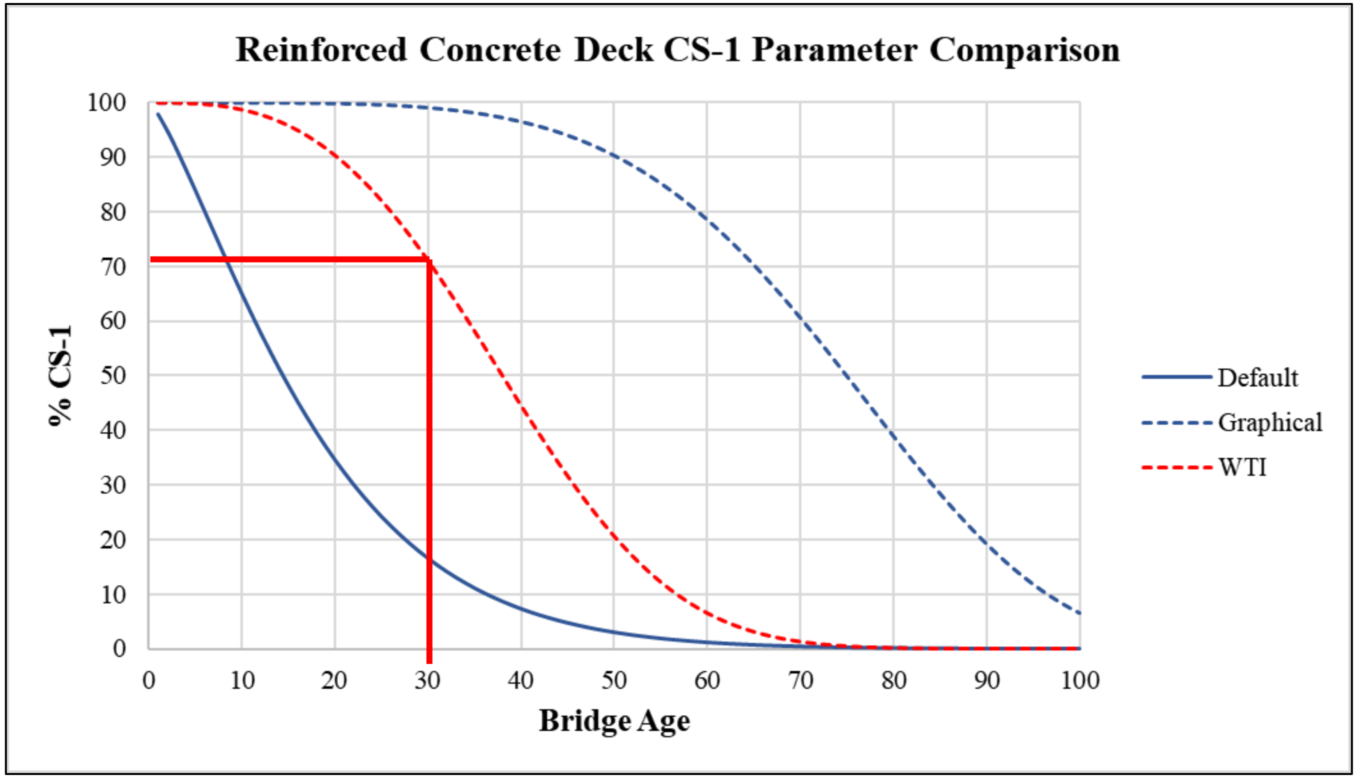
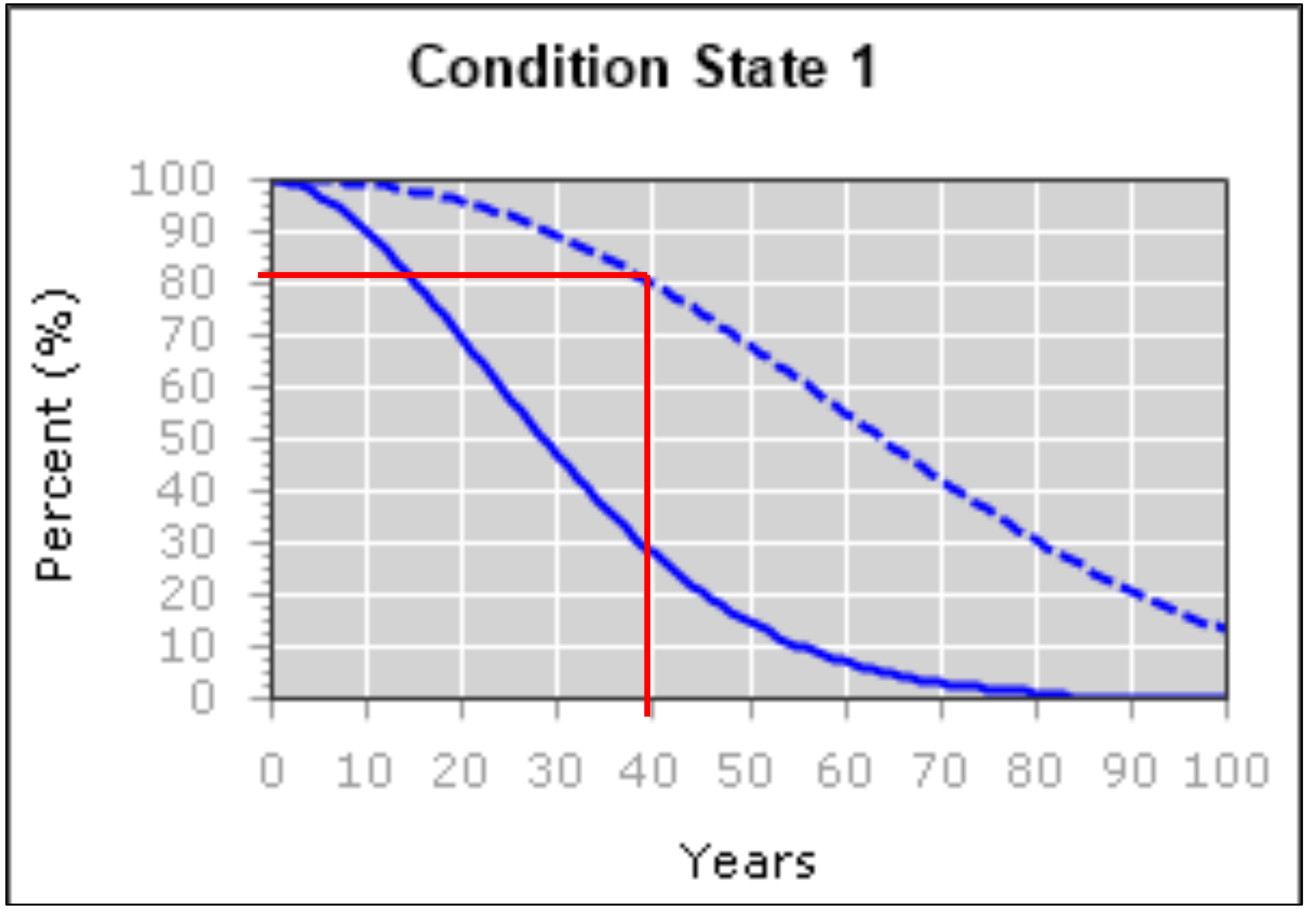


Steel Girders

Parameter Estimates	Shape Factor	Median Years CS-1	Median Years CS-2	Median Years CS-3
BrM Default	1.8	28.5	19.5	13.5
Graphical	2.4	64.0	19.5	13.5
WTI Refinement	-	-	-	-

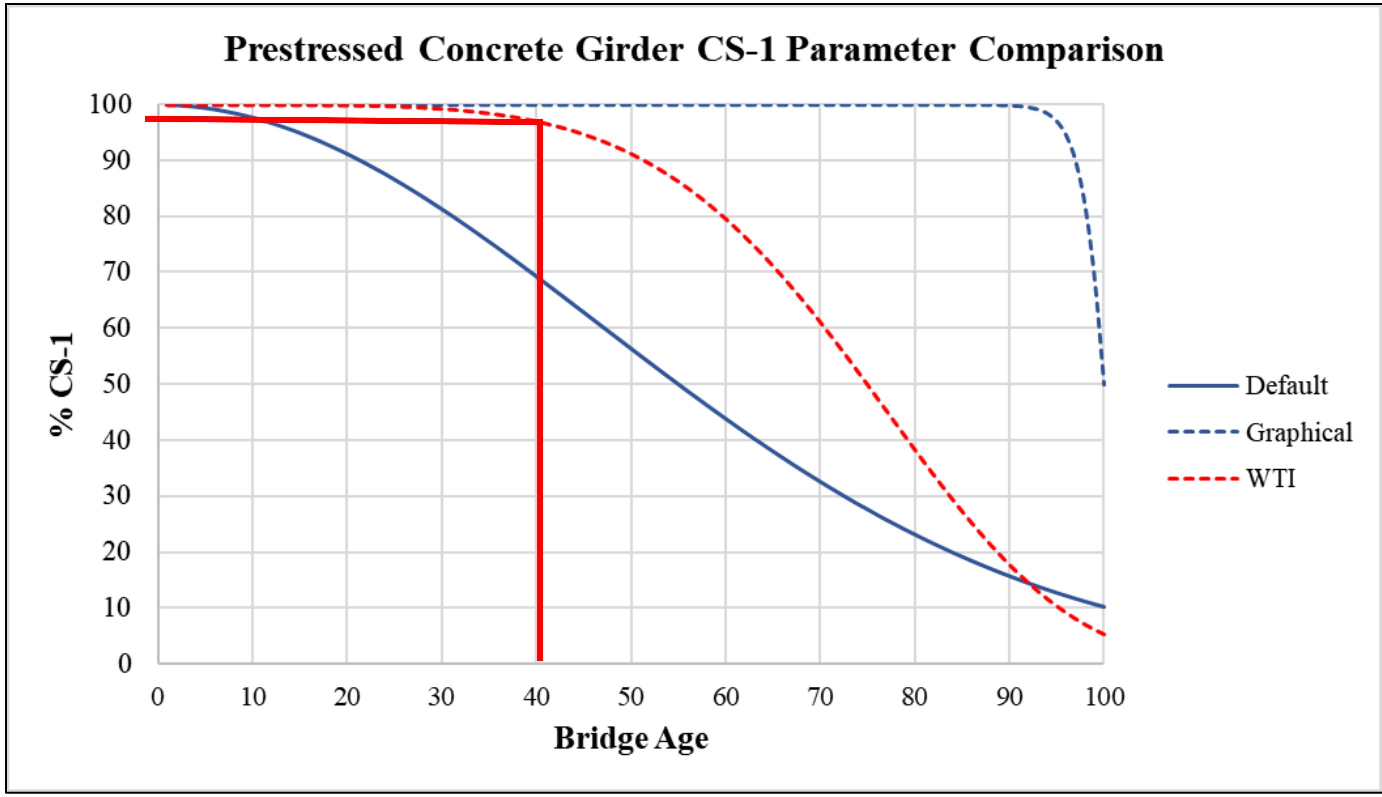
Element	CS-1 Target	Years
Steel Girder	70%	40



Prestressed Concrete Girders

Parameter Estimates	Shape Factor	Median Years CS-1	Median Years CS-2	Median Years CS-3
BrM Default	2.0	55	25.2	28.6
Graphical	61.5	100	25.2	28.6
WTI Refinement	5.0	75	20	20

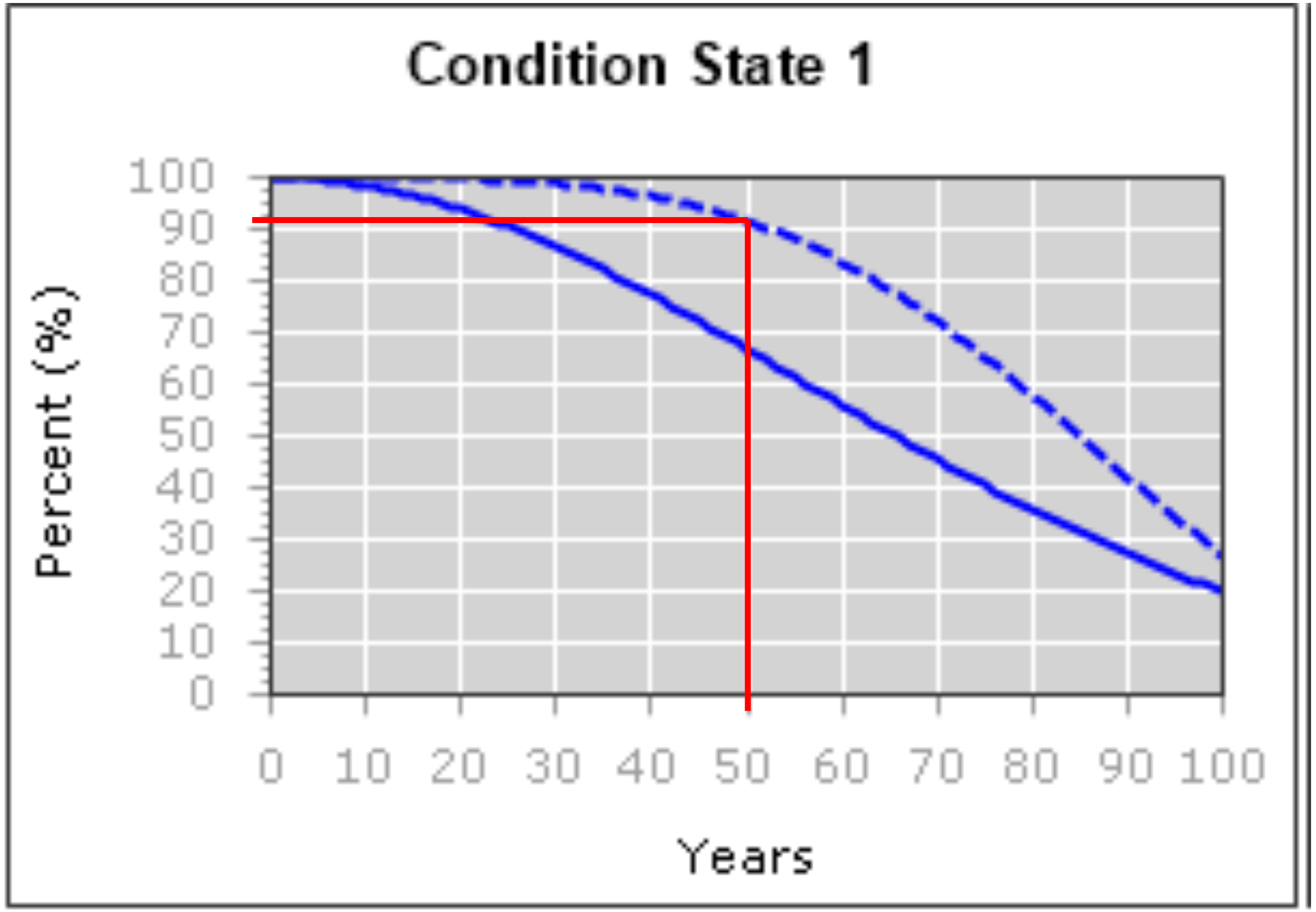
Element	CS-1 Target	Years
Prestressed Concrete Girder	95%	40



Concrete Abutment

Parameter Estimates	Shape Factor	Median Years CS-1	CS-2	CS-3
BrM Default	2.0	65.6	56.2	45.4
Graphical	3.9	85	56.2	45.4
WTI Refinement	-	-	-	-

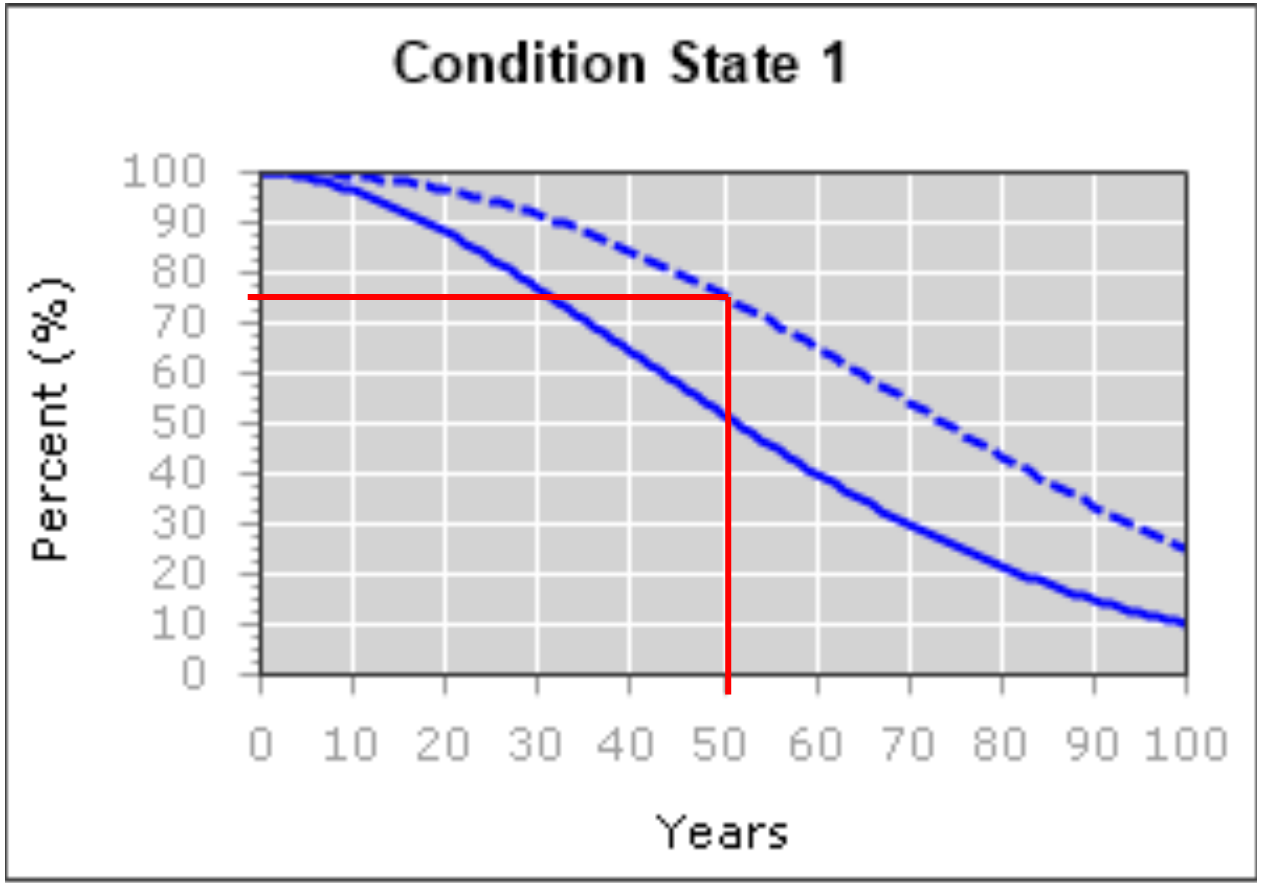
Element	CS-1 Target	Years
Concrete Abutment	90%	50



Steel Culvert

Parameter Estimates	Shape Factor	Median Years CS-1	Median Years CS-2	Median Years CS-3
BrM Default	2.0	65.6	56.2	45.4
Graphical	3.9	85	56.2	45.4
WTI Refinement	-	-	-	-

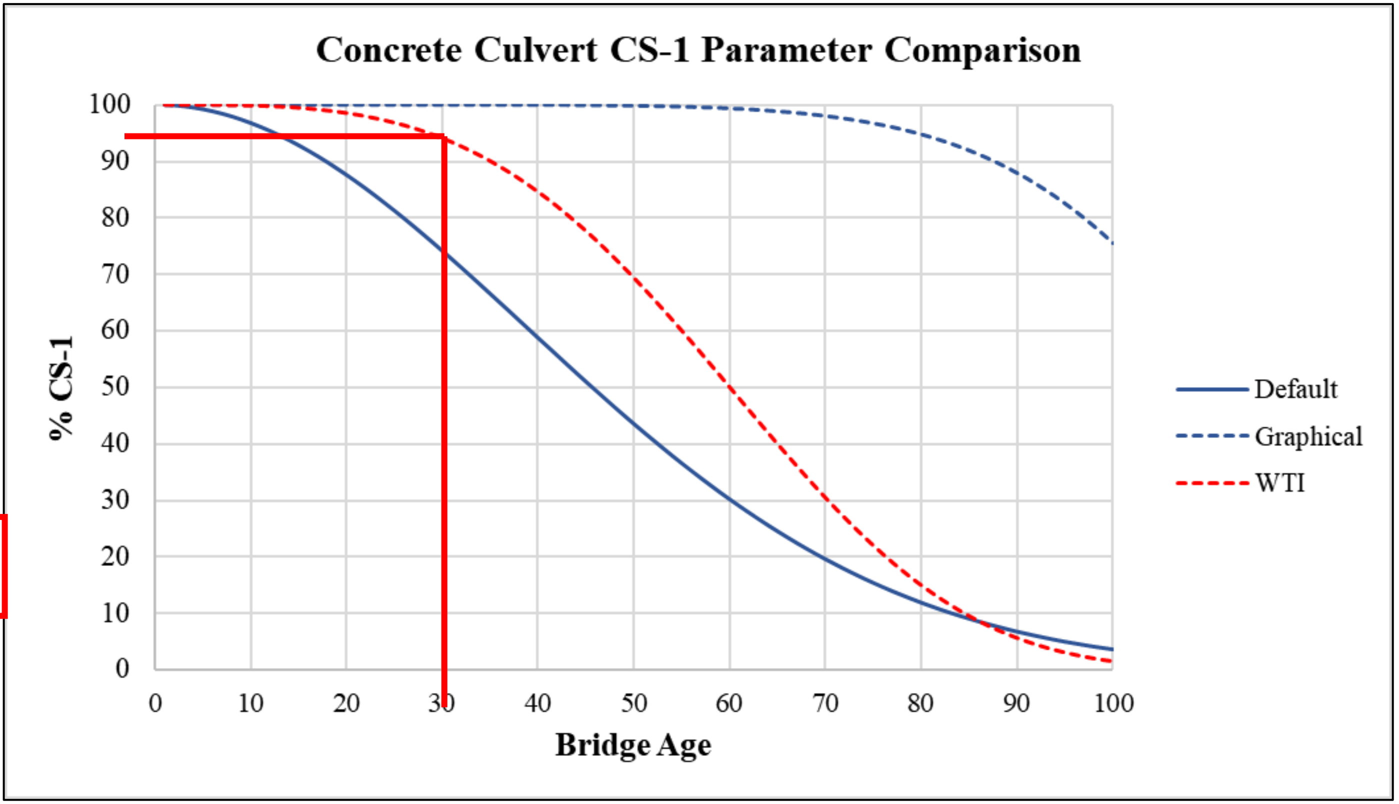
Element	CS-1 Target	Years
Steel Culverts	75%	50



Concrete Culvert

Parameter Estimates	Shape Factor	Median Years CS-1	Median Years CS-2	Median Years CS-3
BrM Default	2	45.6	56.5	34.8
Graphical	7.5	113	56.5	34.8
WTI Refinement	3.5	60	40	20

Element	CS-1 Target	Years
Concrete Culvert	95%	30
	75%	50



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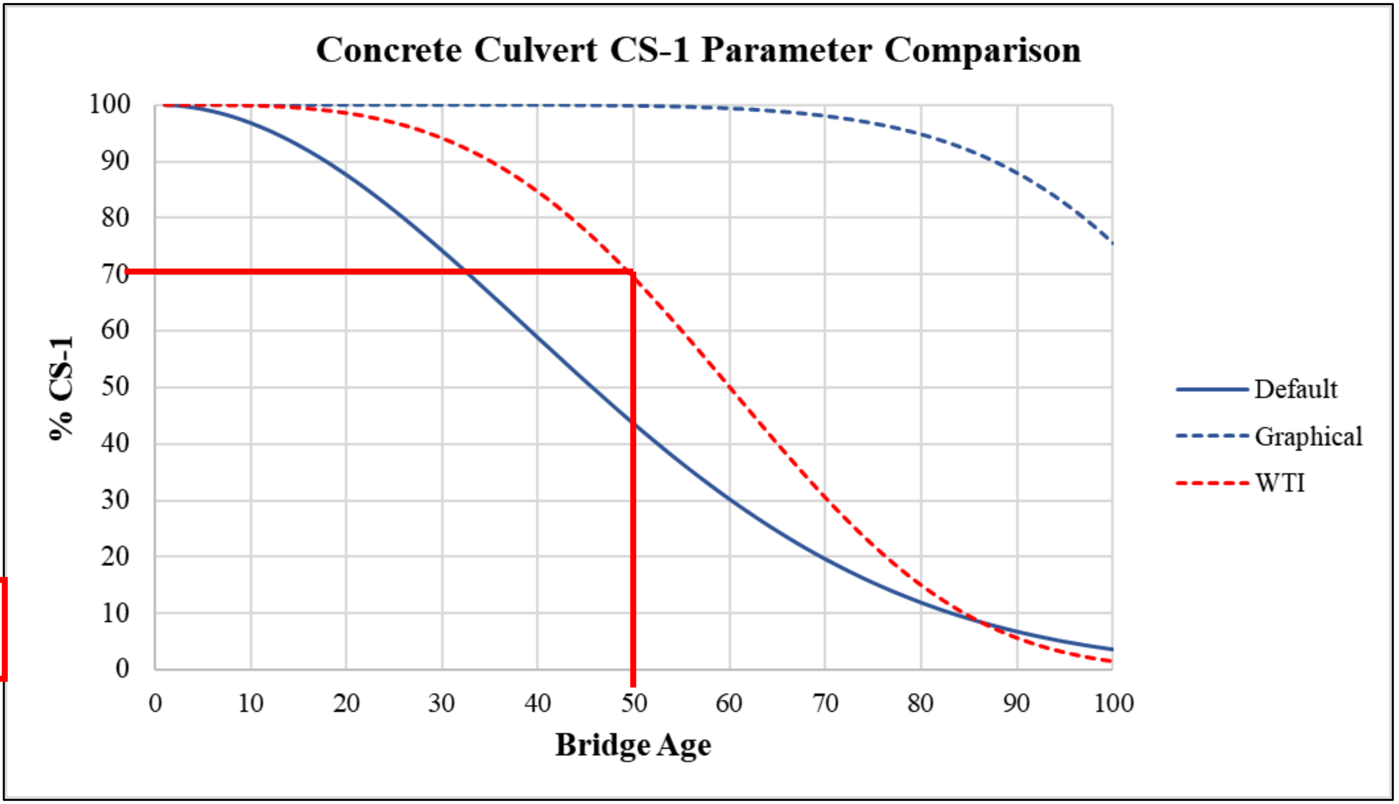


Conclusions

Recommended BrM Input Parameters

Element	BrM Defaults				Graphical Method		WTI Refined Values			
	β	CS-1	CS-2	CS-3	β	CS-1	β	CS-1	CS-2	CS-3
Concrete decks	1.3	14.4	42	14.9	4.8	75	3	38	42	14.9
Steel Girder	1.8	28.5	19.5	13.5	2.4	64	2.4	64	19.5	13.5
Concrete Girder	2	55.0	25.2	28.6	61.5	100	5	75	20	20
Concrete Abutment	2	65.6	56.2	45.4	3.9	85	3.9	85	56.2	45.4
Steel Culvert	1.8	51.5	33.1	39.1	2.3	74	2.3	74	33.1	39.1
Concrete Culvert	2	45.6	56.5	34.8	7.5	113	3.5	60	40	20

Environmental Factors

Region	Graphical-Method Shape Factor (β)	Recommended Environment	BrM Environment Factor
State-wide	4.8	Moderate	1.0
Billings	3.8	Benign	2.0
Butte	3.2	Severe	0.7
Glendive	5.0	Benign	2.0
Great Falls	6.5	Low	1.5
Missoula	6.5	Severe	0.7

Optimization and Implementation

Optimization – using Health Index

BrM Health Index Detailed Calculation

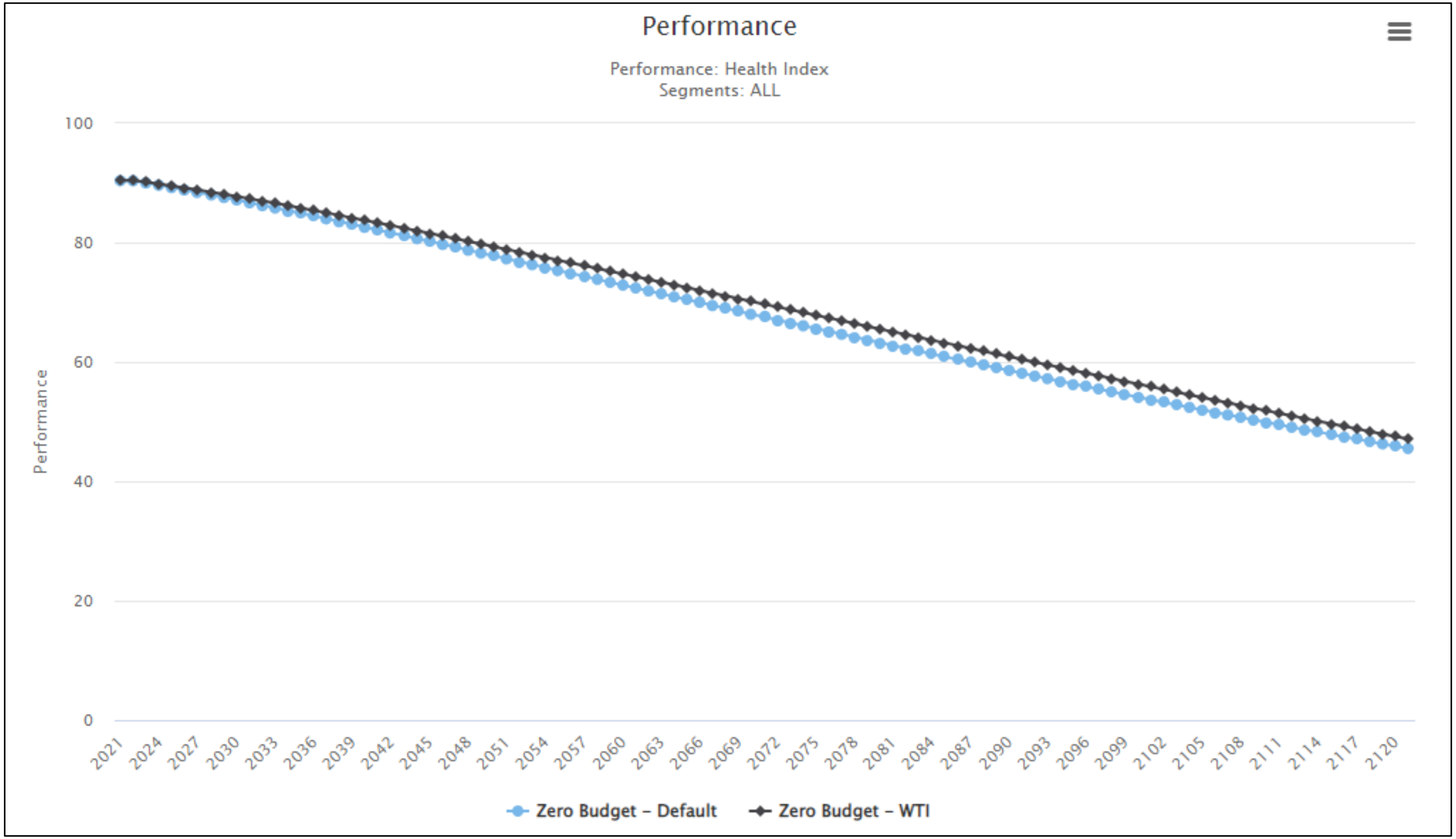
This report exemplifies the values and factors used to determine the Health Index for a particular structure. The elements and quantities for a given structure are modified on the Inspection > Condition page, and the factors and weights for an element are modified on the Admin > Modeling Config > Element Defs page. Defects and protective systems are not included.

$$HI = \frac{\sum_{All\ Elements} W_E \left(\sum_{CS1}^{CS4} C_n Q_n \right)}{\sum_{All\ Elements} W_E Q_{total}}$$

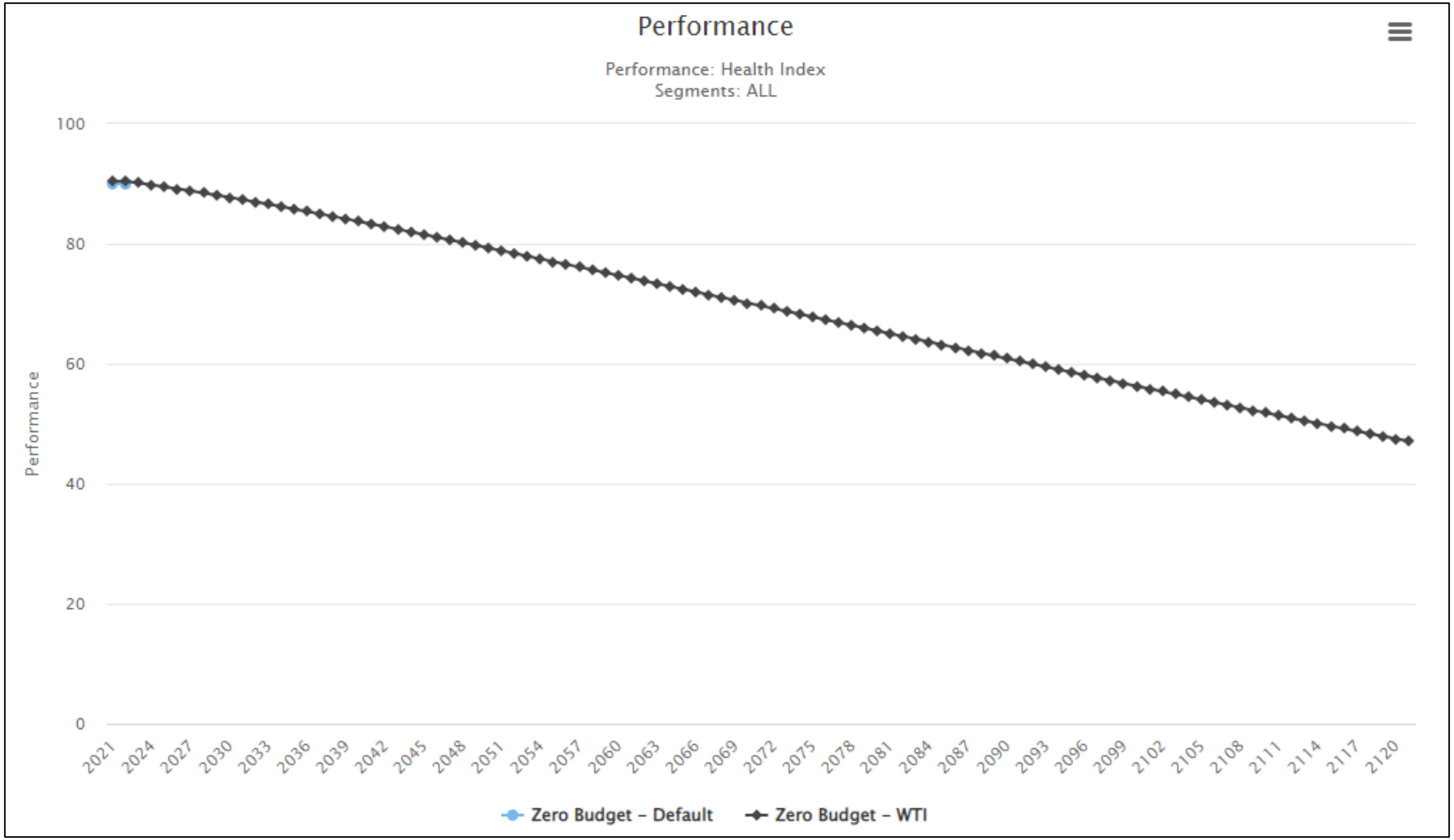
Where:
HI = the Health Index, a measure of remaining health, 0% to 100%
W = the relative weight of an element.
C = the condition state coefficient, between 1 and 0
Q = Quantity in a condition state or Quantity Total, from inspection data

- Coefficients, CS-1 = 1.0, CS-2 = 0.67, CS-3 = 0.33, CS-4 = 0
- Calculated for each bridge and averaged for multi-bridge dataset.
- No-cost optimization analysis

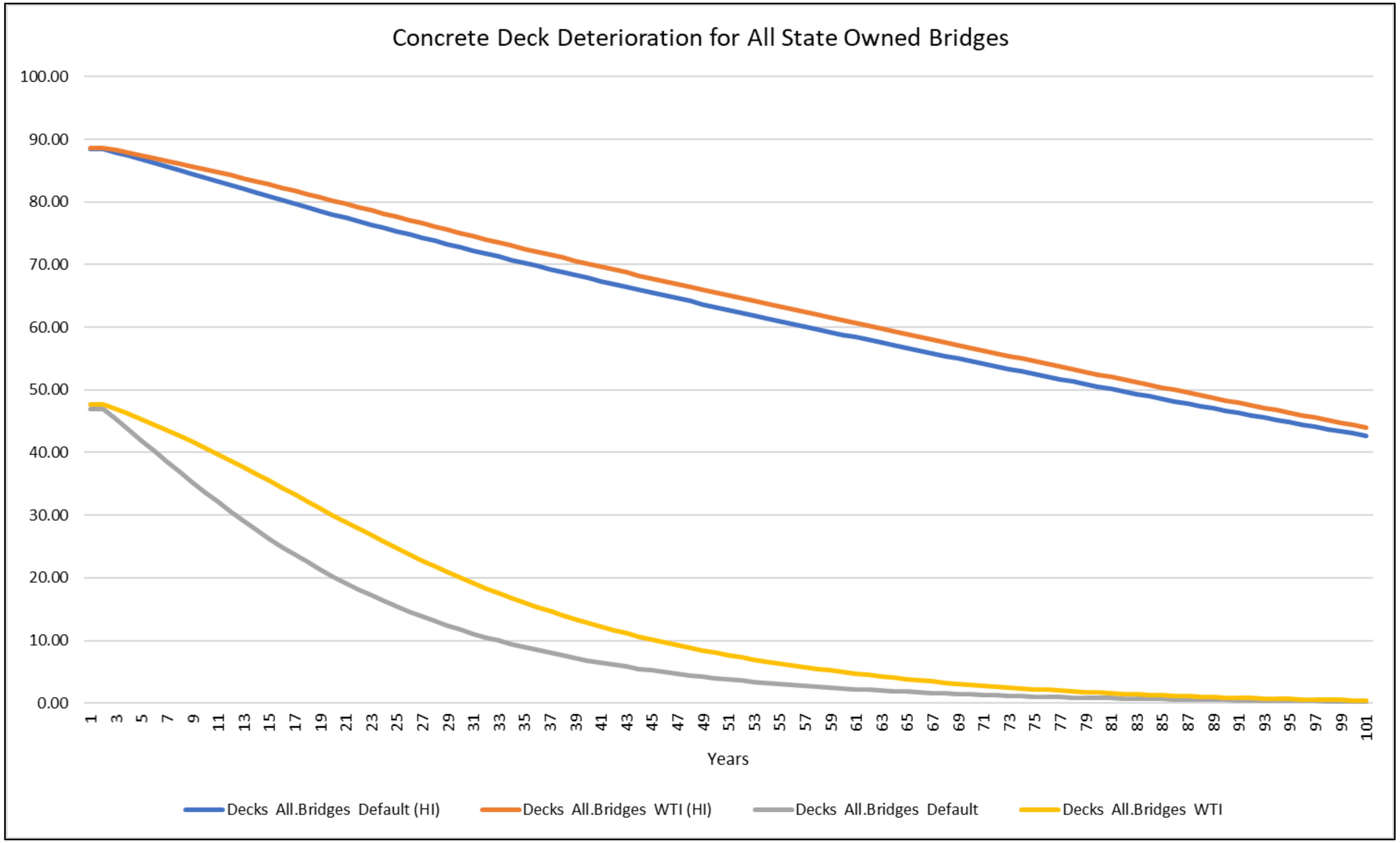
All elements, all bridges

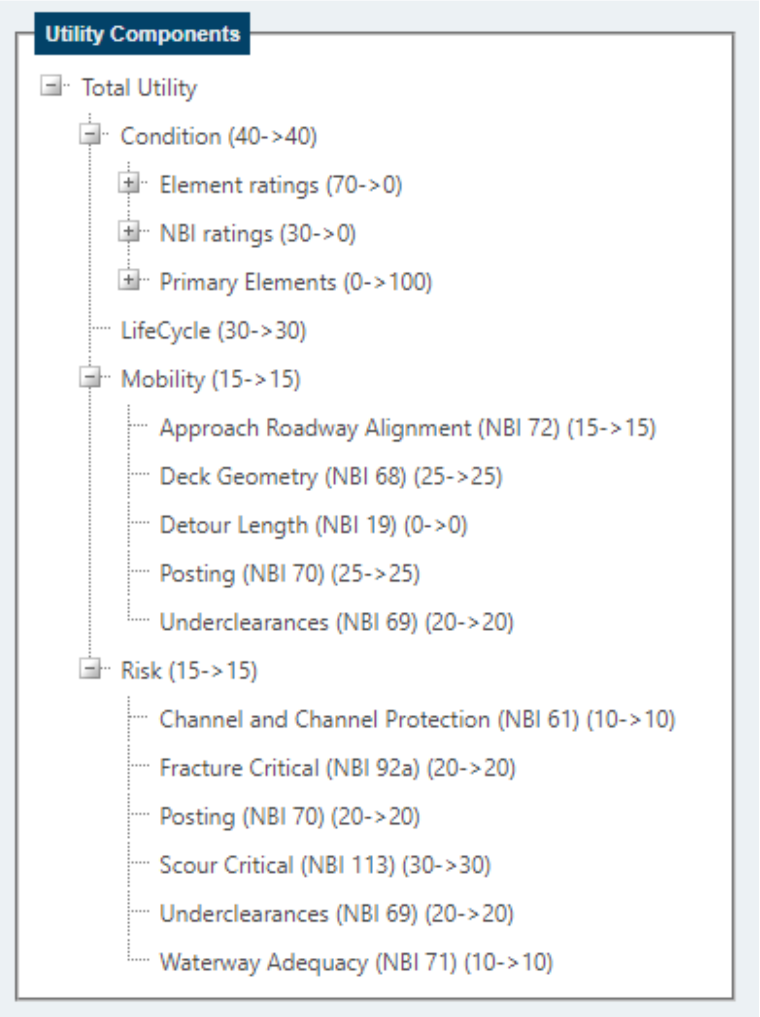


Primary elements, all bridges

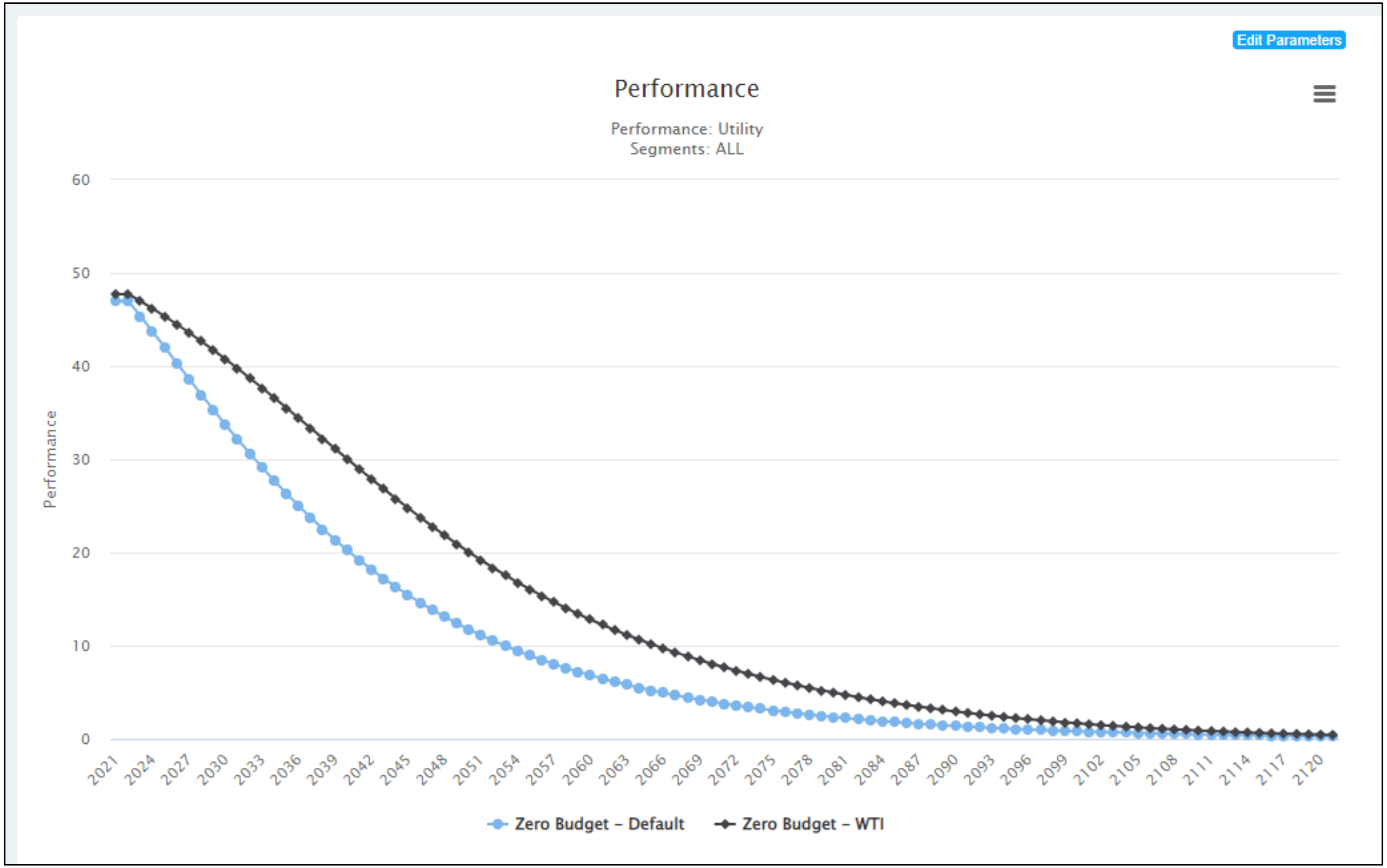


Concrete deck, all bridges

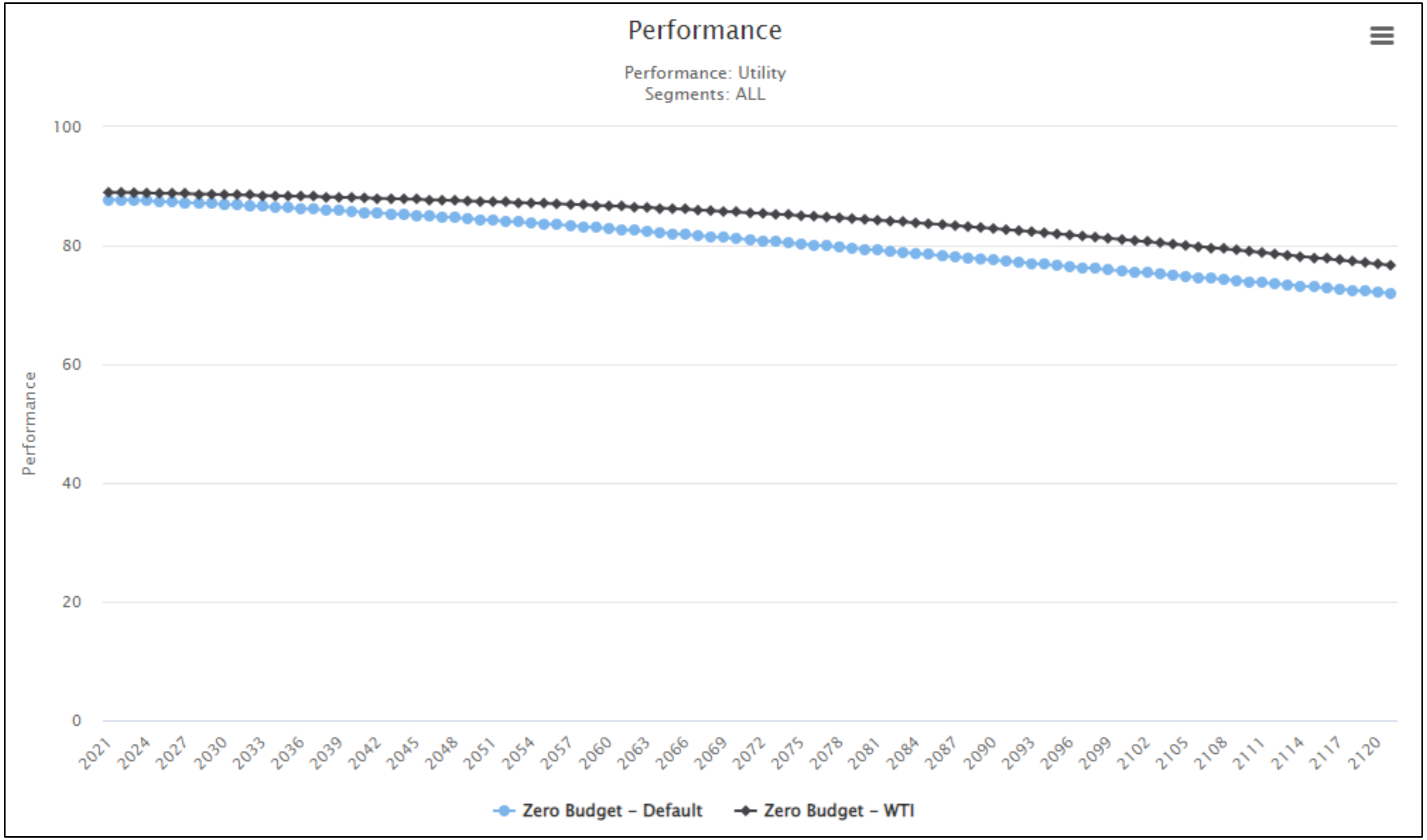




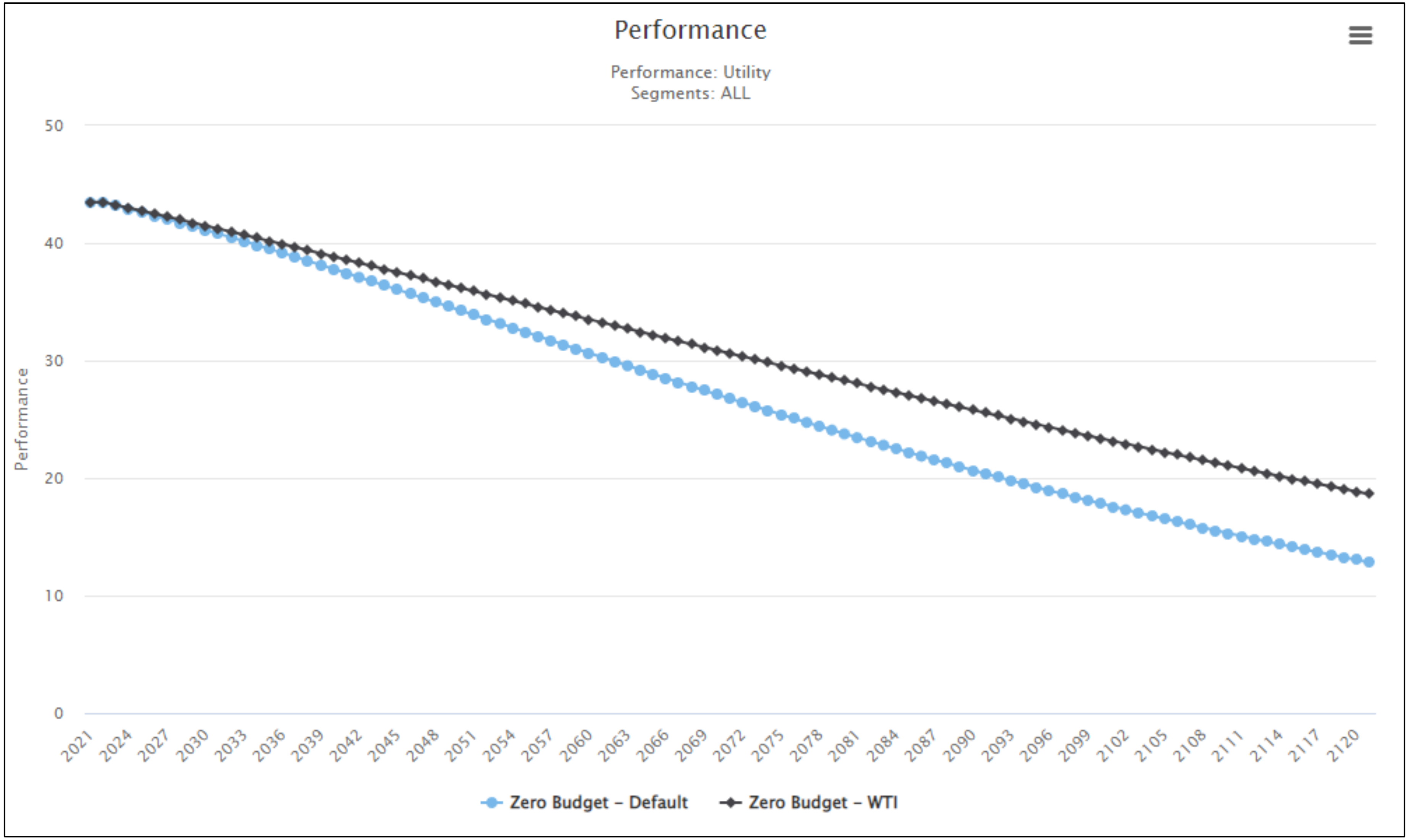
Concrete deck, all bridges



Prestressed concrete girders

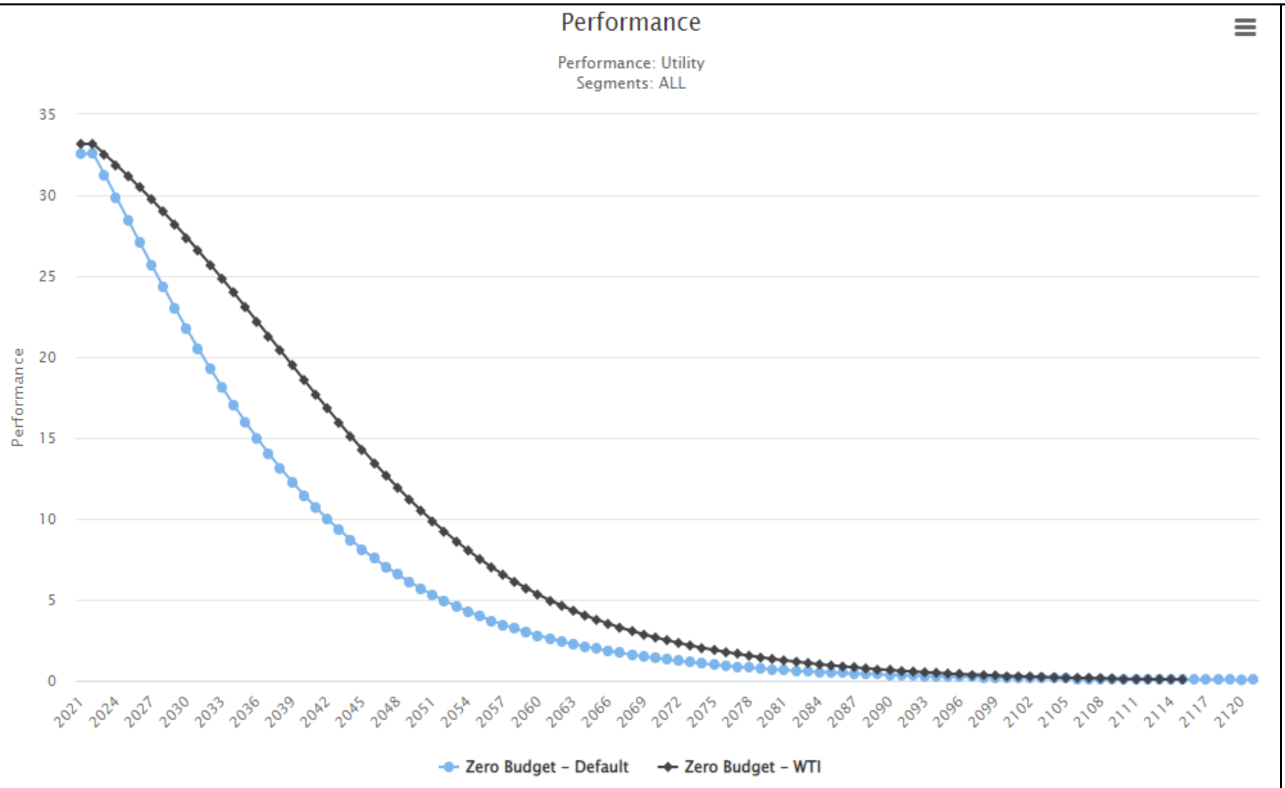


Steel girders

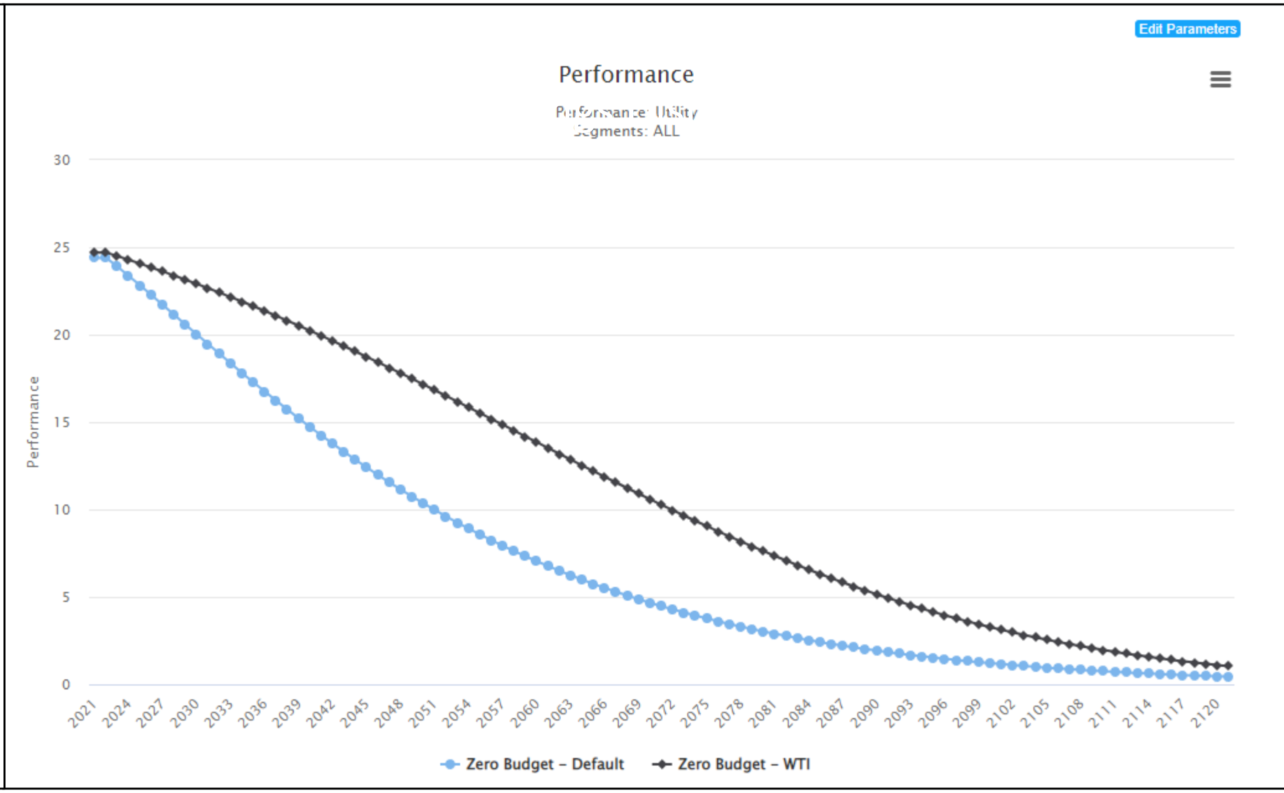


Concrete decks by region

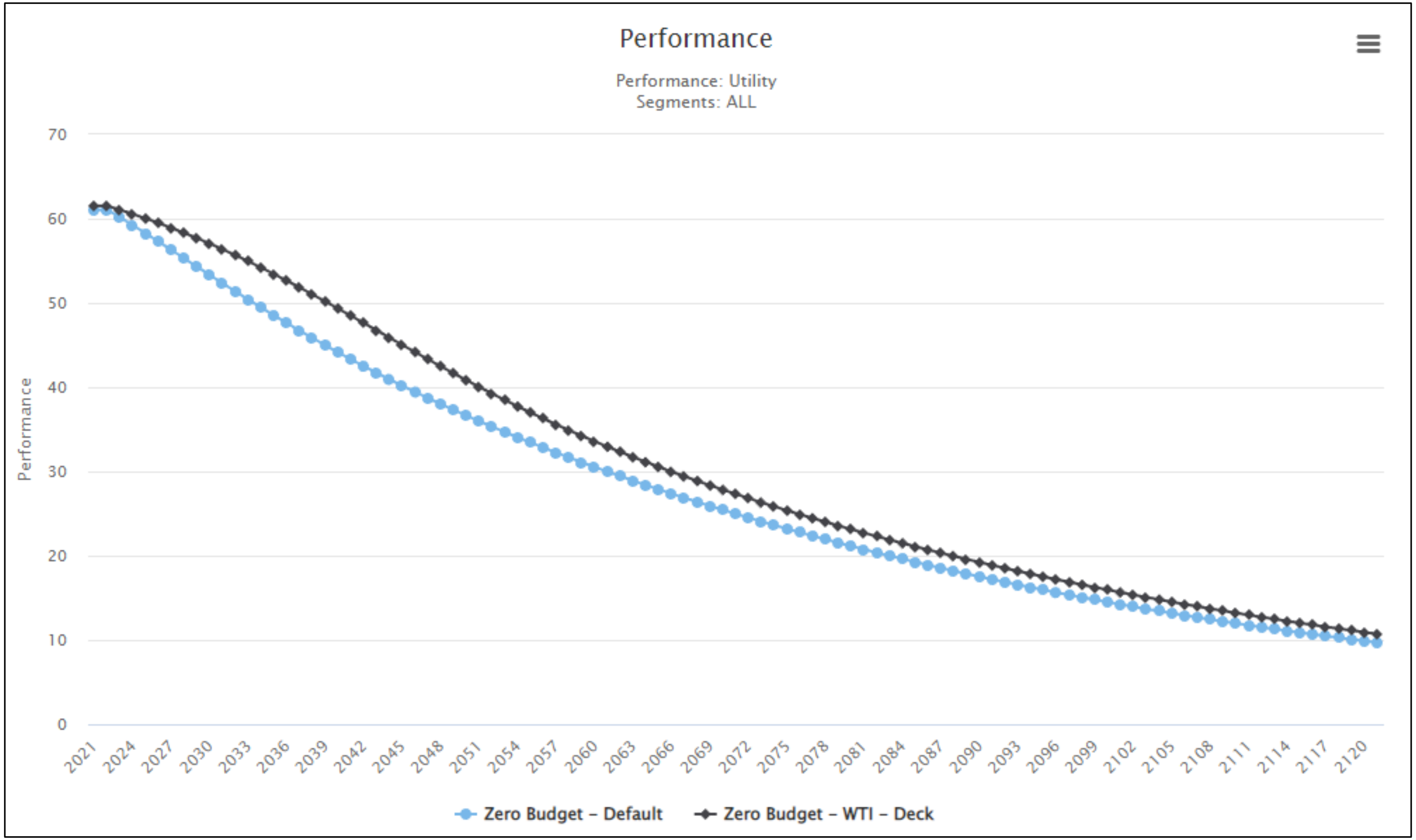
Butte District



Billings District



Concrete decks, interstate, Butte district



Optimization Summary

- Regional subsets result in larger differences between default and WTI values.

- Element deterioration is not a driving factor for shorter (10-15 year) optimization analysis. Element deterioration will make a big difference for 100-year life-cycle cost analysis for a single bridge.

Implementation Recommendations

Implementation Recommendation #1

Use the BrM input parameters determined in this research for optimization analyses to more accurately reflect Montana's bridge deterioration rates. These input parameters are statistically derived from Montana's NBI element-level inspection data and have been refined using MDT's estimated maintenance targets and observed trends from the inspection data.

Implementation Recommendation #2

Environmental factors within BrM can be used to adjust the deterioration rates of reinforced concrete deck elements to reflect subtle differences observed in the five MDT maintenance districts. However, additional research is needed to verify the effect of these environmental factors on deterioration of other bridge elements.

Implementation Recommendation #3

Identify and implement a method to document the date and type of maintenance activity in the inspection database. Accurate maintenance and rehabilitation data will allow enhanced dataset filtering to target pure deterioration and identify the efficacy of specific maintenance activities.

Implementation Recommendation #4

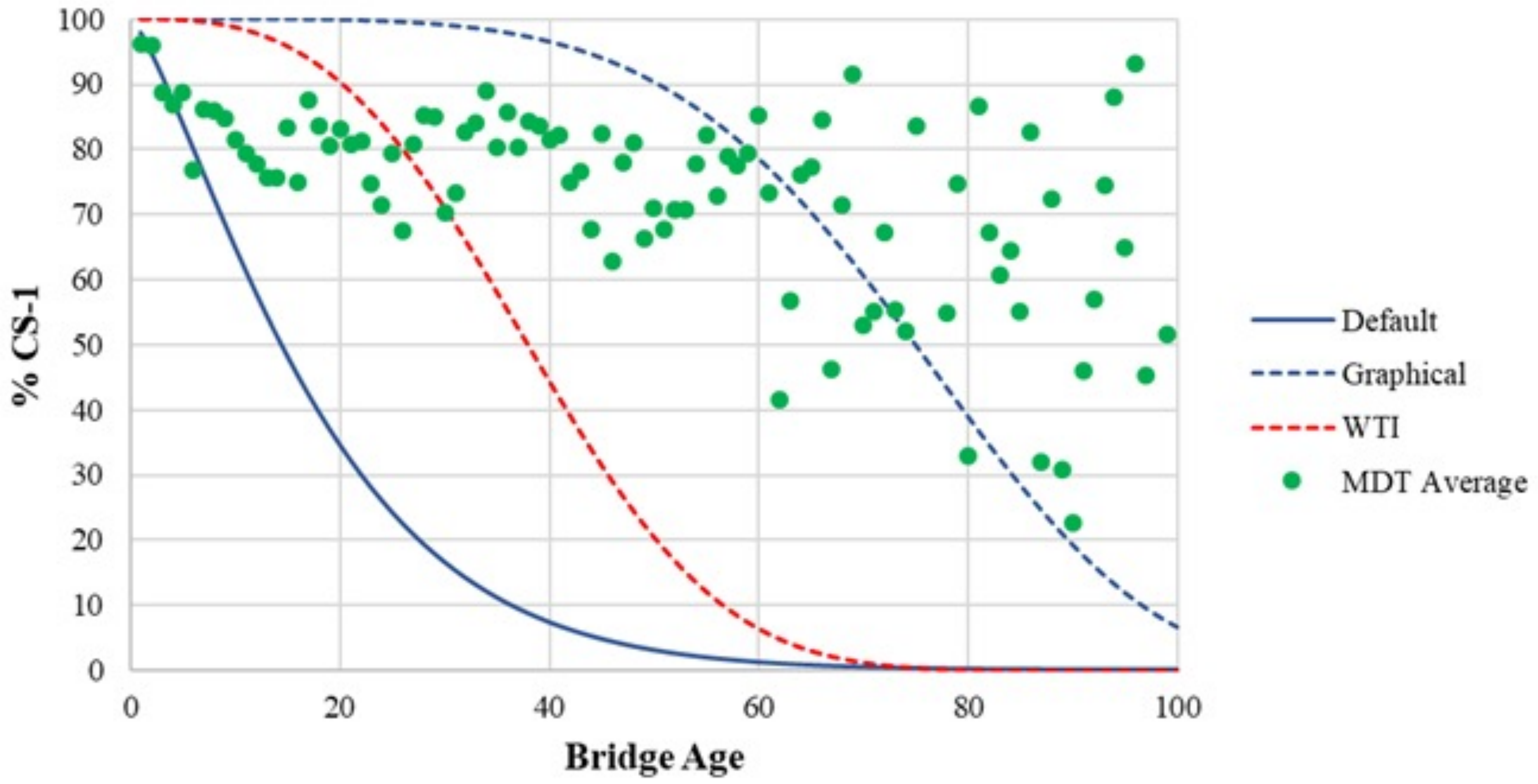
Continue recording and prioritize NBI component-level data using a scale of 0 to 9. New BrM optimization strategies are available that are based on component-level data. Results of this research have identified challenges with using less-granular element-level condition state ratings from 1-4 for estimating bridge deterioration.

Implementation Recommendation #5

Create recommendations and guidance for bridge inspection data entry. Consistent data entry will reduce potential variations in deterioration trends that may be caused by variations in inspector objectivity.

Performance Measures Report

Questions



100
90
80
70
60
50
40
30
20
10
0
% CS-1
0
20
40
60
80
100
Bridge Age
Default
Graphical
WTI
MDT Average

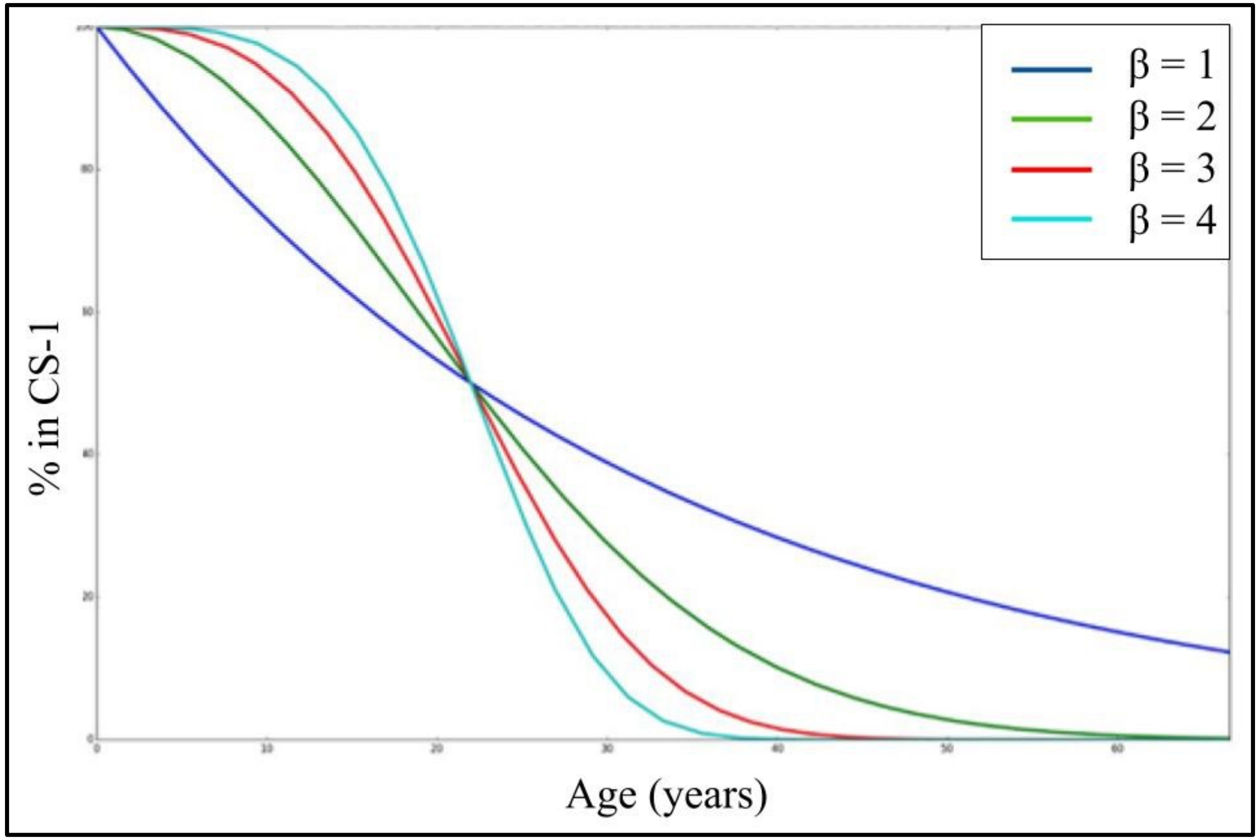
Deterioration trends and revised targets (not optimization)

	Deterioration Targets						Maintenance action	Frequency	
	CS-1	CS-2	CS-3	CS-4	CS-2+CS-3+CS-4	CS-3+CS-4		MDT	WTI
Concrete deck	> 95%				≤ 5%		Bridge Prevent 1	3	15
	< 95%				≥ 5%		Bridge Prevent 2/ Minor Rehab 1	7	15
	> 85%				≤ 15%		Minor Rehab 2	10	25
	< 85%				≥ 15%		Major Rehab 1	15	25
PS girders						≥ 5%	Patch and Seal		55
						≥ 25%	Repair Beam		85
				> 5%			Replace Bridge		75
Steel girders		≥ 25%					Spot painting		60
			≥ 25%				Zone painting		-
				≥ 25%			Repainting		85
Concrete Abutment						≥ 25%	Zone painting		-
				≥ 25%			Repainting		-

AASHTOWare Bridge Management Software (BrM)

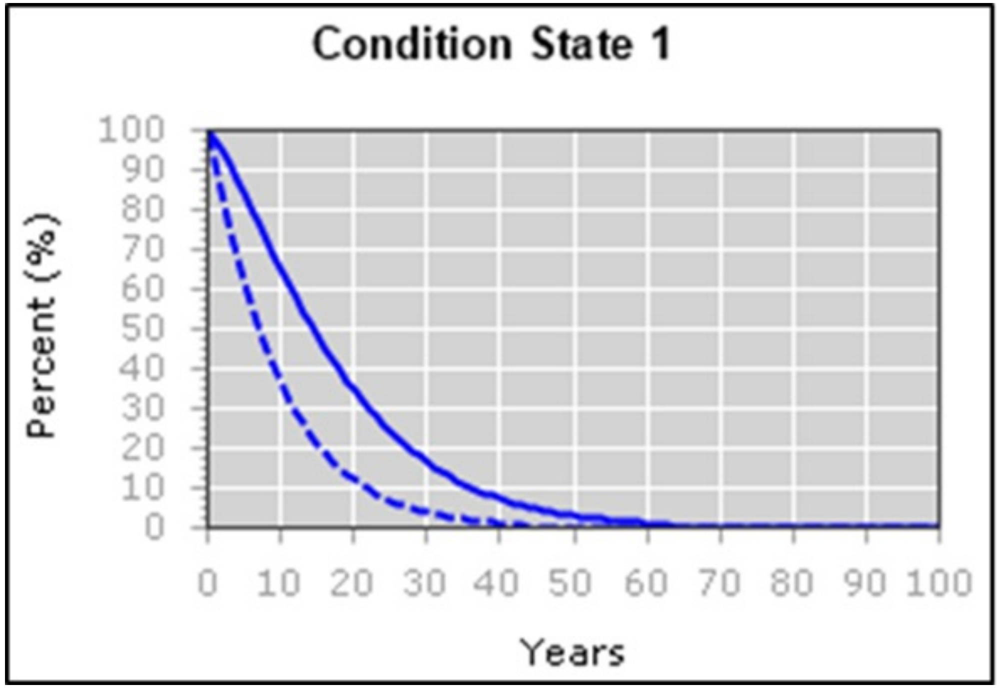
- Weibull distribution used to model deterioration from CS-1 to CS-2
- Parameters
  - shape factor = β
  - median years in CS-1
- Default parameters used in BrM = average of values from Alabama, Idaho, New York, California, and Kentucky.

Effect of Shape Factor (β) on Weibull deterioration

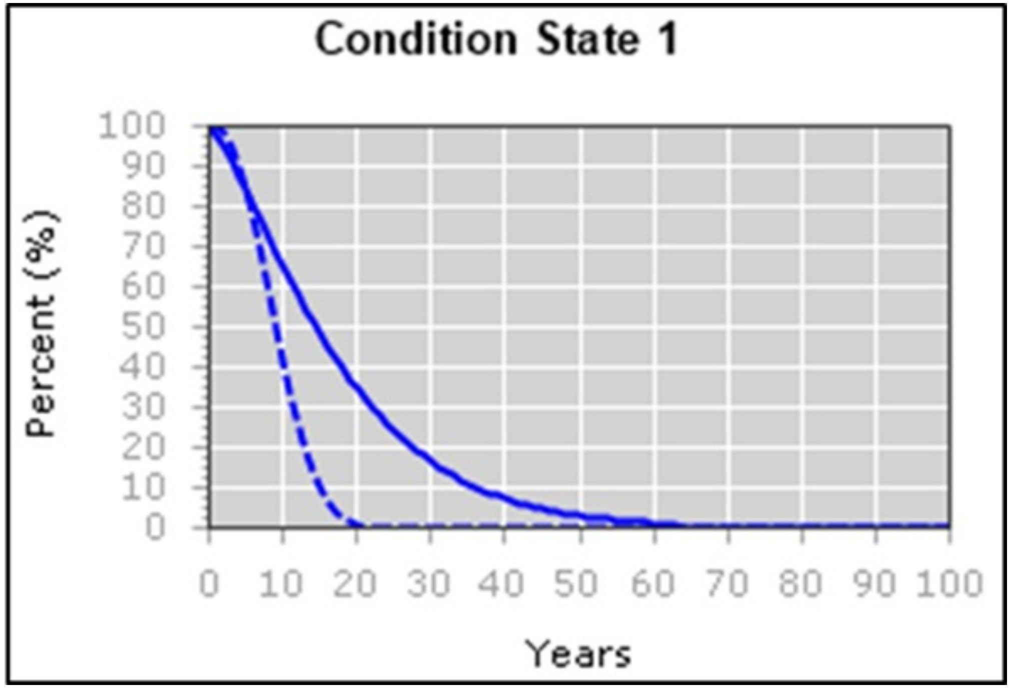


Weibull parameters by two approaches

Algebraic method $y = \beta[-\ln(x)]^{1/\alpha}$



β = 1.06 and median years in CS-1 = 7
bridge ages 2-, 25-, and 50-years

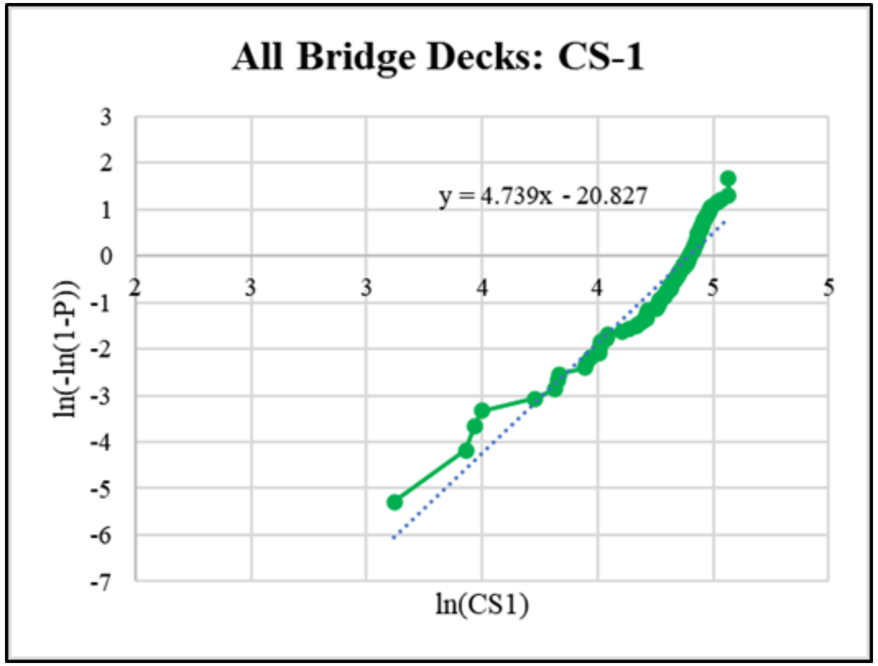


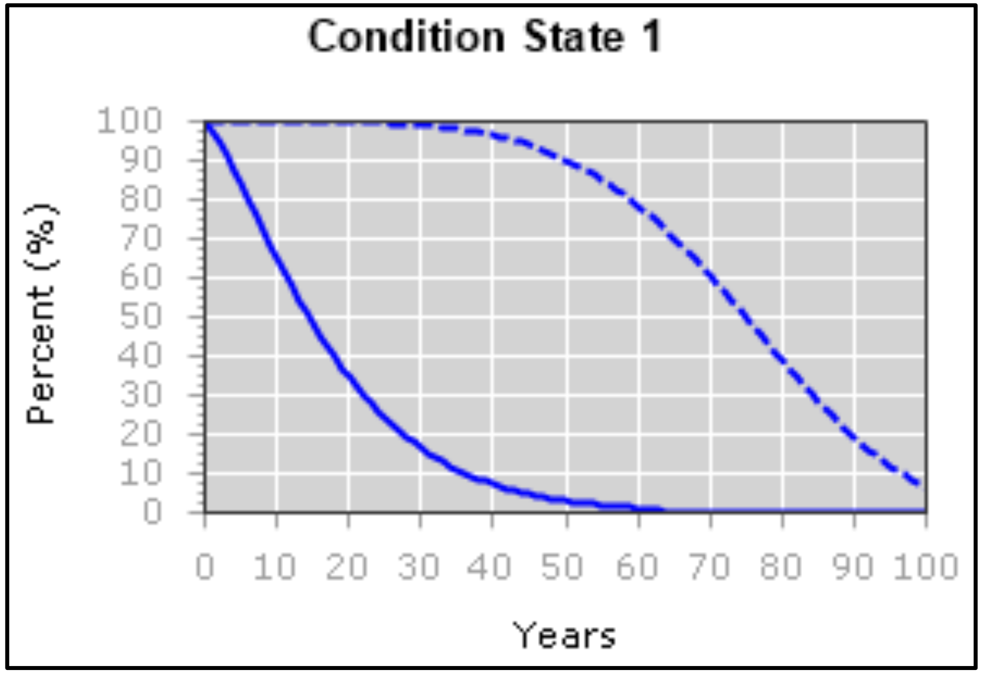
β = 2.36 and median years in CS-1 = 9
bridge ages 2-, 25-, and 99- years.

Weibull parameters by two approaches

Graphical method

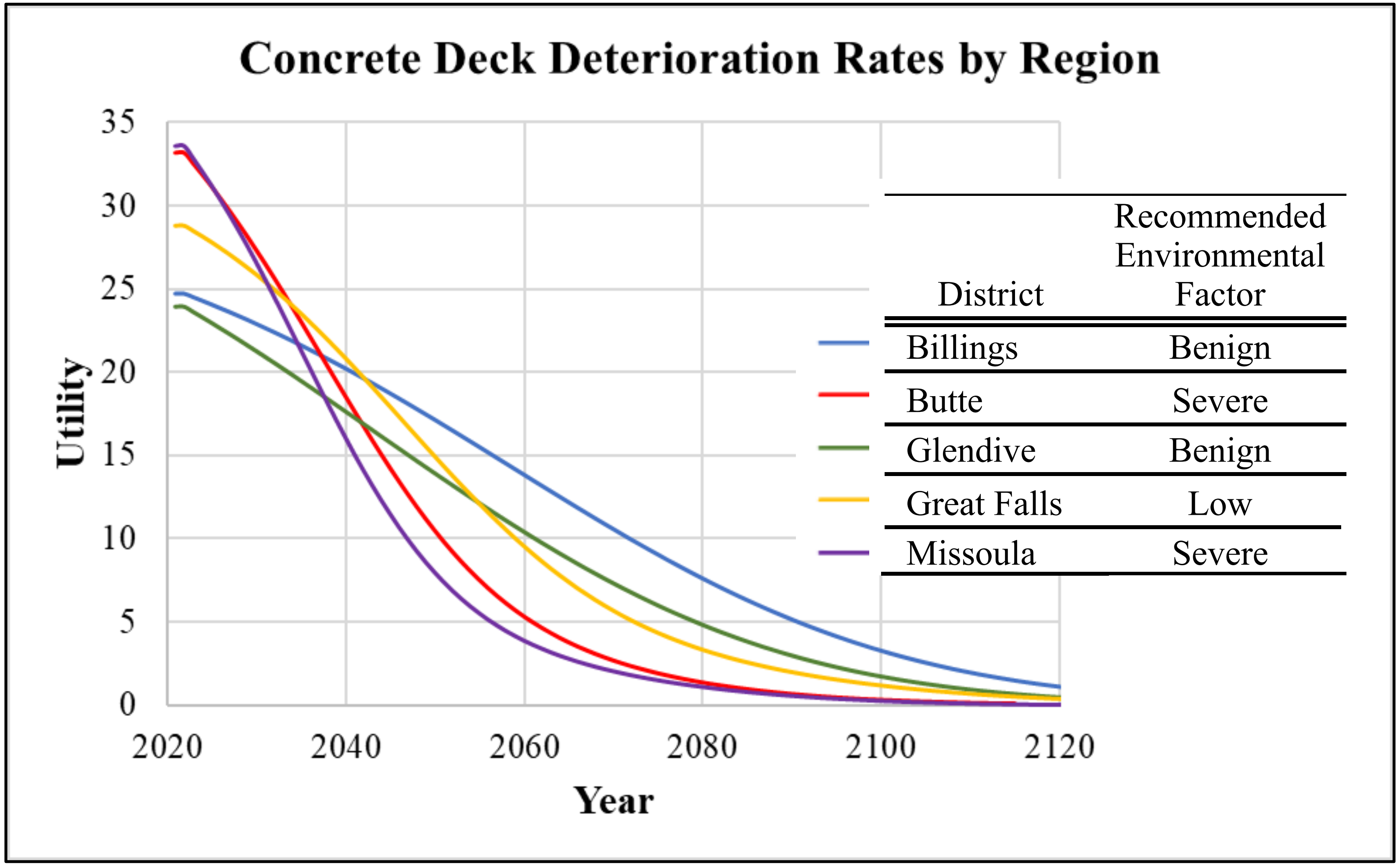
$$y = \beta[-\ln(x)]^{1/\alpha}$$





β = 4.74, median years in CS-1 equal to 75

BrM Environmental factors for concrete decks



Implementation thoughts

- Optimization analysis supports previous result that WTI input parameters (β, median years) result in a more representative deterioration for Montana than BrM default values.

- Fitting deterioration rates to MDT targets may be more valuable than no-cost optimizations.

- Costs and maintenance activities should be implemented before further adjustments should be made to deterioration rates.