Economics of Infrastructure Health Monitoring

September 11, 2015
Thurs, 1:30 - 3:00 pm
Session: 7D

Brian J Westcott Ph.D.
Intelligent Structures, Inc.

bwestcott@intellistruct.com

The Problem

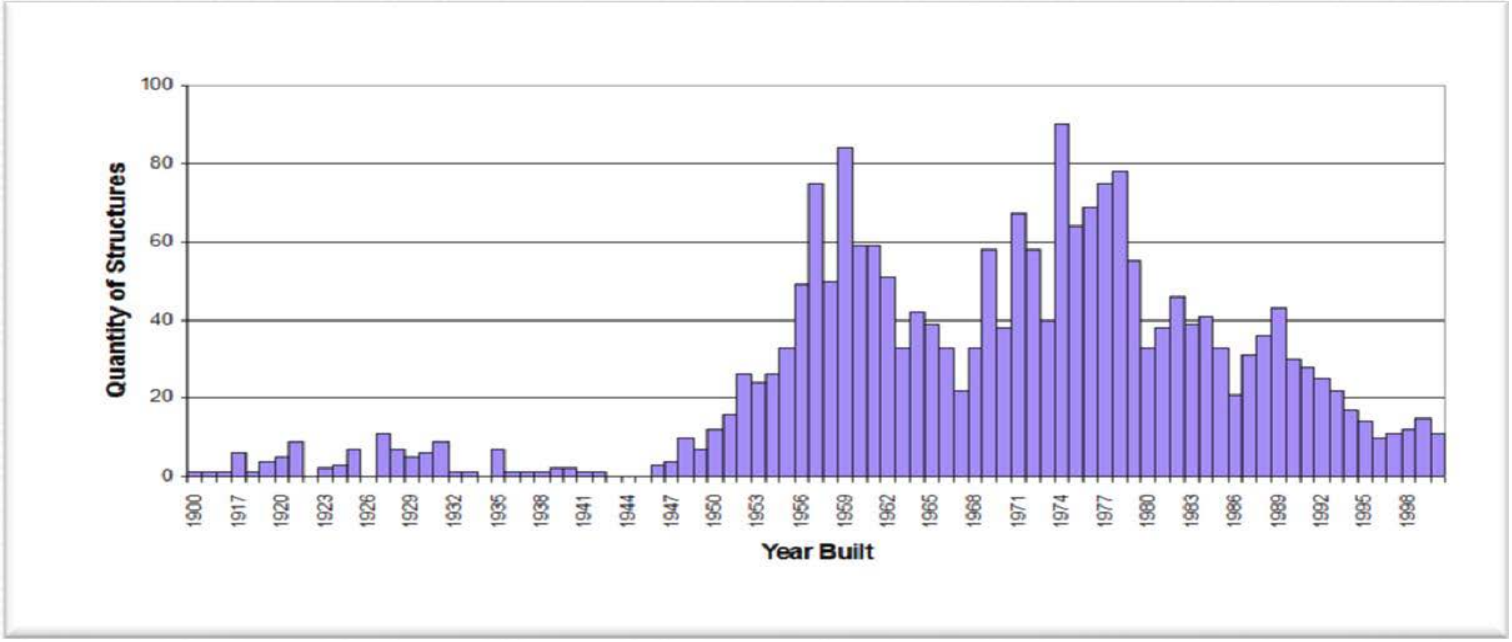
- World Infrastructure is crumbling and causing safety and economic productivity losses
  - How many bridges fail a year ?– how many people are at risk?
  - How much commerce is interrupted ?
- Degrading Bridges beyond design life but not specific life
- 9 out of 10 bridges torn-down and rebuilt have many years of service left
  - “I have inspected 300 bridges in Canada and 9 out of 10 times the bridge can be saved”.
    Baidar Bakdar PhD – Member of the Order of Canada
- 1 out of 10 bridges ready to rebuild should have been torn down and replaced years ago.
  - 50 + % of bridges that collapse are not rated as structurally deficient.

Big problem -- Lack of good accurate information – results in bad decisions

bwestcott@intellistruct.com

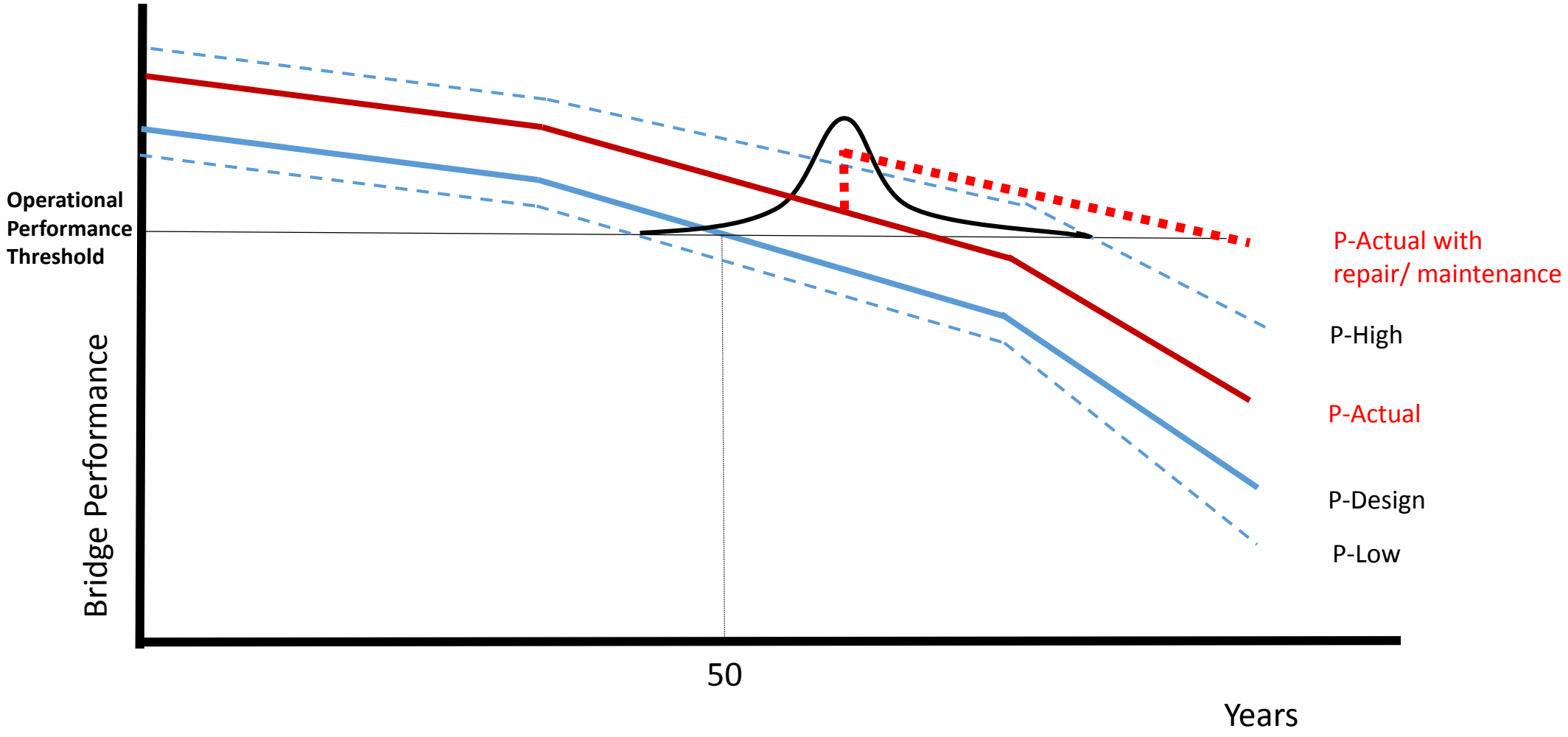
Bridge Management Dilemma:

- Aging infrastructure (45% of structures beyond original design life)
- Limited funding (recent increases in recognition of structure condition)
- Increasing pressure to allow heavier and heavier vehicles
- Increasing traffic volumes (including overload vehicles)
- Increasing public expectation for high(er) levels of service



bwestcott@intellistruct.com

The Problem



Some innovative transportation executives conceive of 80 or more years of useful life for bridges.

Example : Value of service life extension:

Case study- Viaduct Henri-Bourassa

**Courtesy OSMOS Canada

- Built 1938 – No drawings
- Given low load rating – No Trucks
- Slated for replacement 2008
- Could be reopened with SHM?

- 2 mm predicted deflection
- 0.2 mm measured

- Value of overpass ~$3,000,000
- Value of extending service life 1 year
- $3,000,000x0.06=$180,000

- SHM system
  - $44,000 Sensors (4) + installation
  - $25,000 FE analysis
  - $24,000/year reports
- Quite large ROI
- Real-time requirement

- Now slated for replacement in 2013!!

Reference - Prof. D. Thomson University of Manitoba CA

Example: South Carolina –

Load Testing for Assessment and Rating of Highway Bridges SCDOT Research Project No. 655

Table 4.4 shows a comparison of the values with and without the additional benefits. This Figure shows that the inclusion of the test results and the additional benefits resulted in an increase of 38 percent over the theoretical rating. Future research may be warranted to investigate if the testing staff should be allowed to take into account the full testing benefit, or if another load effect will control under the increased capacity.

Table 4.4 Load Rating Program Rating Comparison

Conditions	Inventory Rating	Operating Rating
Standard AASHTO w/ Non-Composite Section	105.7 tons	149.0 tons
Non-Composite Section w/ Testing Benefits	145.8 tons	205.5 tons

Solution: Policy incorporating SHM for Bridge Management

- Comparing Three Scenarios:

  - **Base Policy**: A ten year construction budget with all the budget dollars applied to replacement resulting in an annual replacement of 20 bridges over ten years.

  - **SHM Policy**: A ten year construction budget with implementation of SHM for bridge testing and classification followed by ongoing continuous monitoring to maintain accurate bridge performance information and extending bridge life.

  - **SHM Policy with Repair and Maintenance**: A ten year construction budget with implementation of SHM for bridge testing and classification followed by ongoing continuous monitoring to maintain accurate bridge performance information combined with repair and maintenance based on the bridge condition determined through continuous monitoring and extending bridge life.

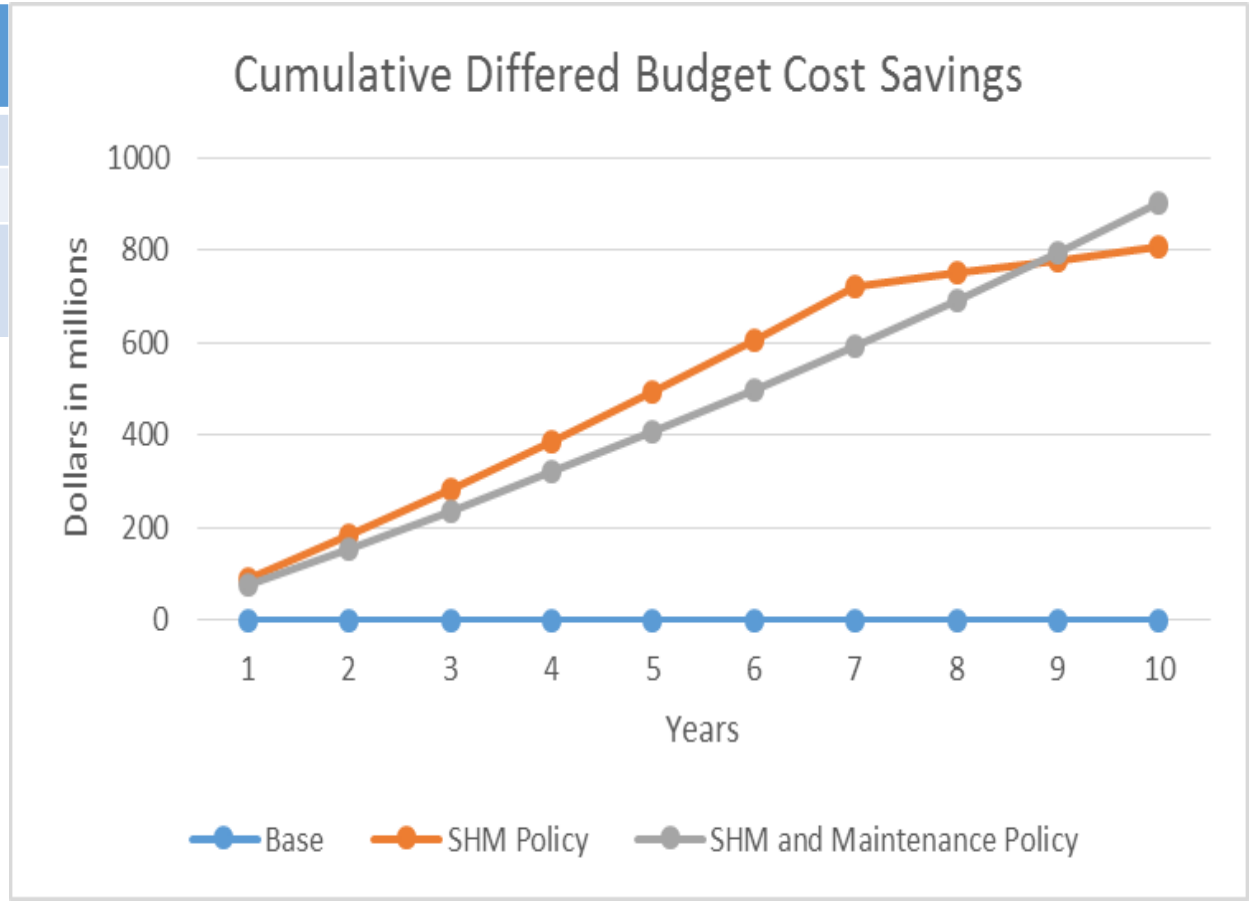
Solution: Example $200 million annual bridge construction budget

The model parameters used to review the effects of various policies include:

Annual Bridge Construction Budget:	$100 million for structurally deficient bridges
Unit price per bridge replacement:	$5 million
Annual discount rate:	5% based on (a 6% standard municipal bond less 2% inflation rate plus 1% annual construction productivity gain)
Bridge SHM Testing Results:	90% of bridge tested by SHM found with remaining life
	10% of bridge tested by SHM found with no life
Cost of SHM Bridge Test:	$100,000 including hardware, software, installation /test
Cost of SHM Bridge Monitoring:	$50,000 including data, analytics and engineering analysis

Solution: Policy Results

	Bridges Rebuilt	Bridges Monitored at 10 years	Total Budget Allocated	Total Budget Differed Cost Savings
Base	200	0	$1 billion	$0.00
SHM Policy	44	126	$1 billion	$810 million
SHM and Maintenance Policy	20	180	$1 billion	$903 million



Reference: Deferred Cost Savings for an inventory of bridges using SHM
(Westcott and Thomson)
International Workshop on Structural Health Monitoring 2015

bwestcott@intellistruct.com

Intelligent Structures, Inc.

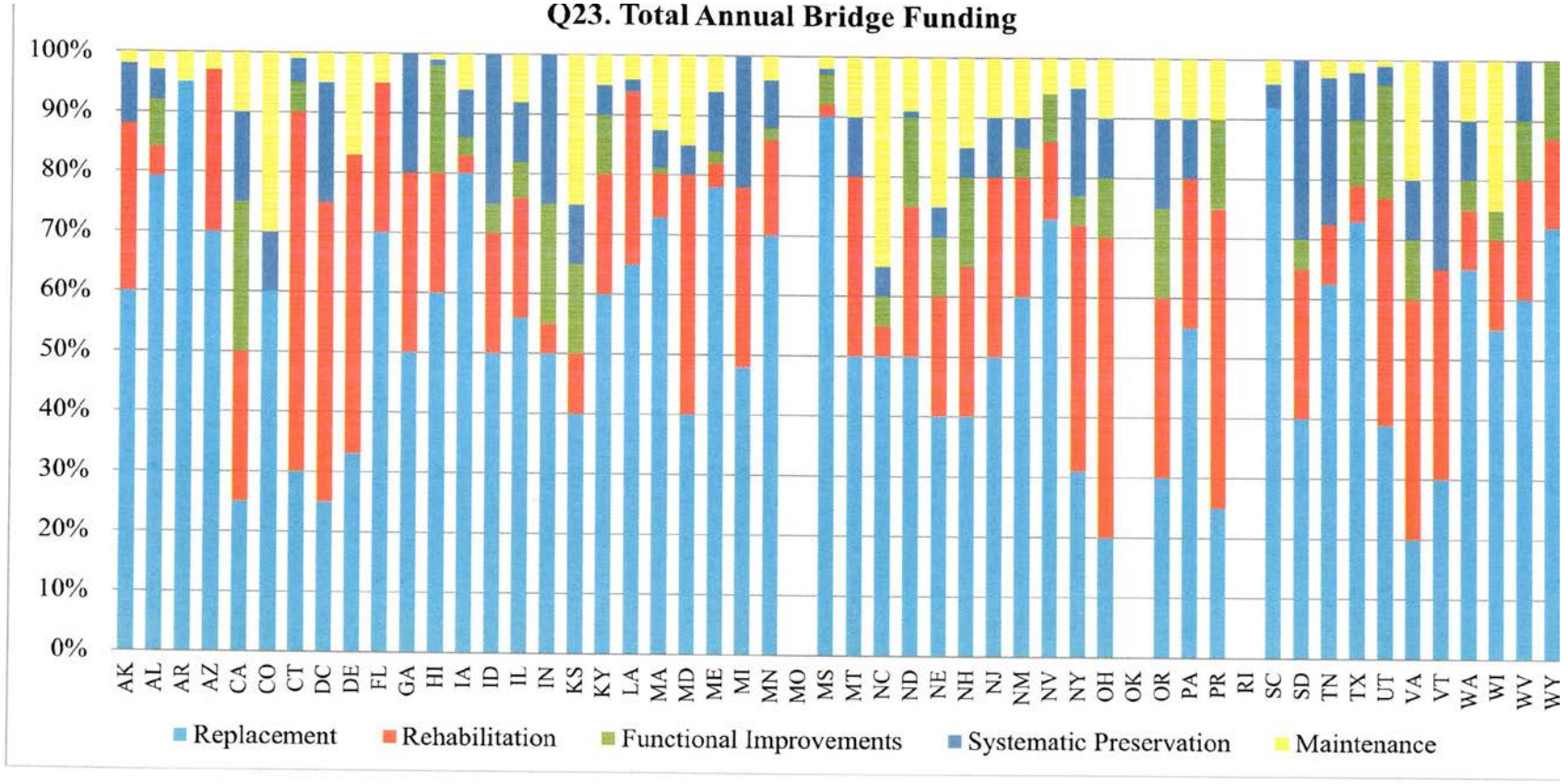
Western States – Deficient Bridges

State	Number of Bridges	Number Deficient
Alaska	1544	351
California	24955	6953
Oregon	7656	1754
Washington	7902	2066
Arizona	7682	954
Nevada	1853	253
Idaho	4431	877

bwestcott@intellistruct.com

Intelligent Structures, Inc.

Bridge Budget Allocation



Notes:

1. CA: 75% of bridge fund spread over Replacement, Rehabilitation, & Functional Improvements.
2. FL: Do not separate Functional Improvements & Systematic Preservation from the others.
3. LA: Functional Improvements is included in Rehabilitation fund.
4. MT: Functional Improvements is included in Replacement fund.
5. MO: Unknown funding allocation across all activities.
6. OK: Funding allocation not available.
7. RI: No response.

Reference: US DOT Bridge Management Survey 2013

bwestcott@intellistruct.com

Incorporating SHM into Bridge Management Policy

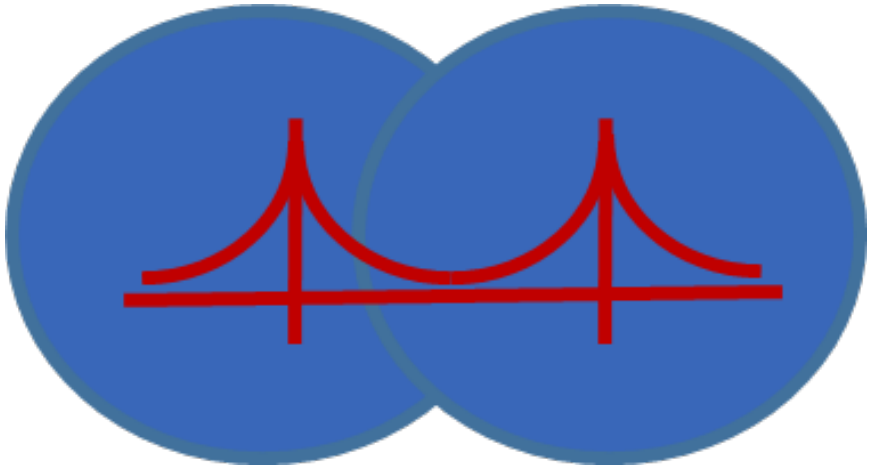
- Classify Entire State of Bridge Inventory
  - Functional and Structurally Sound
  - Structurally Deficient
  - Functional Obsolete
  - Functionally Obsolete and Structurally Deficient
- Determine Actually State of Bridges - SHM Testing – starting with Structurally Deficient
  - Two groups : Estimated Beyond Rehabilitation / Able to Rehabilitate /
  - SHM - Test the Rehabilitate Group – classify state – understand /reclassify Bridge rating
- Determine Inventory of Bridges eligible for rehabilitation and extended life cycle management
  - Maintain monitoring on bridges following testing
  - Determine rehabilitation cost per bridge
- Prioritize Bridge Rehabilitation, Systematic Preservation and Maintenance budget by:
  - SHM information and actually life cycle state of bridges
  - Value Engineering and NPV / IRR
  - Factor in Life Cycle of Bridge and weighted by traffic – or bridge importance to traffic infrastructure
- Replace
  - Critically Deficient Bridges both Structurally Deficient and Functionally Obsolete

Economics of Bridge SHM and Preservation

- **National Bridge Management, Inspection and Preservation conference: Beyond the Short Term**

December 2011

- No one would build a house, neglect its upkeep for 50 years and then build a new house, he said as an analogy for bridge management. However, to some degree highway agencies failed to adequately preserve their bridges throughout their first 50 years necessitating the need for replacement.
- **Bridge preservation can be made smarter through the embrace of innovations, research findings, monitoring of bridge health, asset management and performance management, data-driven decisions and partnerships.** The bridge community also needs performance measures that are technically sound and understandable to the public. Adopting a mindset of being "owners and operators" who inspect and preserve bridges so they last for 100 years.
- **U.S. Department of Transportation: Federal Highway Administration**



Intelligent Structures, Inc.

Creating high performing structures for a safer and more productive world

Brian J Westcott Ph.D.
Intelligent Structures, Inc.

bwestcott@intellistruct.com