
VDOT
Virginia Department of Transportation

SPECIAL STRUCTURES HEALTH INDEX
EXPERT ELICITATION FOR MOVABLE BRIDGES

Marc Stecker, PE, & Adam Matteo, PE
November 16, 2020

Outline

- What is the Health Index?
- Why We Developed the Health Index?
- What are Purpose and Use of the Health Index?
- Elements and Element Level Condition Data
- How is the Health Index Calculated?
- Concept of Damage Index
- Formula Modifying Factors
- Next Steps in Development Process
- Pause for Demonstration of Spreadsheet Tool & Expert Elicitation
- Additional and Future Uses

Reach out to Facility Managers for an Expert Elicitation

- $CS4_{equiv}$ weighting factors for CS2 & CS3
- $CS4_{equiv\text{-}max}$ per element
- DL (Design Life)
- FP (Functional Performance)
- OP (Operational Performance)
- SI (Safety & Importance Weighting)

What is the Health Index (HI)?

- The HI is a calculated index measuring the current overall condition of a structure on a 0 to 100 scale, with 100 corresponding to an ideal (new) structure
- HI for each element of a structure is calculated with detailed condition data from inspections and modified by:
  - Design Life (Age)
  - Functional Performance (Design Adequacy)
  - Operational Performance (Risk Consequence)
- Overall HI for each structure is calculated using the weighted average of the element HIs (weighted by safety and importance)
- The special structures HI aligns with the methodology used to calculate health index for conventional bridges

Why Have We Developed the Health Index (HI)?

- Performance measures and targets were established for bridges and pavements during the 2019 Comprehensive Review, but there were no readily available performance measures for tunnels and movable bridges
- Commissioner directed Structure & Bridge Division to develop a health index to measure condition and health of tunnels and movable bridges and for use as a performance measure
- Contacted several DOTs but none had yet developed a health index
  - Pennsylvania Dept. of Transportation (PennDOT)
  - Louisiana Dept. of Transportation & Development (La DOTD)
  - Washington State Dept. of Transportation (WSDOT)

What are Purpose and Use of the Health Index (HI)?

Immediate Use:

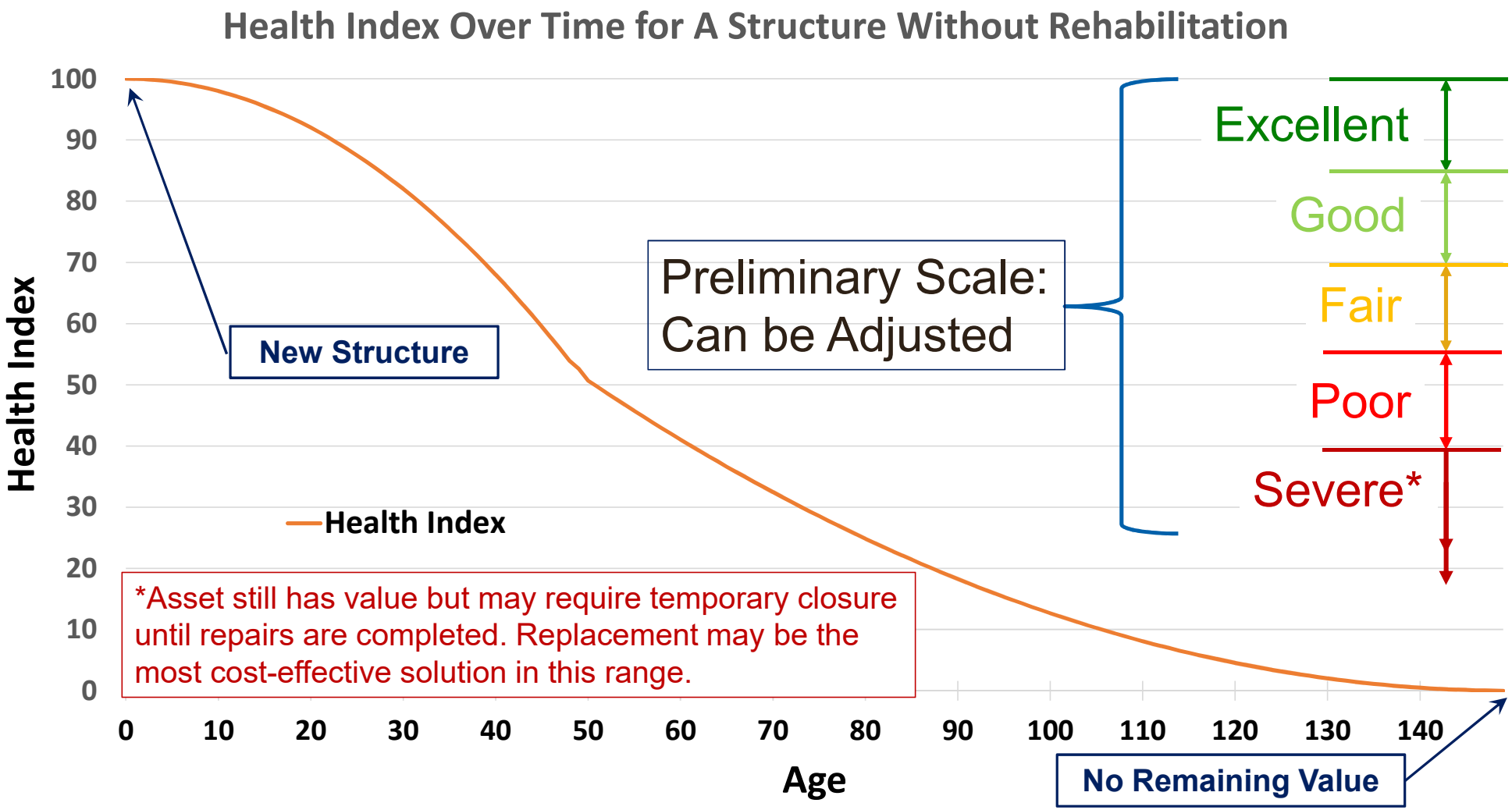
- Measure relative health of individual movable bridges and tunnels
- Measure relative health of individual systems (i.e. mechanical, electrical, structural, and house) for a given category of Special Structure.

Near Term Use:

- Use health index along with project prioritization formula for scenario analyses of 50 Year long term plan to maximize benefits with limited funds.

Long Term Use:

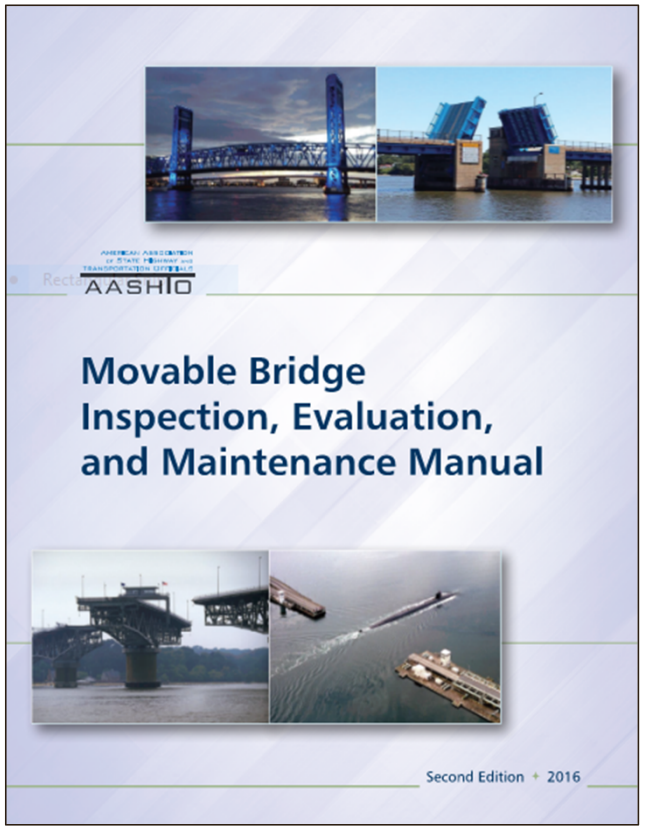
- Determine which treatments provide optimal life-cycle value.
- Possibly replace project prioritization formula with health index.


Health Index Over Time for A Structure Without Rehabilitation
Health Index
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Age
New Structure
Health Index
Preliminary Scale:
Can be Adjusted
Excellent
Good
Fair
Poor
Severe*
*Asset still has value but may require temporary closure until repairs are completed. Replacement may be the most cost-effective solution in this range.
No Remaining Value

What is an “Element”?

Each structure has many elements in 4 major systems:

- Mechanical
- Structural
- Electrical
- House



At each field inspection, all elements receive a set of condition state (CS) ratings on a scale of 1 to 4 as follows:

- CS1 = Good
- CS2 = Fair
- CS3 = Poor
- CS4 = Severe

What is an “Element”?

PART 3 – MOVABLE BRIDGE ELEMENT DESCRIPTIONS

Example - How Condition States Are Assigned by Inspectors Element 604 Movable Bridge Drive System - Mechanical

- **Power Subsystem**
  - Electric Motors
  - Hydraulic Pumps
  - Generators
  - Auxiliary Motor
  - Manual Drive
- **Brakes/Mechanical Deceleration Subsystem**
  - Motor Brakes
  - Machinery Brake
  - Buffer Cylinders
- **Power Transmission Subsystem**
  - Shafts
  - Couplings
  - Bearings
  - Operating Wire Ropes
  - Chains
  - Differentials
  - Hydraulic Cylinder
  - Hydraulic Motor
  - Enclosed Gear Boxes
  - Open Gearing

Examples of Bridge Elements & Condition States Assigned During Inspection

System	Short Element #	Full Element #	Element Description	Units	Total Quantity	Quantity in Condition State 1	Quantity in Condition State 2	Quantity in Condition State 3	Quantity in Condition State 4
Movable Bridge Support System - Structural	600	600Trunnion and Bearing Assemblies	Trunnion and Bearing Assemblies	Each	2	2	0	0	0
Movable Bridge Support System - Structural	600	600Trunnion Bearing Supports	Trunnion Bearing Supports	Each	2	0	2	0	0
Movable Bridge Support System - Structural	600	600Counterweight Linkage Members	Counterweight Linkage Members	Each	2	2	0	0	0
Movable Bridge Support System - Structural	600	600Live Load Shoes	Live Load Shoes	Each	2	0	2	0	0
Movable Bridge Support System - Structural	600	600Rack Girders	Rack Girders	Each	2	0	2	0	0
Movable Bridge Support System - Structural	600	600Shear/Moment Lock Assemblies	Shear/Moment Lock Assemblies	Each	2	0	0	2	0
Movable Bridge Support System - Structural	600	600Drive System Supports	Drive System Supports	Each	2	0	2	0	0
Movable Bridge Support System - Mechanical	601	601Trunnion and Bearing Assemblies	Trunnion and Bearing Assemblies	Each	2	0	2	0	0
Movable Bridge Support System - Mechanical	601	601Live Load Shoes	Live Load Shoes	Each	2	0	0	2	0
Movable Bridge Support System - Mechanical	601	601Pinion	Pinion	Each	2	0	2	0	0
Movable Bridge Support System - Mechanical	601	601Shear/Moment Lock Assemblies	Shear/Moment Lock Assemblies	Each	2	0	0	2	0
Movable Bridge Balance System - Structural	602	602Counterweights	Counterweights	Each	1	1	0	0	0
Movable Bridge Balance System - Mechanical	603	603Imbalance Condition	Imbalance Condition	Each	1	1	0	0	0
Movable Bridge Balance System - Mechanical	603	603Span Balance Guide Assemblies	Span Balance Guide Assemblies	Each	1	0	1	0	0
Movable Bridge Drive System - Mechanical	604	604Electric Motors	Electric Motors	Each	2	2	0	0	0
Movable Bridge Drive System - Mechanical	604	604Generator	Generator	Each	1	0	1	0	0
Movable Bridge Drive System - Mechanical	604	604Auxiliary Motors	Auxiliary Motors	Each	2	2	0	0	0
Movable Bridge Drive System - Mechanical	604	604Shafts	Shafts	Each	4	0	4	0	0
Movable Bridge Drive System - Mechanical	604	604Couplings	Couplings	Each	8	0	8	0	0
Movable Bridge Drive System - Mechanical	604	604Chains	Chains	Each	2	1	1	0	0
Movable Bridge Drive System - Mechanical	604	604Differentials	Differentials	Each	1	0	1	0	0
Movable Bridge Drive System - Mechanical	604	604Motor Brakes	Motor Brakes	Each	2	2	0	0	0
Movable Bridge Drive System - Mechanical	604	604Open Gearing	Open Gearing	Each	2	0	2	0	0
Movable Bridge Drive System - Mechanical	604	604Enclosed Gear Boxes	Enclosed Gear Boxes	Each	2	0	2	0	0
Movable Bridge Drive System - Mechanical	604	604Buffer Cylinders	Buffer Cylinders	Each	2	0	2	0	0
Movable Bridge Drive System - Electrical	605	605Main Motors	Main Motors	Each	2	0	2	0	0
Movable Bridge Drive System - Electrical	605	605Emergency Motors	Emergency Motors	Each	2	2	0	0	0

Element 604 Movable Bridge Drive System - Mechanical Condition State Definitions by Defect

Defect	Condition State			
	1	2	3	4
	GOOD	FAIR	POOR	SEVERE
Operation (9000)	Movable span operates smoothly. Major mechanical elements are properly adjusted.	Movable span operates with minor flaws, such as light vibration or noise. Equipment may be slightly out of adjustment. Filters or breathers may require replacement. None of the major mechanical elements require remedial action.	Movable span operates with significant flaws, including vibration, noise, or undesirable heating. Auxiliary operating systems may be nonfunctional. Equipment out of adjustment. Filters or breathers may be missing. Major mechanical elements may require short-term replacement or adjustment.	Movable span does not operate or operates in an erratic or uncontrolled manner. Various pieces of equipment may be significantly out of adjustment or nonfunctional. Required pieces of equipment may be missing. Major mechanical elements may require immediate replacement.
Lubrication (9001)	Lubricants are fresh, clean, and well-distributed. Oil levels are appropriate.	Lubricants exhibit minor contamination. Oil levels slightly low. Minor lubricant leaks may exist. Application of grease is excessive or barely adequate on major mechanical elements.	Lubricants exhibit moderate contamination. Oil levels low. Moderate lubricant leaks may exist. Application of grease is spotty and inadequate in places on major mechanical elements.	Lubricants exhibit heavy contamination. Oil levels extremely low. Heavy lubricant leaks may exist. Application of grease is inadequate in many places on major mechanical elements.

Defect	Condition State			
	1	2	3	4
	GOOD	FAIR	POOR	SEVERE
Wear (Mechanical) (9002)	None.	Light wear present. Clearances related to major mechanical elements are within operational limits. No remedial action required.	Moderate wear present. Clearances related to major mechanical elements are near operational limits. Short-term replacement of components may be required.	Heavy wear present. Clearances related to major mechanical elements exceed operational limits. Immediate replacement of components may be required.
Damage (Mechanical) (9014)	None.	Minor damage noted such as pitting or scoring. Hoses may exhibit light abrasion. None of the major mechanical elements require remedial action.	Moderate damage such as pitting and scoring with plastic flow. Hoses may exhibit moderate abrasion. Major mechanical elements may require short-term replacement or adjustment.	Heavy damage present. Components may be cracked or broken. Overstress of components occurring. Hoses may exhibit heavy abrasion. Major mechanical elements may require immediate replacement.

Element 604 Movable Bridge Drive System - Mechanical Condition State Definitions by Defect

Defect	Condition State			
	1	2	3	4
	GOOD	FAIR	POOR	SEVERE
Alignment (Mechanical) (9003)	Components are aligned within manufacturer's recommended operational tolerances or code requirements. Components exhibit proper contact.	Certain components slightly outside of manufacturer's recommended operational tolerances or code requirements. No operational issues noted. None of the major mechanical elements require realignment.	Components outside of manufacturer's recommended operational tolerances or code requirements. Some shaft or coupling movement noted during operation. Components may exhibit improper contact. Major mechanical elements may require realignment.	Components well outside of manufacturer's recommended operational tolerances or code requirements. Significant shaft or coupling movement noted during operation. Unusual noises noted during operation. Overstress of components occurring. Components may exhibit extremely poor contact. Immediate replacement or realignment of major mechanical elements may be required.
Corrosion (Mechanical) (9015)	None.	Minor paint system failure and light corrosion present. None of the major mechanical elements require remedial action.	Spotty paint system failure and moderate corrosion present. Major mechanical elements may require short-term replacement.	Extensive paint system failure and heavy corrosion present. Immediate replacement of major mechanical elements may be required.

Defect	Condition State			
	1	2	3	4
	GOOD	FAIR	POOR	SEVERE
Connections (Mechanical) (9016)	Fasteners and keys are intact, tight, and without corrosion.	Fasteners or keys exhibit minor corrosion. Some fasteners related to major mechanical elements may be loose. No missing fasteners.	Fasteners or keys exhibit moderate corrosion. Fasteners or keys are loose. Some fasteners or keys related to major mechanical elements may be missing. Short-term repair of major mechanical elements may be required.	Fasteners or keys exhibit heavy corrosion. Many Fasteners or keys are loose. Fasteners or keys related to major mechanical elements are missing. Immediate repair of major mechanical elements may be required.
Housekeeping (9004)	The machinery access areas are clean, sanitary, and free of debris and trip or fall hazards. Machinery guards are intact.	The machinery access areas are generally safe, but may have minor debris or inconvenient access. There may be minor mechanical issues related to weather exposure.	The machinery access areas have safety issues. Machinery guards may be out of place. There may be significant issues related to weather exposure. Short-term repairs may be required.	The machinery access areas have significant safety issues such as: unsanitary waste, excessive guano, debris, or missing machinery guards. Alternatively, there are unsafe trip or fall hazards or machinery is inadequately protected from weather. Immediate repair may be required.

The Health Index is Calculated in 3 Steps

1. Determine the Condition-based Health Index of each element ($CHI_{element}$)
   - Uses detailed element condition data
   - Employs concept of a Damage Index (DI)
   - Applies a Design Life (DL) factor based on age of each element
2. Determine the Modified Health Index of each element ($MHI_{element}$)
   - Modifies the $CHI_{element}$ by two factors:
     - Functional Performance (Design Adequacy)
     - Operational Performance (Risk Consequence)
3. $MHI_{element}$ values for each element are weighted by Safety/Importance (SI) factors to calculate a HI for each structure and system on each structure (SI varies from 1 to 10)

Step 1: Condition-Based Health Index of each element ($CHI_{element}$)

1. $CHI_{element}$ is a function of the Damage Index (DI) and the age of the element
2. $CHI_{element} = DL*(1-DI_{element})$
   - Damage Index (DI) calculates the percentage of maximum acceptable deterioration that has occurred

$$DI_{element} = \%CS4_{equiv} \div \%CS4_{equiv\text{-}max}$$

   - $\%CS4_{equiv}$ is based on element level condition data
   - $\%CS4_{equiv\text{-}max}$ is derived from expert elicitation
   - DL = Design Life = 1.0 for new, 0.9 for midlife, or 0.8 for old

Step 1a: Determine Damage Index (DI) of each element

$$(DI_{element}) = (\%CS4_{equiv}) \div (\%CS4_{equiv\text{-}max})$$

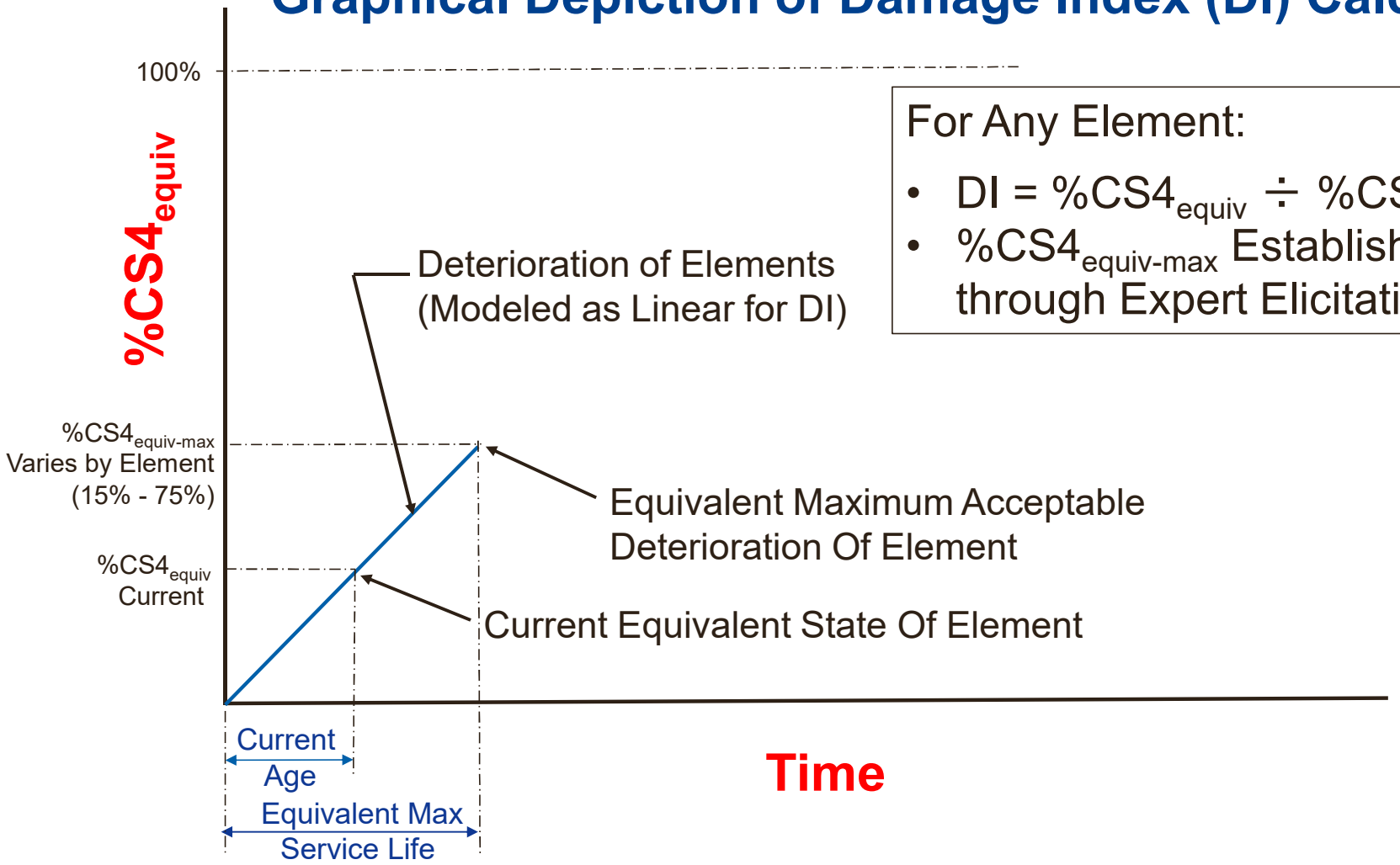
- $\%CS4_{equiv}$ is the equivalent percentage in CS4
  - $$\%CS4_{equiv} = \frac{(0.1*CS2_{quantity} + 0.4*CS3_{quantity} + 1.0*CS4_{quantity})}{\text{Total Quantity of Element}}$$
  - Weighting factors for CS2 and CS3 can be varied where appropriate
- $\%CS4_{equiv\text{-}max}$ is the maximum tolerable percentage of an element that is in $CS4_{equiv}$ condition state. In other words, the amount of deterioration or damage at which a state of emergency is reached or replacement of the element is required.

Step 1a: Example Damage Index (DI) Calculation

					Weighting Factor $CS4_{equiv}$		
					0.1	0.4	1
Element Number	Element Description	Units	Total Quantity	Condition State 1	Condition State 2	Condition State 3	Condition State 4
612	612Short Circuit and Over-Current Protective Devices	Each	39	0	26	13	0

- $CS4_{equiv} = [0.1*(26) + 0.4*(13) + (1.0)*0] \div 39 = 20\%$
- $CS4_{equiv\text{-}max} = 25\%$ (Expert Elicitation)
- $DI_{element} = 20\% \div 25\% = 0.80$

Graphical Depiction of Damage Index (DI) Calculation



For Any Element:

- $DI = \%CS4_{equiv} \div \%CS4_{equiv\text{-}max}$
- $\%CS4_{equiv\text{-}max}$ Established through Expert Elicitation

Step 1b: CHI of each element using DI and age factor (Design Life)

$CHI_{element} = DL*(1-DI_{element})$ where:

- DL = 1.0 for new
- DL = 0.9 for midlife
- DL = 0.8 for old

So, for the previous example:

- DL = 0.9 for midlife
- DI = 0.80
- $CHI_{element} = 100*(1-DI)*DL = 100*(1-0.80)*0.90 = 18$

Step 2: Determine Modified Health Index for each element ($MHI_{element}$)

$MHI_{element} = (0.7*CHI_{element}) + (0.15* FP) + (0.15 *OP)$ where:

- FP = Functional Performance (Design Adequacy)
  - FP = 1.0 (excellent)
  - FP = 0.9 (good)
  - FP = 0.7 (adequate)
  - FP = 0.5 (marginal)
  - FP = 0.2 (poor*)
- OP = Operational Performance (Risk Consequence)
  - OP = 1.0 (insignificant consequence)
  - OP = 0.9 (minor consequence)
  - OP = 0.7 (moderate consequence)
  - OP = 0.4 (major consequence)
  - OP = 0.2 (catastrophic consequence)

*If a needed element is missing, it will affect the design adequacy of the existing elements performing a similar function

Step 3a: Health Index for Major System

$$HI_{system} = \frac{\Sigma(SI_{element} * MHI_{element})}{\Sigma SI_{elements}}$$

Where:

- $MHI_{element}$ = Modified HI for each element of the Major System
- $SI_{element}$ = Safety and Importance Weighting Factor for Each Element

Element Safety/Importance (SI) Factors

Element Safety & Importance Description	Factor
Key Element – High	10
Key Element – Medium	9
Key Element – Low	8
Major Element – High	7
Major Element – Medium	6
Major Element – Low	5
Minor Element – High	4
Minor Element – Medium	3
Minor Element – Low	2
Minor Element - Minimal Importance	1

Element Safety/Importance (SI) Factors - Definitions

Element	The element of the structure is designed to prevent inadvertent or hazardous utilization and operation.
Element Safety	Element Safety is the condition of the element of being safe from causing hurt, injury, or loss of structure's users or operators.
Element Importance	Element Importance rates the significance of the complete group of elements relative to the impact on the operation of the entire structure.
Key Element	Primary and/or most significant element(s) in the group of elements in the structure impacting the rating of the element regarding its Safety and/or Importance.
Major Element	Prominent or significant - but not a key element(s) - in the group of elements in the structure impacting the rating of the element regarding its Safety and/or Importance.
Minor Element	Very limited significant element(s) in the group of elements in the structure impacting the rating of the element regarding its Safety and/or Importance.
Minor Element - Minimal Importance	In-significant element(s) in the group of elements in the structure, not impacting the rating of the element regarding its Safety and/or Importance
High	Most importance and/or significance in the current Key, Major, or Minor group.
Medium	Average importance and/or significance in the current Key, Major, or Minor group.
Low	Minor importance and/or significance in the current Key, Major, or Minor group.

Step 3a: Health Index for Major System – Example Calculation

Calculating HI for the Structural System on A Movable Bridge					
Full Element #	**System**	**Safety & Importance Factor**	**Modified Health Index $MHI_{element}$**	**Safety & Importance Weight Factor**	**MHI*SI**
601Swing Bridge End Lifts (Movable Roadway Grating)	Support System - Mechanical	Key Element - Medium	0.00	9	0.00
601Swing Bridge Center Wedges	Support System - Mechanical	Key Element - High	0.46	10	4.57
601Center Bearings	Support System - Mechanical	Key Element - High	0.77	10	7.71
601Shear/Moment Lock Assemblies	Support System - Mechanical	Key Element - High	0.00	10	0.00
603Imbalance Condition	Balance System - Mechanical	Major Element - Medium	1.00	6	6.00
603Balance Wheel Assemblies or Tracks	Balance System - Mechanical	Key Element - High	0.89	10	8.89
604Electric Motors	Drive System - Mechanical	Key Element - High	1.00	10	10.00
604Hydraulic Pumps	Drive System - Mechanical	Key Element - High	0.90	10	9.00
604Generator	Drive System - Mechanical	Minor Element - High	0.45	4	1.79
604Shafts	Drive System - Mechanical	Key Element - Medium	0.81	9	7.29
604Hydraulic Motors	Drive System - Mechanical	Key Element - High	0.45	10	4.50
604Hydraulic Power Unit	Drive System - Mechanical	Key Element - High	0.23	10	2.33
604Hydraulic Brakes	Drive System - Mechanical	Major Element - Medium	0.81	6	4.86
604Open Gearing	Drive System - Mechanical	Key Element - High	0.00	10	0.00
604Buffer Cylinders	Drive System - Mechanical	Major Element - Low	0.54	5	2.70
606Limit Switches and Supports	Control System - Mechanical	Minor Element - High	0.38	4	1.51
606Gearboxes	Control System - Mechanical	Minor Element - Medium	0.35	3	1.04
606Shafts	Control System - Mechanical	Minor Element - Medium	0.45	3	1.34
606Couplings	Control System - Mechanical	Minor Element - Medium	0.00	3	0.00
613Traffic Gates	Traffic Control System - Mechanical	Major Element - High	0.60	7	4.20
613Resistance Gates	Traffic Control System - Mechanical	Major Element - High	0.30	7	2.10
			Total	**156**	**79.84**

HI_{system}	100*(79.84÷156) = 51

Step 3b: Health Index for Structure

$HI_{structure}$ is calculated in the same way as is done for each system (see previous slide for an example)

$$HI_{structure} = \frac{\Sigma(SI_{element} * MHI_{element})}{\Sigma SI_{elements}}$$

Where:

- $MHI_{element}$ = Modified HI for each element of the Structure
- $SI_{element}$ = Safety and Importance Weighting Factor for Each Element

Calculation Summary (Numbers are Preliminary Only*)

Summary of HI for Each System on Each Bridge					
Movable Bridge	**Electrical**	**House**	**Mechanical**	**Structural**	**Total**
Berkley EBL	28	73	48	44	**39**
Berkley WBL	22	69	37	26	**28**
Chincoteague	64	76	50	57	**58**
Coleman	55	55	51	7	**46**
Eltham	38	67	54	57	**47**
Gwynn's Island	22	65	16	3	**17**
High Rise	35	60	36	48	**38**
James River	28	53	33	41	**33**

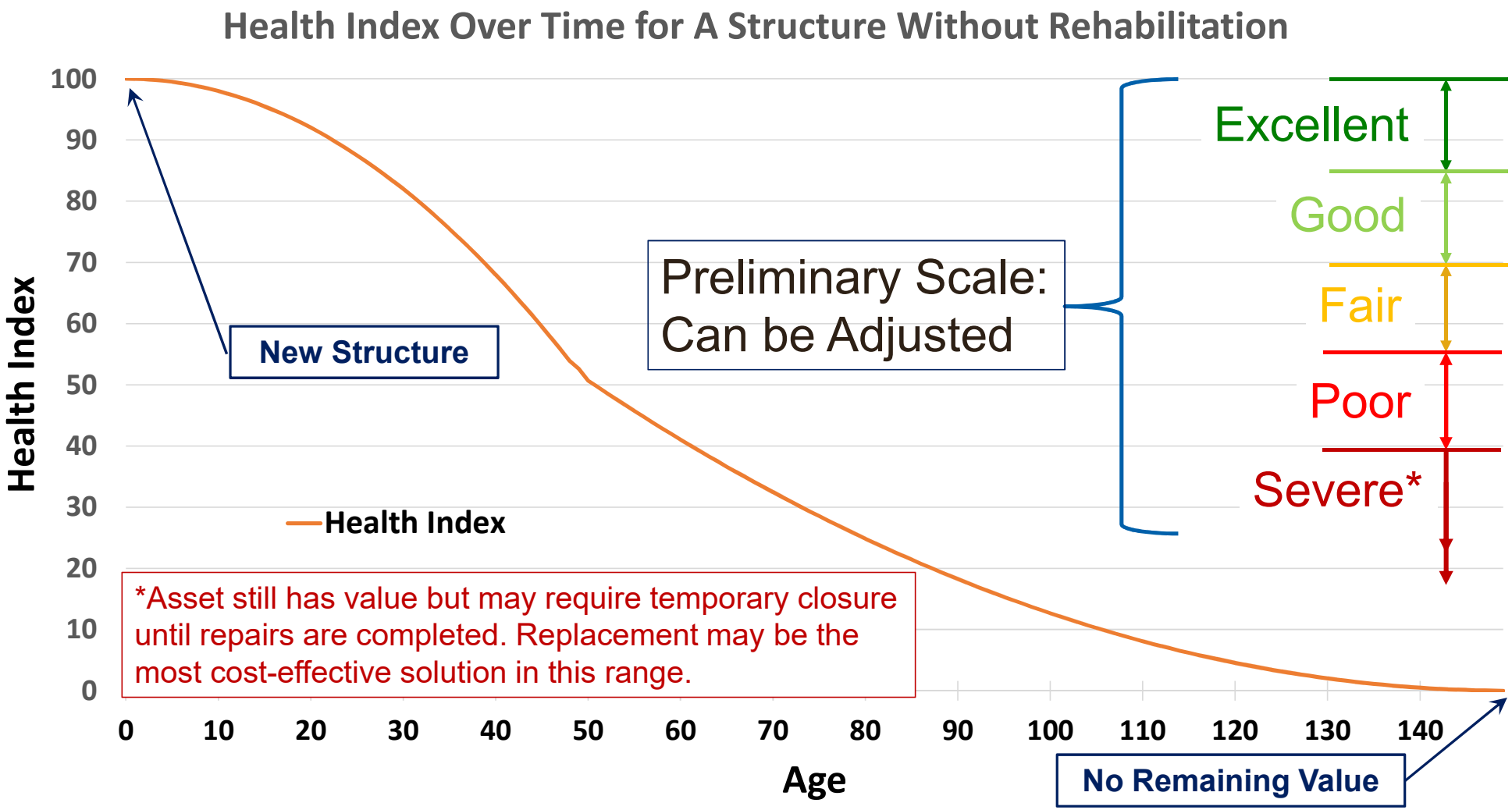
*Data for Benjamin Harrison Bridge not available.

Health Index Formula - Review

1. $CHI_{element}$ = Condition Health Index of an element = $DL*(1-DI_{element})$
   - where $DI_{element} = \%CS4_{Eq} \div \%CS4_{equiv\text{-}max}$
   - DL = 1.0 for new, 0.9 for midlife, or 0.8 for old
2. $MHI_{element}$ = Modified Health Index of an element
   - $MHI_{element} = (0.7*CHI_{element}) + (0.15*FP) + (0.15*OP)$, where:
   - FP = Functional Performance (Design Adequacy) varies from 1.0 to 0.2
   - OP = Operational Performance (Risk Consequence) varies from 1.0 to 0.2
3. MHI values are weighted by Safety/Importance (SI)
   - SI varies from 1 to 10 depending on the element
   - $HI_{system} = \Sigma(SI_{element}*MHI_{element})/\Sigma SI_{elements}$
   - $HI_{structure} = \Sigma(SI_{element}*MHI_{element})/\Sigma SI_{elements}$

Next Steps

1. Reach out to Facility Managers for an Expert Elicitation
2. Finalize Movable Bridge Spreadsheet Tool
3. Testing & Calibration – Review by Facility Managers
4. Reach out to AASHTO Bridges & Structures Technical Committees (T-8 Movable Bridges & T-20 Tunnels) for input


Health Index Over Time for A Structure Without Rehabilitation
Health Index
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Age
New Structure
Health Index
Preliminary Scale:
Can be Adjusted
Excellent
Good
Fair
Poor
Severe*
*Asset still has value but may require temporary closure until repairs are completed. Replacement may be the most cost-effective solution in this range.
No Remaining Value

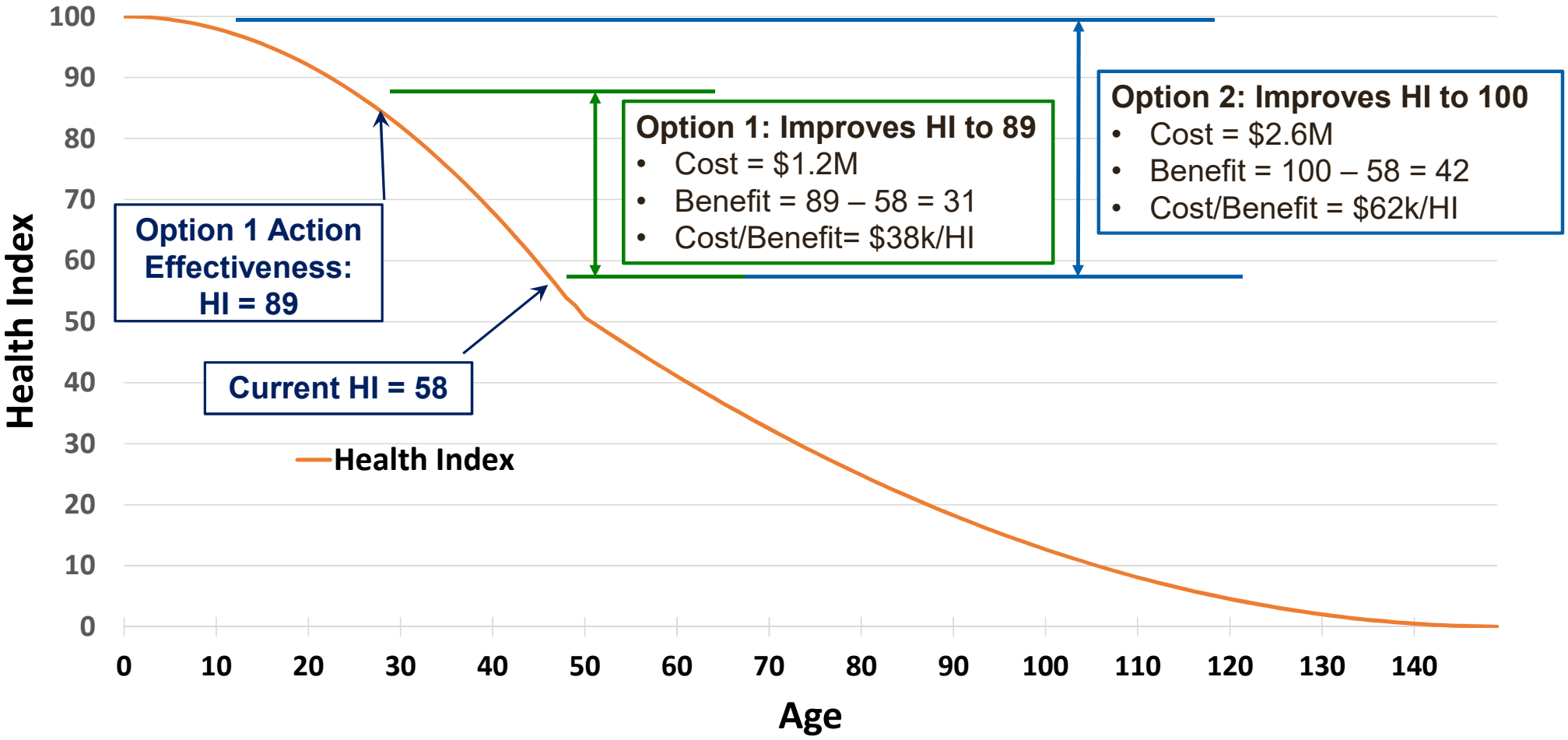
Pause for Demonstration of Tool & Expert Elicitation

1. **Demonstration of Spreadsheet Tool**
2. **Expert Elicitation**
   - **$CS4_{equiv}$ weighting factors for CS2 & CS3**
   - **$CS4_{equiv\text{-}max}$ per element**
   - **DL (Design Life)**
   - **FP (Functional Performance)**
   - **OP (Operational Performance)**
   - **SI (Safety & Importance Weighting)**

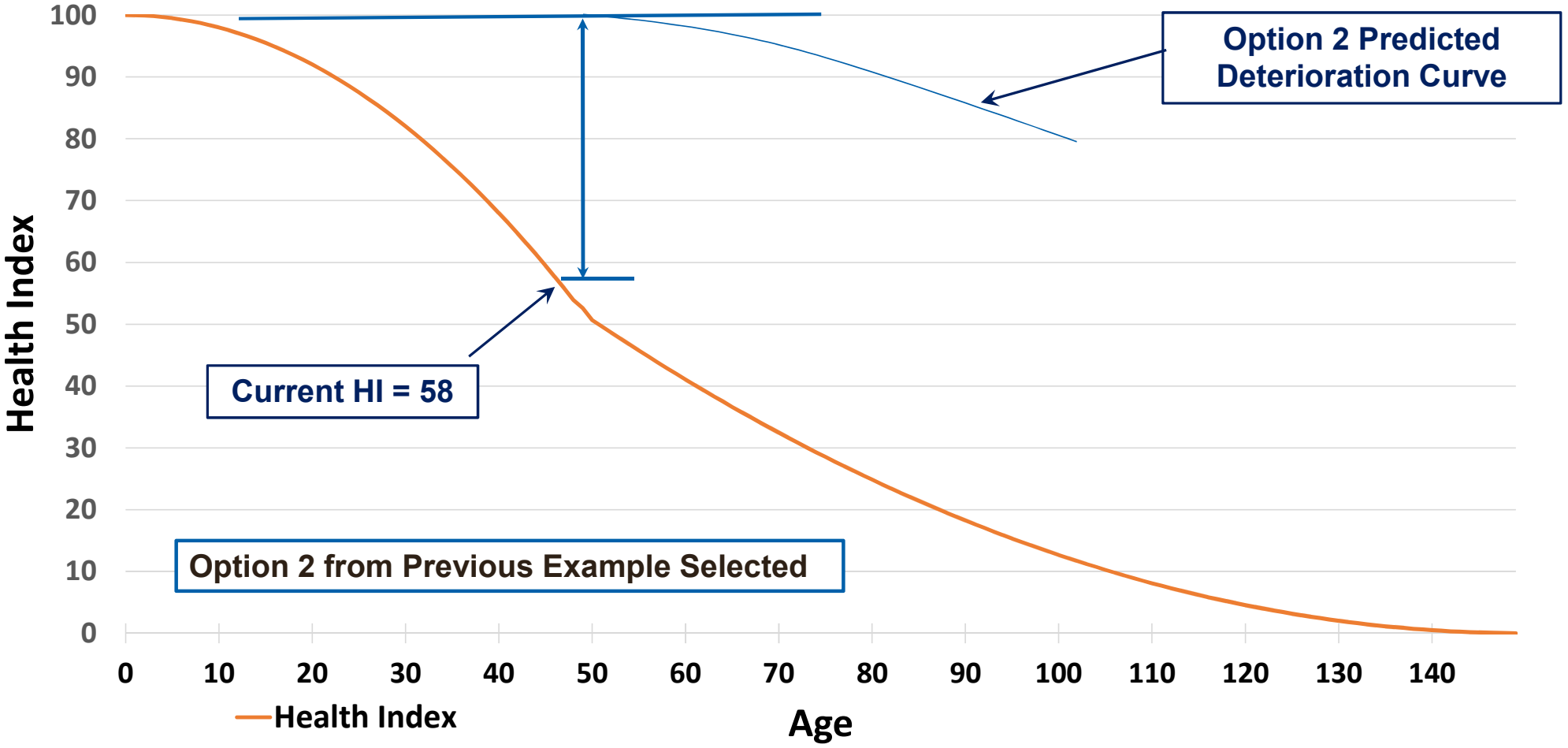
Additional and Future Uses of the HI

1. Calculate immediate cost/benefit of any action
   - Incorporates all the variables in prioritization formula, so an immediate "benefit" can be predicted
2. Predict future conditions
3. Calculate long term (life cycle) value of any action
4. Can eventually replace the prioritization formula for project selection

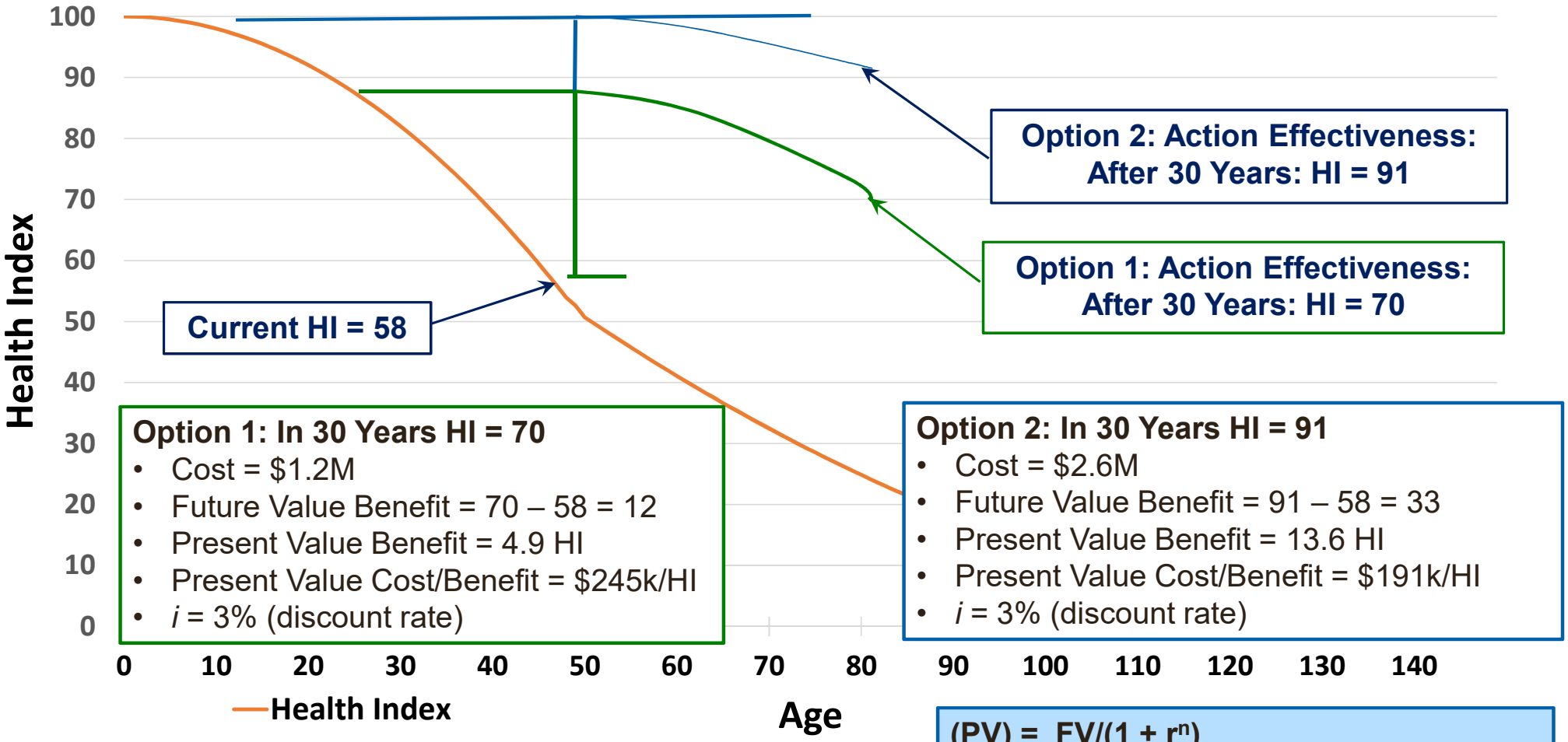
1. Using HI to Calculate Immediate Cost/Benefit Ratio



2. Using HI to Predict Future Conditions



3. Using HI to Calculate Life Cycle Cost/Benefit Ratio



$(PV) = FV/(1 + r^n)$

- PV = Present Value
- FV = Future Value
- n = number of periods
- r = rate of return (discount rate)

4. Eventual Replacement of Existing Prioritization Formula with the HI

- The HI incorporates all the variables in the current prioritization formula, so the transition should be smooth
- Once the HI is tried out and well-established, it would make sense to move to one tool rather than multiple tools.
- The prioritization formula uses a great deal of judgement-based scores. HI removes that to the best extent possible
- By separating the cost factor from the non-cost factors, we can select projects by a cost/benefit ratio