Bridge Preservation: Estimating the time for element repair and replacement

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By
John Sobanjo
Florida State University
Tallahassee, Florida

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Presentation Outline

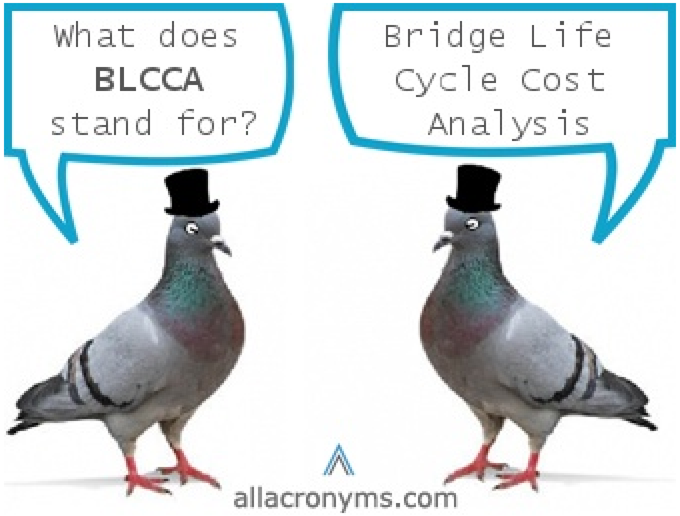
- Why estimate time to do bridge repairs?
- Review of existing methods and data.
- Bridge historical database: cost and date of actions.
- Results from Florida bridges.
- Age replacement models.
- Conclusions.

In a nutshell…..

- To do life-cycle analyses and predict needs we need to know timing for future repairs.
- There are several literature on using the timing for repairs but most assume standard time intervals.
- Historical data indicates ages at which various types of repairs are done on bridges – statistical distributions for each type and for some specific design/material types of bridges.
- How early or late in the bridge service life is a type of repair being done on the bridge?
- A mathematical model based on reliability theory can also be used to estimate time to do repairs or replace bridge elements – it has limitations.

Why estimate time for bridge repairs?

- Life cycle analyses (agency costs)
  - Network and project level preservation
  - Design alternatives
  - Repair effectiveness
- Programming long-term needs



Review of existing methods and data

- Bridge Preservation Guide, Maintaining a State of Good Repair Using Cost Effective Investment Strategies, USDOT/ FHWA, FHWA Publication Number: FHWA-HIF-11042, August 2011.
- Life-Cycle Cost Analysis - Resources - TPM - Federal Highway. Available (2015) at *http://www.fhwa.dot.gov/infrastructure/asstmgmt/lcca.cfm*
- NCHRP REPORT 483, Bridge Life-Cycle Cost Analysis, Transportation Research Board Washington, D.C., 2003.

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Cyclical PM Activity Examples	Commonly Used Frequencies (Years)(4)
Wash/clean bridge decks or entire bridge	1 to 2
Install deck overlay on concrete decks such as: - Thin bonded polymer system overlays - Asphalt overlays with waterproof membrane - Rigid overlays such as silica fume and latex modified	 10 to 15 10 to 15 20 to 25
Seal concrete decks with waterproofing penetrating sealant	3 to 5
Zone coat steel beam/girder ends	10 to 15
Lubricate bearing devices	2 to 4

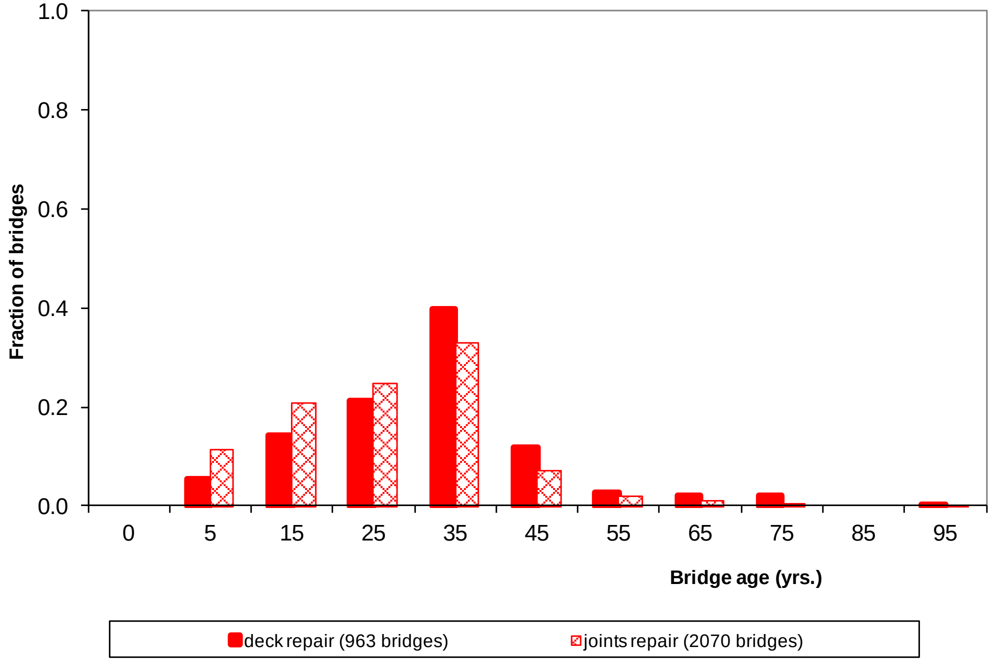
(4) - *Frequencies are based on FHWA's knowledge of typical State DOT practices*

FDOT bridge historical data: cost & date of actions

- Maintenance Management System (MMS) (maintenance and repair).
- AASHTO Tran*sport cost database (rehabilitation and replacement bids).
- 15 year data.
- Merged actions data with bridge inventory data (linked by bridge ID).
- Focus on date recorded for action and cost.
- Estimated bridge age at which action was done based on recorded year bridge was built.

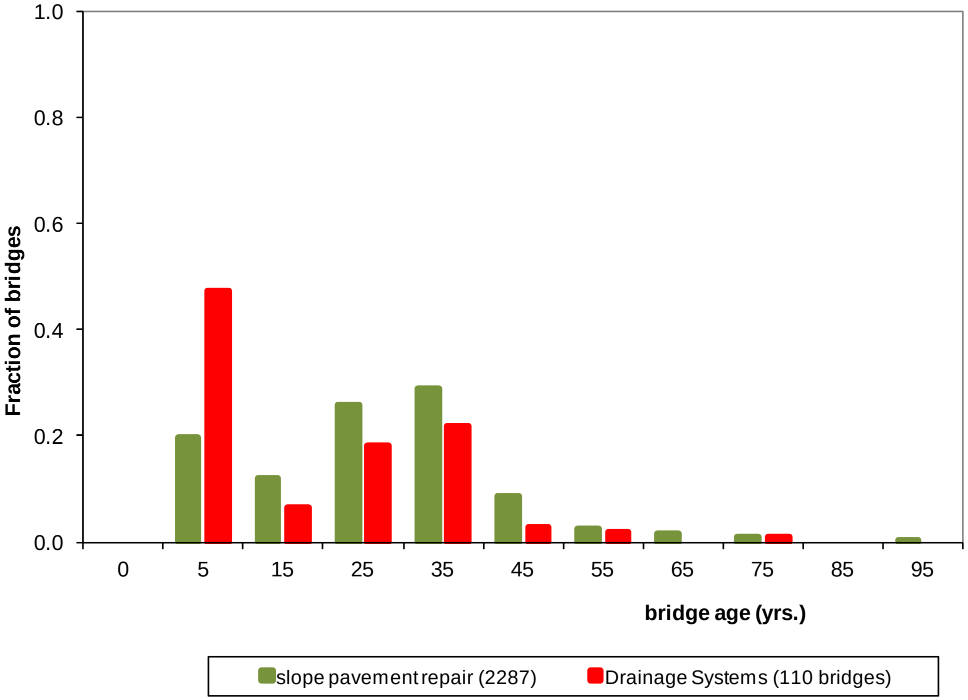
Results: repair actions

- Deck and joints (examples):
  - Patch deck spalls in span #2 at bent #3
  - Repair intermediate Expansion Joint No. 2.
  - Repairs done mostly at 35 years.



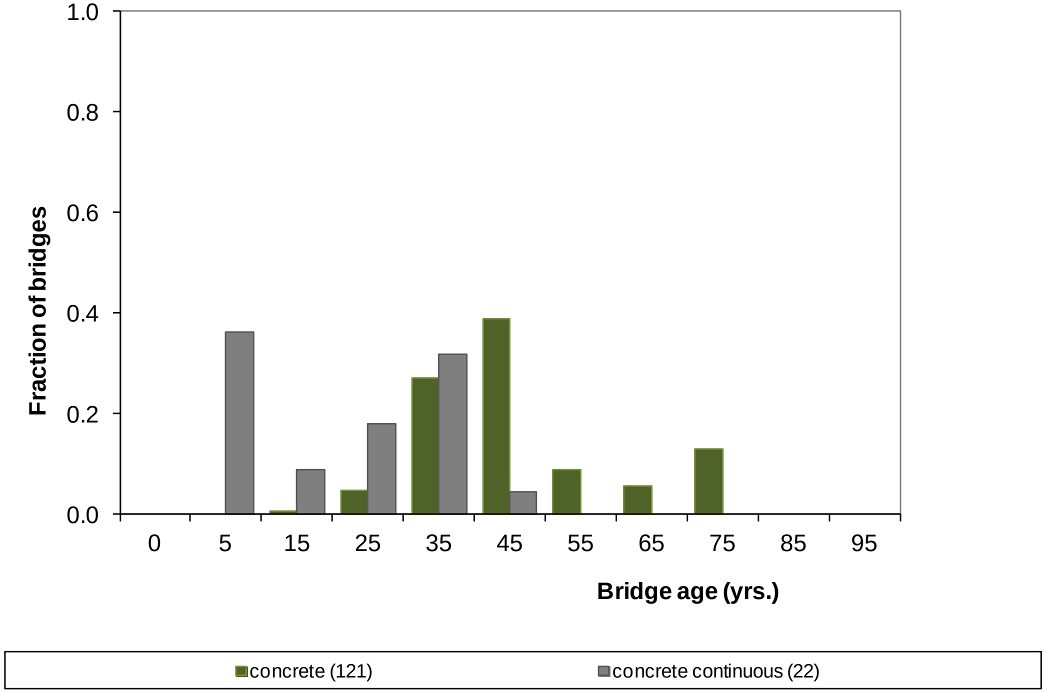
Results: repair actions

- Slope pavement and drainage:
  - Many drainage repairs done early.
  - Slope pavements repaired mostly between 25 and 35 years



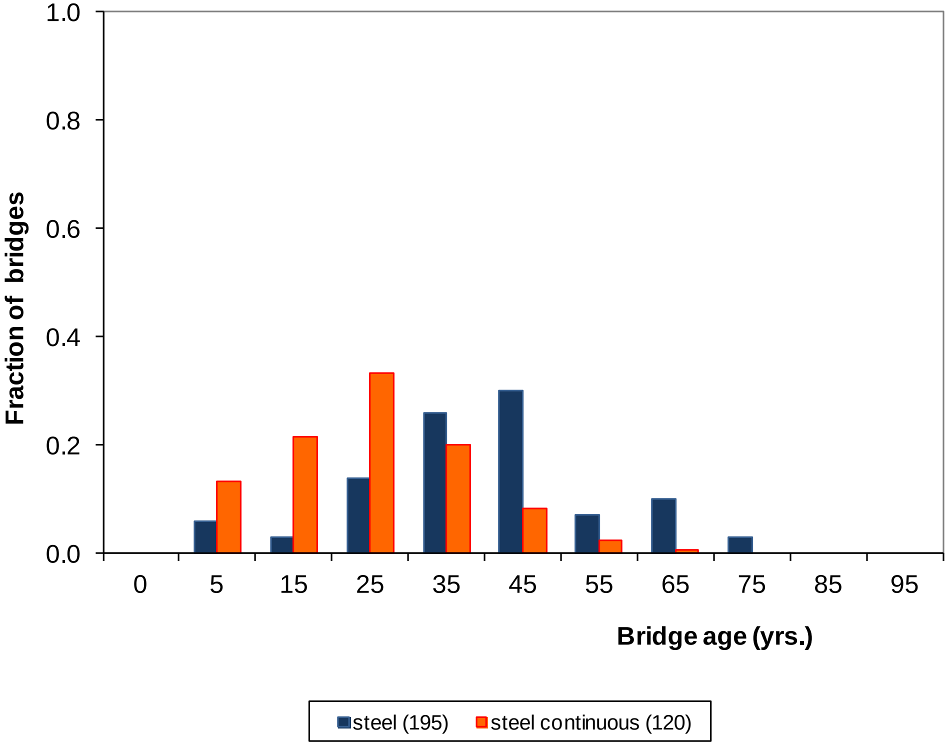
Results: repair actions

- Beam repairs on concrete and concrete continuous types:
  - Repairs done earlier on concrete than concrete continuous bridges



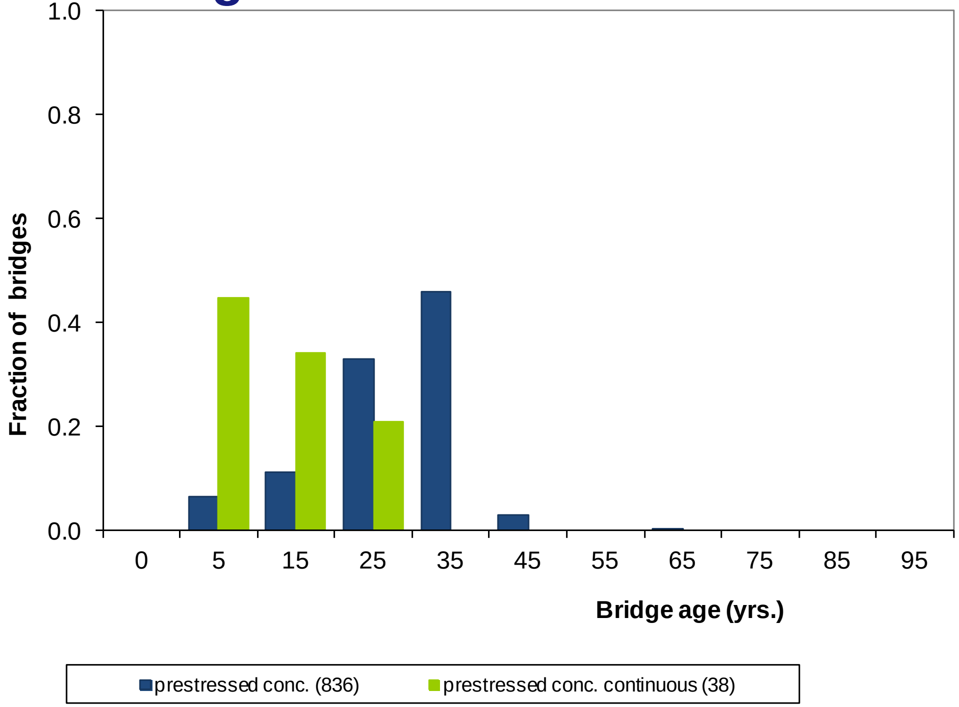
Results: repair actions

- **Beam repairs on steel and steel continuous types:**
  - **Repairs done earlier on steel continuous than steel bridges.**



Results: repair actions

- **Beam repairs on prestressed concrete and prestressed concrete continuous types:**
  - **Repairs done earlier on prestressed concrete continuous than prestressed concrete bridges.**



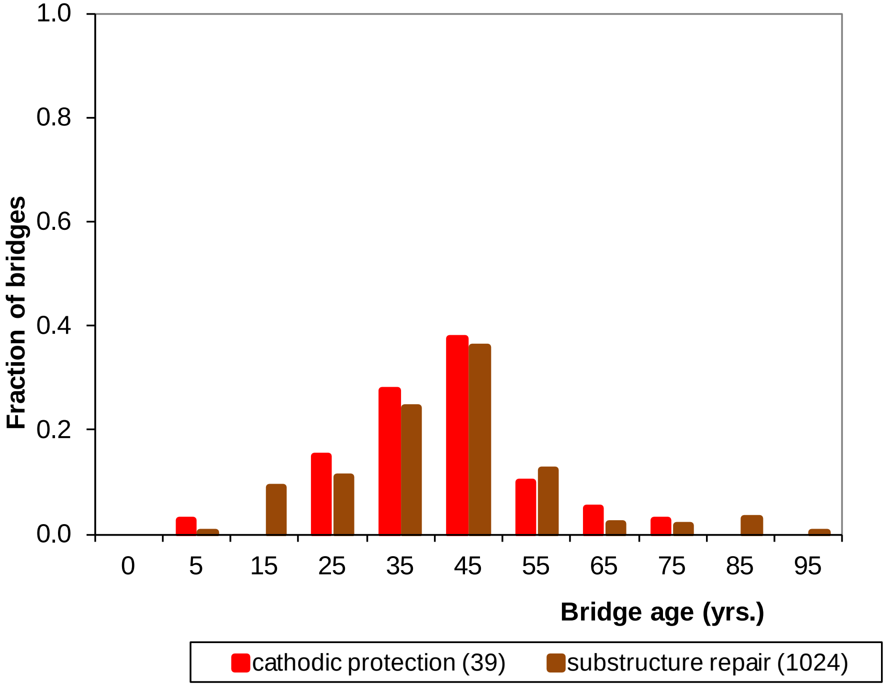
Results: repair actions

- **Beam repairs on bridge types:**

Type of bridge (no. of bridges)*	Mean repair age (yrs.)
concrete (121)	47.1
concrete continuous (22)	20.7
steel (195)	40.8
steel continuous (120)	25.4
prestressed conc. (836)	28.2
prestressed conc. continuous (38)	12.7
*Based on NBI definition	

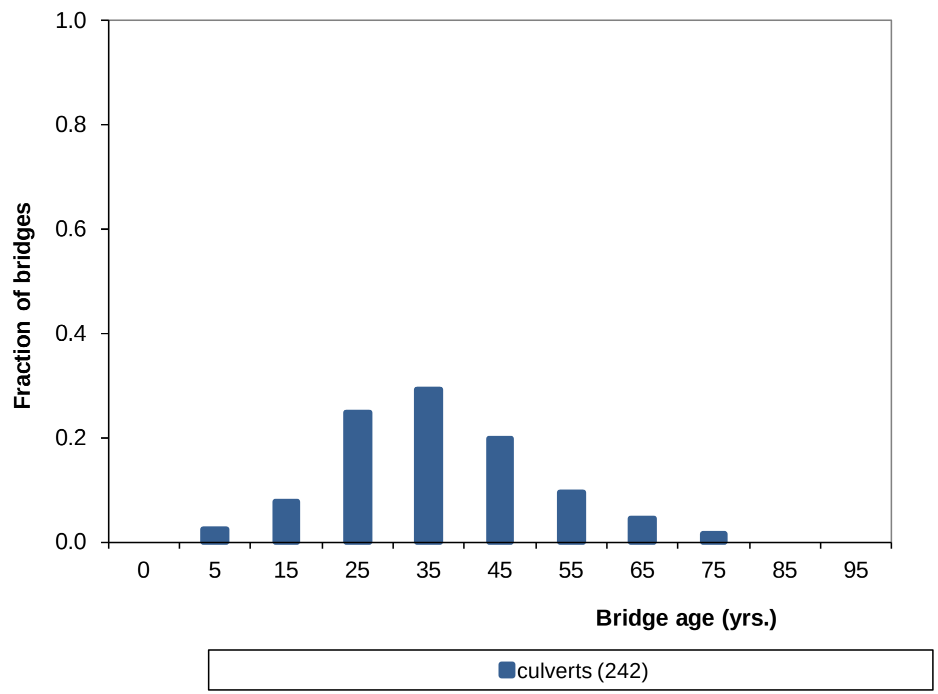
Results: repair actions

- **Cathodic protection and substructure:**
  - **Repairs done mostly at about 45 years.**



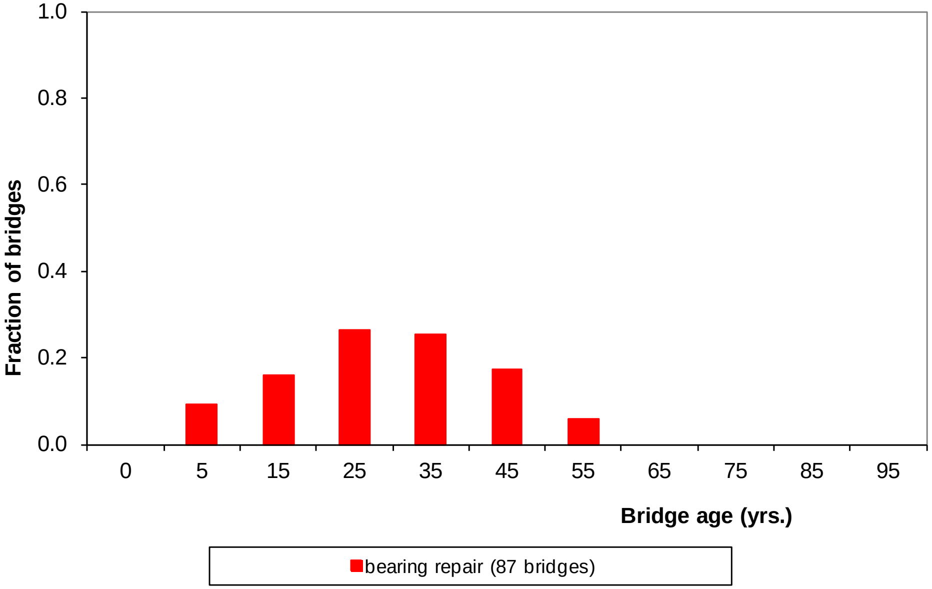
Results: repair actions

- Culverts:
  - Repairs done mostly at 35 years.



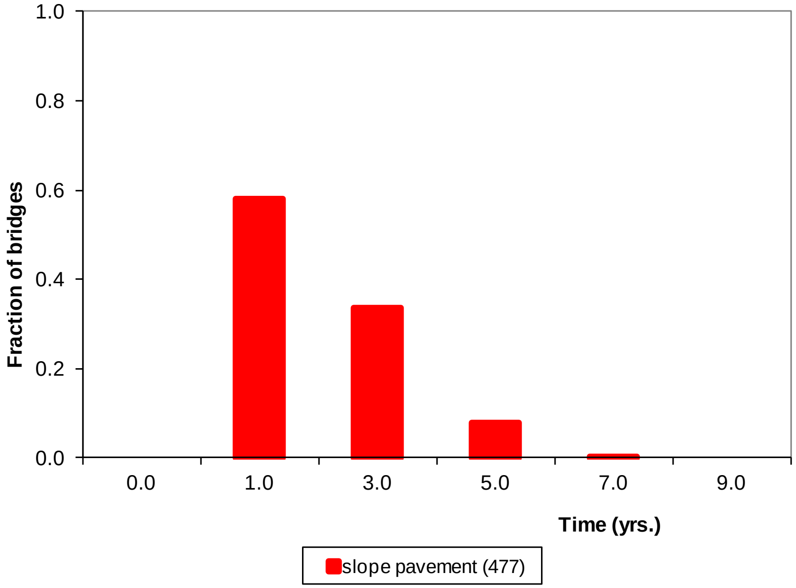
Results: repair actions

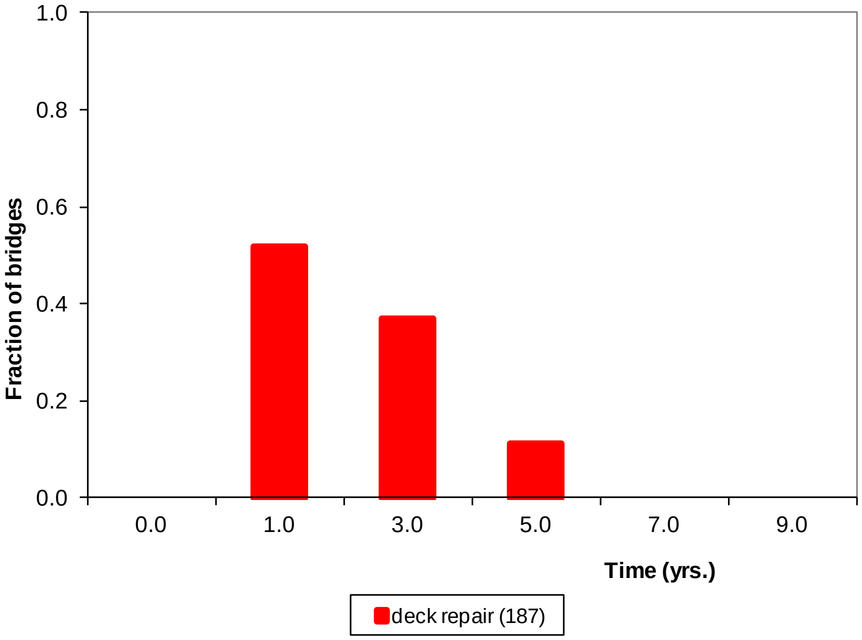
- **Bearings:**
  - **Repairs done mostly between 25 and 35 years.**



Results: repair actions

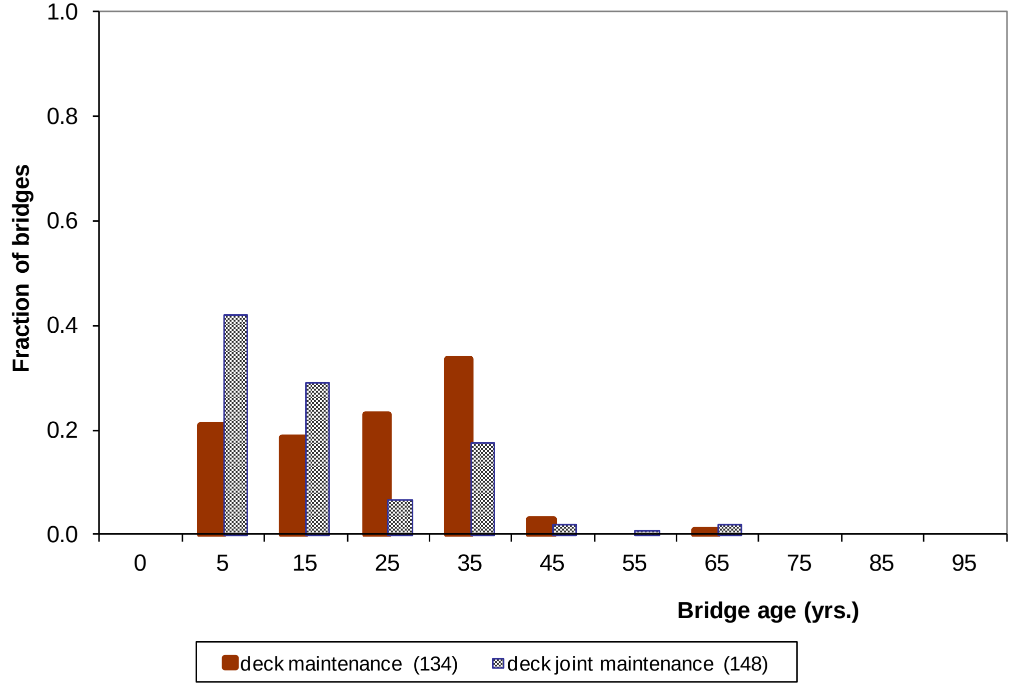
- **Deck and slope pavement (time between actions on same bridge):**
  - **About 3 yrs interval.**





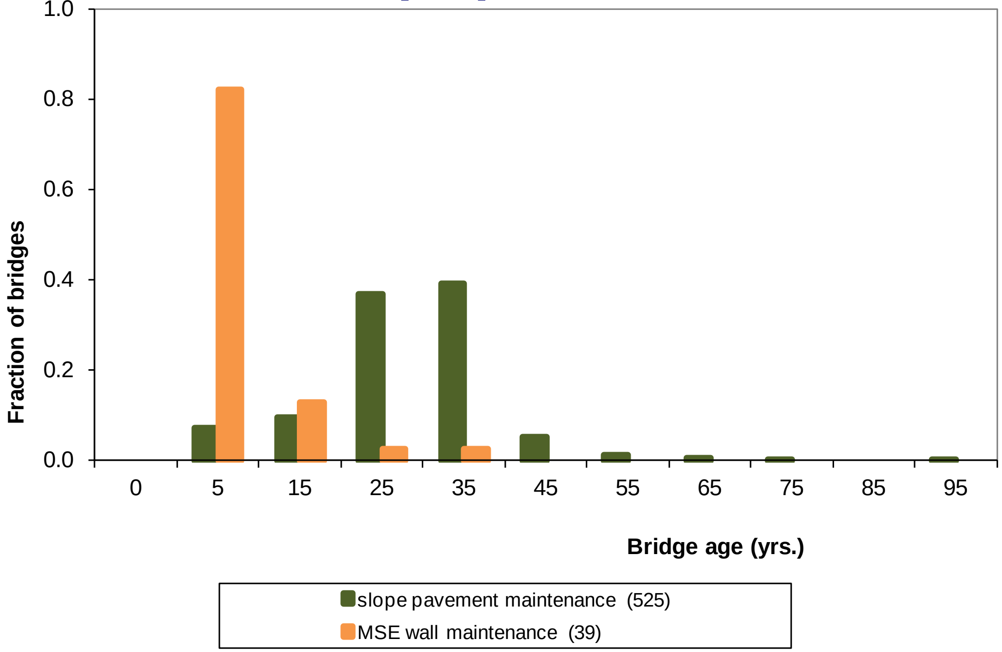
Results: maintenance actions

- **Deck and joint maintenance (examples):**
  - **Clean trash and debris from top of deck full length of structure.**
  - **Clean dirt and debris from all expansion joints.**



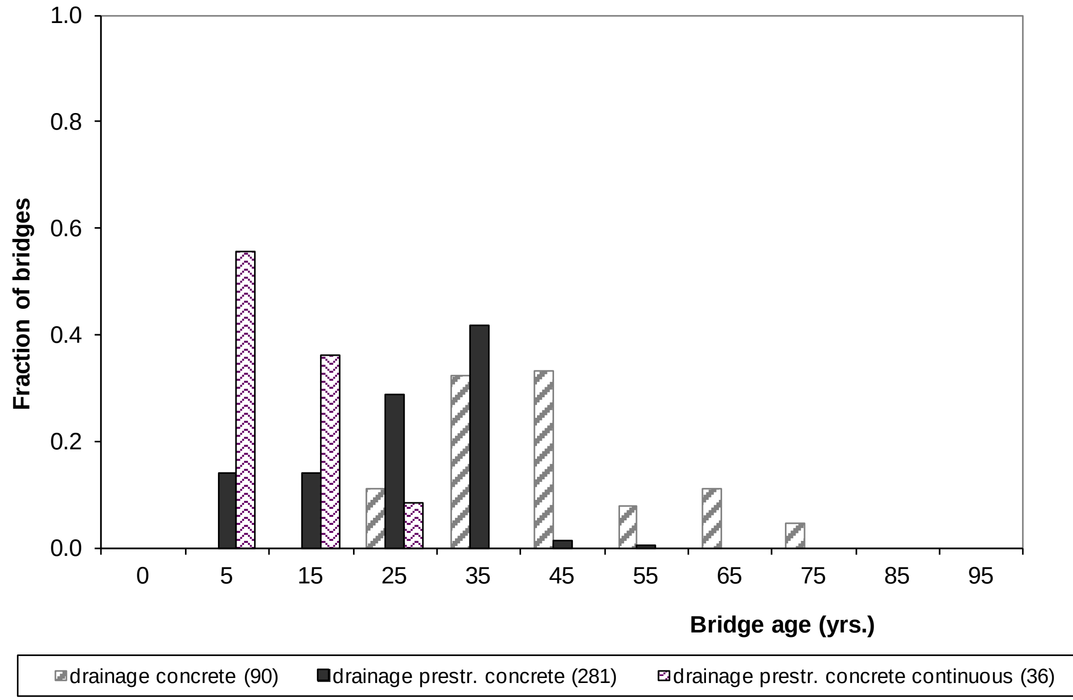
Results: maintenance actions

- **MSE wall and slope pavement maintenance (examples):**
  - **Remove vegetation from northeast MSE wall.**
  - **Herbicide the vegetation on the slope protection.**



Results: maintenance actions

- Drainage maintenance (examples):
  - Clean left scuppers spans 2 & 5 & 7.
  - Clean and flush all clogged drainage inlets and piping system on the deck in spans 2-8.



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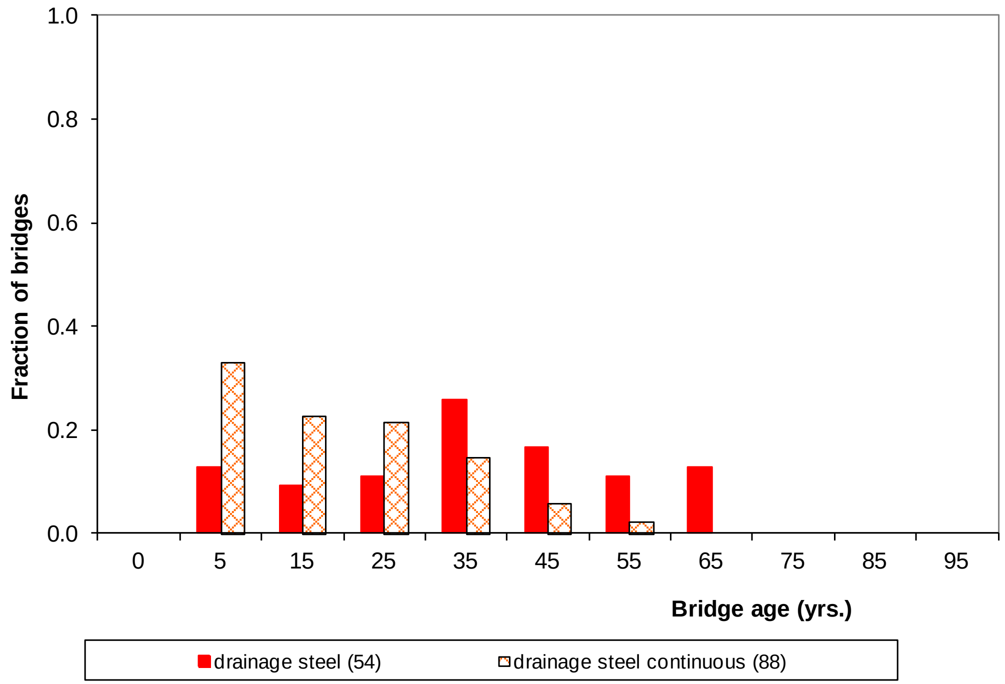
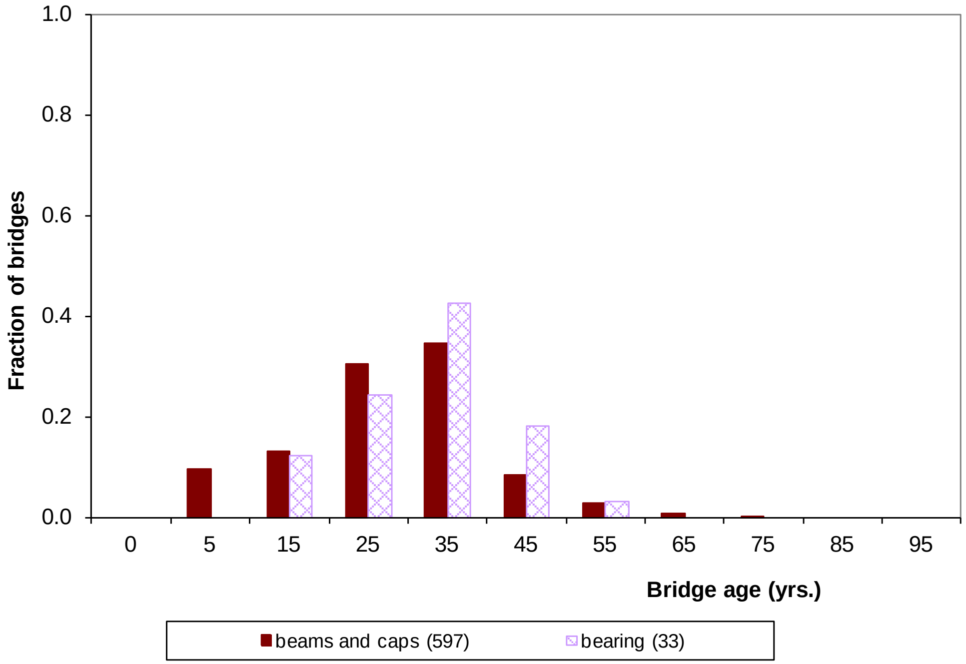


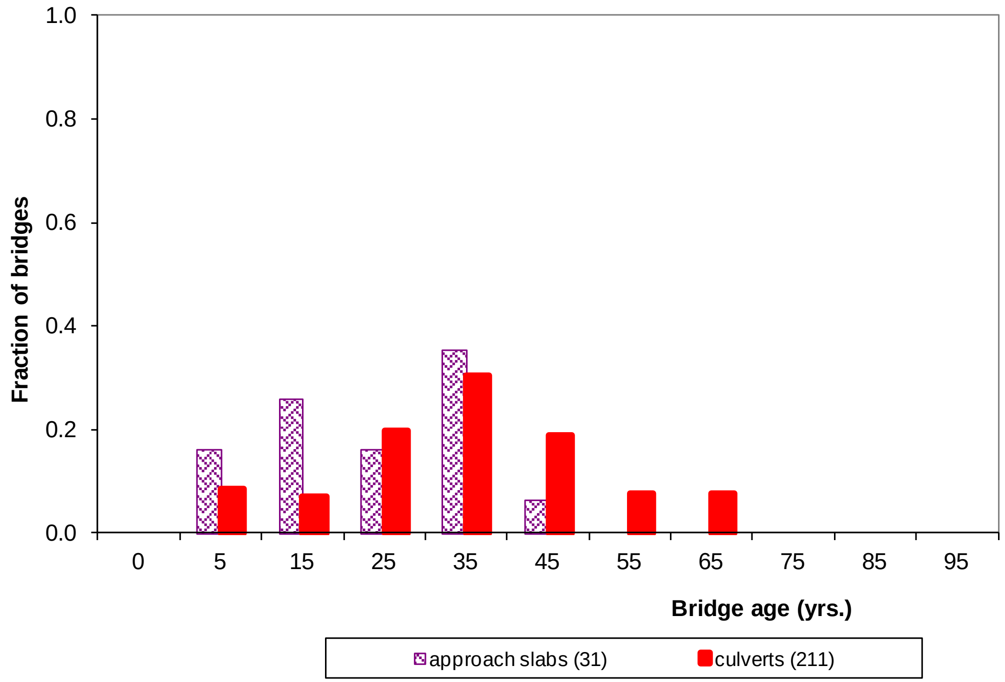
Results: maintenance actions

- Bearing, beam & cap maintenance (examples):
  - Remove the dirt and debris around the bearing…
  - Clean graffiti from beams and diaphragms…
  - Remove debris from both abutment caps.



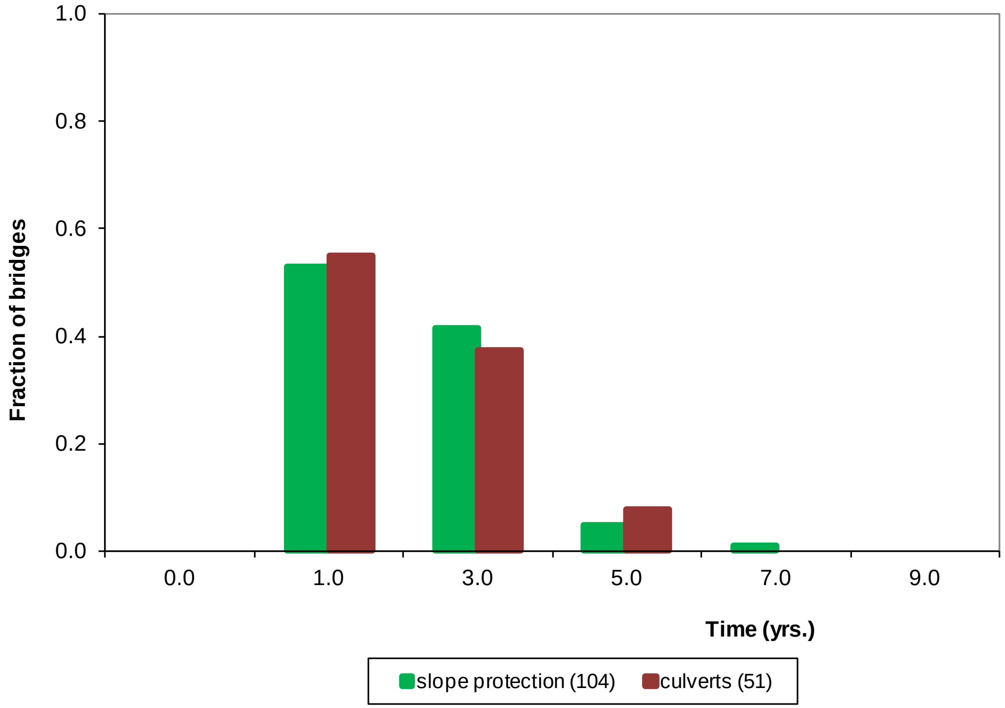
Results: maintenance actions

- Approach slabs and culverts (examples):
  - Remove the excess asphalt to match bridge deck at Approach Slab No. 1.
  - Remove vegetation build-up at both ends of the culvert.



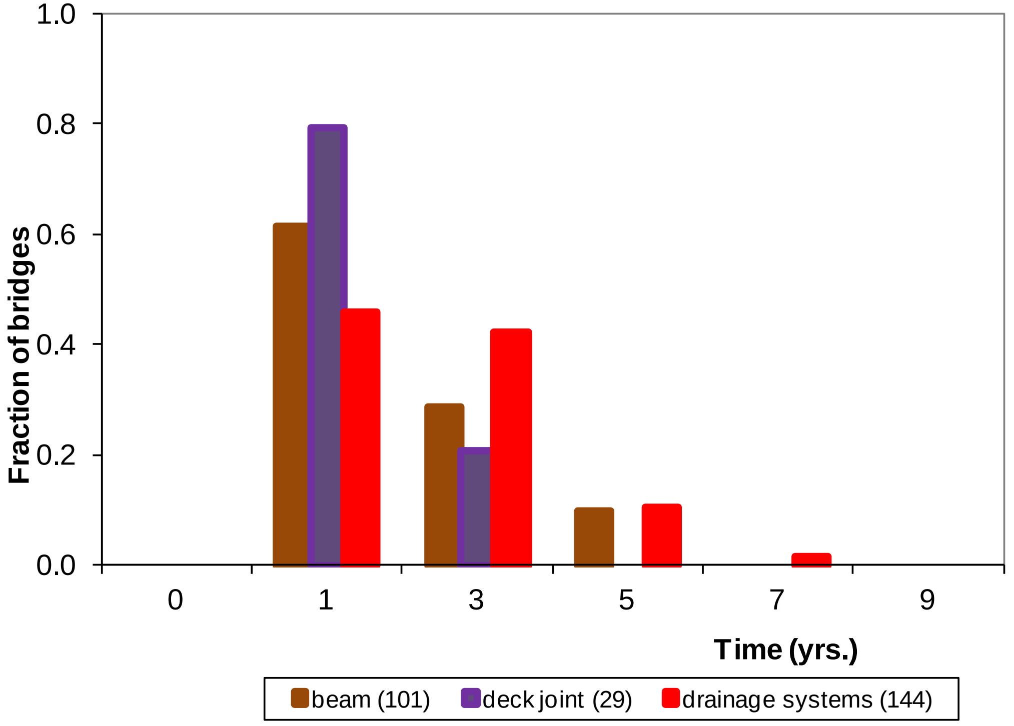
Results: maintenance actions

- **Time between actions for slope protection and culverts (same bridge):**



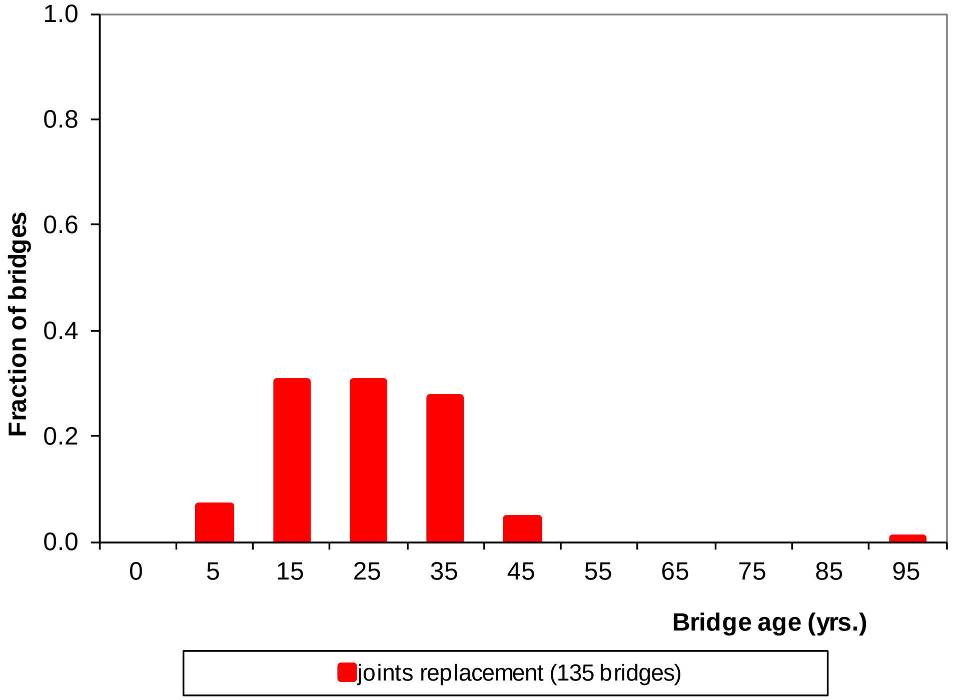
Results: maintenance actions

- **Time between actions for beams, deck joints and drainage system**



Results: replacement actions

- **Deck joints:**
  - **Most replacements done between 15 and 35 years.**



Age replacement models

- Based on reliability theory (See TRB Paper by Sobanjo "Estimating the Timing of Rehabilitation and Replacement of Bridge Elements" for more details).
- Objective is to minimize the average long-run costs per year on the repair and the replacement of the bridge elements.
- Consideration of the bridge element repair, replacement and failure costs.
- Model will suggest the time (age) to schedule the repair or replacement of bridge element.

Age replacement models

- **Optimal age to replace bridge element.**

If c_T represents the total cost for the element, then a policy, $Z(t_o)$, can be defined for long-term average yearly cost for a replacement age, t_o

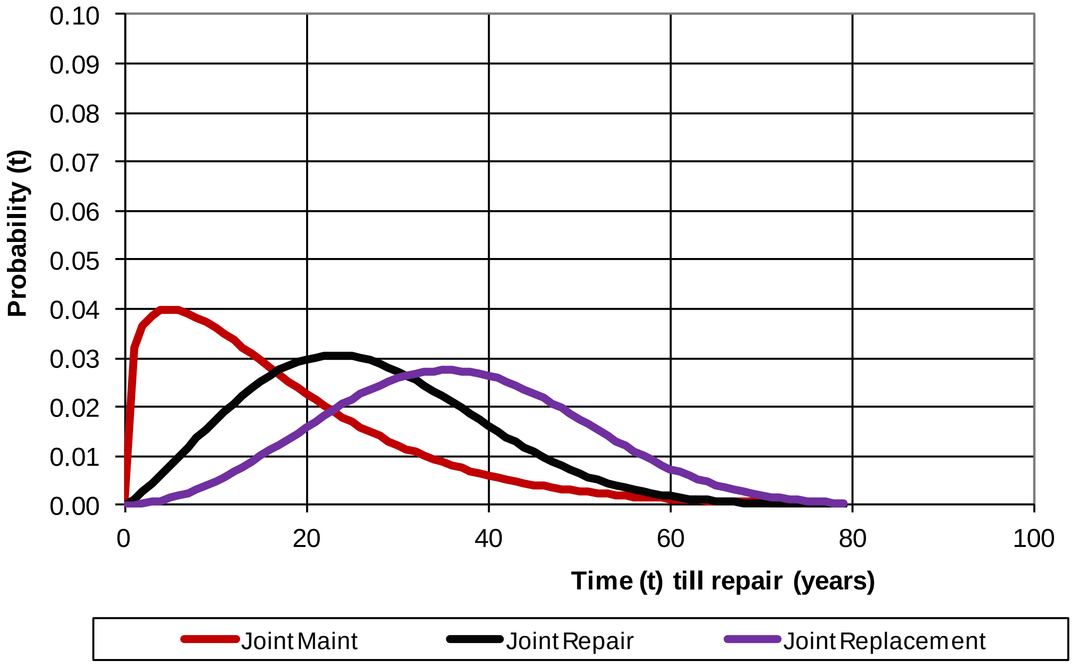
$$\min Z(t_o) = \frac{E(c_T)}{E(\min(T, t_o))}$$

$$S(t_o) = \int_0^{t_o} (1 - F(x))dx$$

$$Z(t_o) = \frac{c_R + c_F F(t_o)}{\int_0^{t_o} (1 - F(x))dx}$$

Age replacement models

- **Need fitted distribution (Weibull) of times till maintenance, repair and replacement.**



Age replacement models

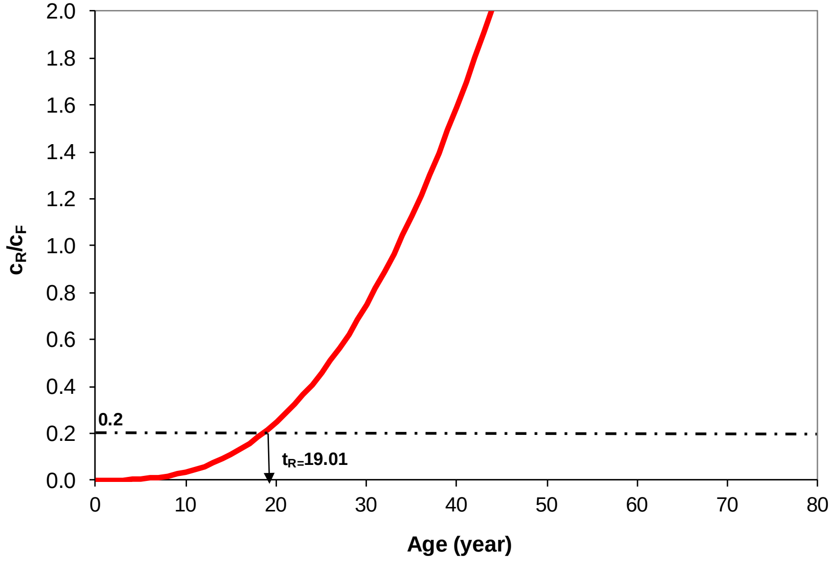
- **Need fitted distribution (Weibull) of times till maintenance, repair and replacement.**

	Fitted probability distribution parameters					
Bridge activity	Type	shape	scale	mean	stdev	median
Maintenance of deck joints	Weibull	1.24	18.61	17.38	14.15	13.83
Repair of deck joints	Weibull	2.23	30.34	26.88	12.73	25.75
Replacement of deck joints	Weibull	2.87	41.18	36.71	13.87	36.25
Repair of beams	Weibull	2.35	34.76	30.81	13.95	29.74
Repair of bearings	Weibull	2.41	33.15	29.39	12.99	28.48

Age replacement models

- **Optimal age to replace bridge element.**

Bridge element	Replacement cost*	Failure cost*	Optimal Age (yr.)
Deck joints	$12,000	$60,000	19.0
Beams	$105,000	$450,000	18.4
Bearings	$20,000	$80,000	16.4
*Costs assumed for illustration purposes			



Acknowledgment

- Results presented are from a study sponsored by the Florida DOT State Maintenance Office. Their assistance is greatly appreciated.
- The results do not reflect any final conclusions on the performance of Florida bridges.

Conclusions

- Historical data on bridge element maintenance, repair and replacement can indicate the bridge age (timing) to apply the action.
- Statistical distributions of timing include the point estimates and variance; can be useful for simulation models.
- Some types of repair are done earlier in the bridge service life than the other types.
- The timing of repair may depend on the design/material type of the bridge.
- Age replacement models may be used to suggest timing for repair actions.

Suggestions for future study

- Investigate results for specific types or categories of bridge maintenance & repair
- Identify patterns for specific types of bridge elements (seal joint, elastomeric bearings, etc.).
- Increase the data period for bridge service lives observed.
- Used the results to develop life cycle cost models to enhance bridge design (type & material).
- Improve age replacement models with focus on older bridges.

Any questions!