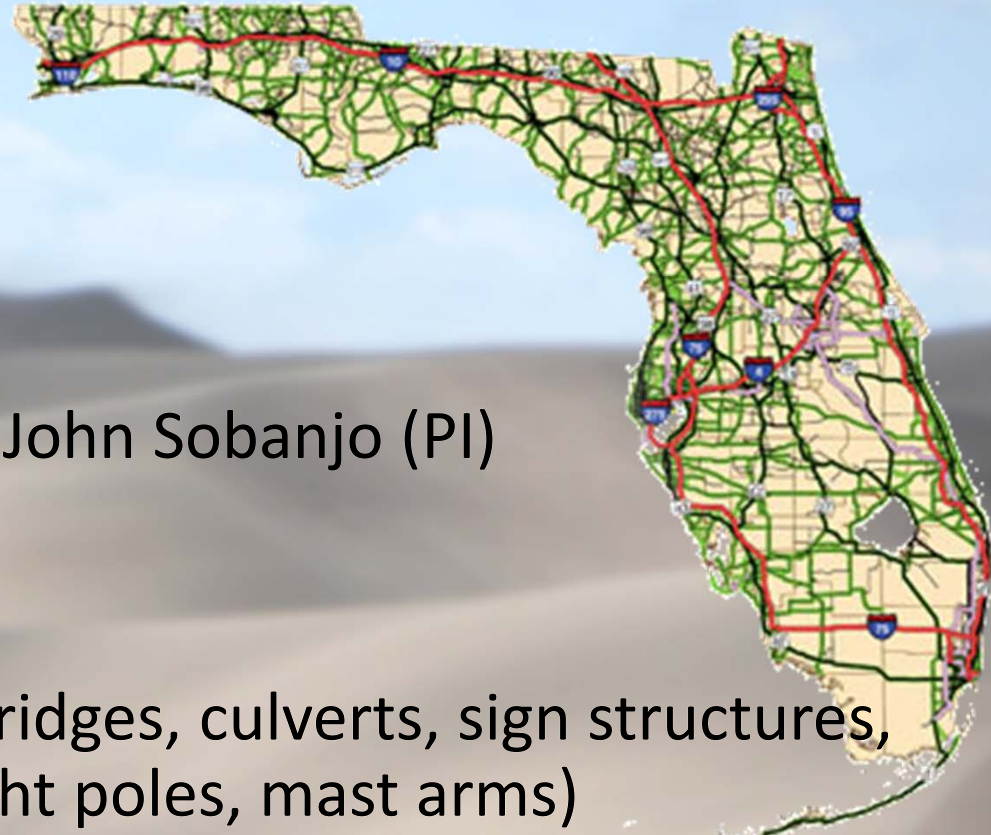
Migration probability matrix for bridge element deterioration models

Paul D. Thompson

Background



- Research team
  - Florida State University – John Sobanjo (PI)
  - Paul D. Thompson (co-PI)
- Florida DOT
  - 36,889 structures (bridges, culverts, sign structures, high-mast light poles, mast arms)
  - 198,030 inspections over >17 years
  - 1,529,894 element inspections

Background

- October 2016 transition to new AASHTO Manual for Bridge Element Inspection
  - Many custom elements, especially movable bridges and non-bridge structures
  - Deterioration model based on expert judgment in 2001
  - Deterioration model based on statistical analysis in 2011
- Old models and >17 years of data based on old AASHTO CoRe Elements

Changes in elements and condition states

- More precise state definitions based on defects
- Separation of protective elements
- Standardization to 4 states for every element
- Examples of smaller but still significant changes:
    - Whether structural review required in worst state
    - Whether reinforcing steel exposed in state 2

The problem

- Need a deterioration model compatible with the new AASHTO Manual (and FDOT field guide) and AASHTOWare Bridge Management 5.2.2 software
- Desire to use FDOT's valuable 17+ years of inspection data
- Unwilling to wait 4 or more years before having a functional bridge management system based on the new element inspection manual

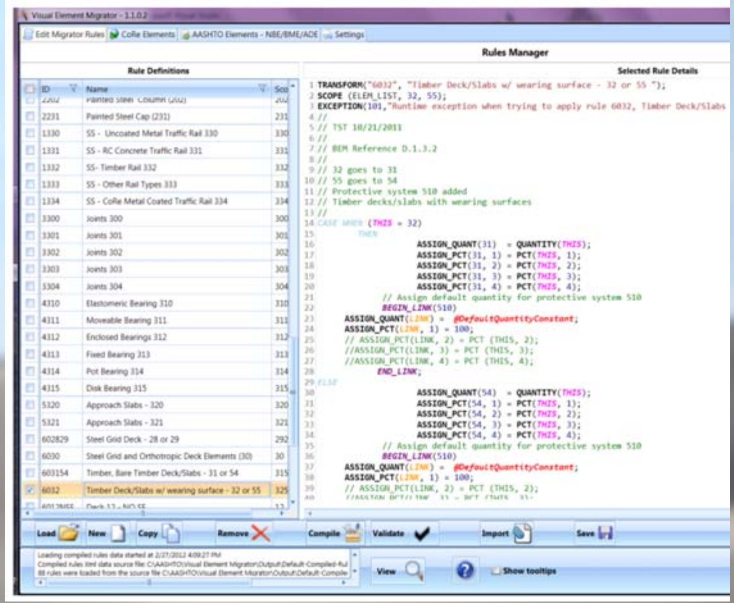
Every state DOT has the same problem because of federal bridge inspection and management requirements

Potential solutions

Suppose 100 elements are in this condition state today. After how many years will 50 of them reach the next-worst state if no action is taken?			
Respondent	State 1	State 2	State 3
Beckie	20	15	10
Barry	20	15	10
Paul	15	12	9
Bob	25	20	15
Aine	21	14	7
Darren	17	13	11
Richard	15	15	12

- Repeat the expert elicitation conducted 15 years ago, but using the new inspection manual
  - FDOT research showed that these models under-estimated transition times by a factor of 2 on average
  - Would not be able to take advantage of the inspection data or statistical research done since then

Potential solutions



- Apply the Visual Element Migrator and estimate a new model based on migrated element inspection data
  - Migrator meant only for inspection data
  - Migration process is deterministic, would not produce realistic variability needed for a probabilistic model
  - A lot of judgment-based post-processing would be required because the migrator can't produce all the necessary elements and condition states

Selected solution

- Multiply old deterioration model by a migration probability matrix to yield a new model
  - Migration prob matrix developed using judgment, based on the changes in element/state definitions
  - We know the old CoRe element models are solid – this method minimizes changes to the old model
  - Can be done quickly

	Migration probabilities																			
	Probability to state 1					Probability to state 2					Probability to state 3					Probability to state 4				
Element type name	From 1	From 2	From 3	From 4	From 5	From 1	From 2	From 3	From 4	From 5	From 1	From 2	From 3	From 4	From 5	From 1	From 2	From 3	From 4	From 5
Name	P11	P21	P31	P41	P51	P12	P22	P32	P42	P52	P13	P23	P33	P43	P53	P14	P24	P34	P44	P54
A1- Concrete deck	100%	0%	0%	0%	0%	0%	80%	30%	0%	0%	0%	20%	70%	70%	0%	0%	0%	0%	30%	100%
A2- Concrete slab	100%	0%	0%	0%	0%	0%	80%	60%	20%	0%	0%	20%	40%	70%	50%	0%	0%	0%	10%	50%
A3- Prestressed concrete slab	100%	0%	0%	0%	0%	0%	80%	60%	20%	0%	0%	20%	40%	70%	50%	0%	0%	0%	10%	50%
A4- Steel deck	100%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%
A5- Timber deck/slab	100%	0%	0%	0%	0%	0%	60%	0%	0%	0%	0%	40%	70%	0%	0%	0%	0%	30%	100%	100%
A6- Approach slabs	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	60%	0%	0%	0%	0%	40%	100%
B1- Strip Seal expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B2- Pourable joint seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B3- Compression joint seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B4- Assembly joint/seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B5- Open expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B6- Other expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
C1- Uncoated metal rail	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C2- Coated metal rail	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C3- Reinforced concrete railing	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C4- Timber railing	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	100%	100%
C5- Other railing	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
D1- Unpainted steel super/substructure	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
D2- Painted girder/floorbeam/cable/p&h	100%	50%	0%	0%	0%	0%	50%	100%	50%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	100%
D3- Painted steel stringer	100%	50%	0%	0%	0%	0%	50%	100%	50%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	100%

Migration probability matrix

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A2- Concrete slab	100%	0%	0%	0%	0%	0%	80%	60%	20%	0%	0%	20%	40%	70%	50%	0%	0%	0%	10%	50%
A3- Prestressed concrete slab	100%	0%	0%	0%	0%	0%	80%	60%	20%	0%	0%	20%	40%	70%	50%	0%	0%	0%	10%	50%
A4- Steel deck	100%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%
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A6- Approach slabs	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	60%	0%	0%	0%	0%	40%	100%
B1- Strip Seal expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B2- Pourable joint seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B3- Compression joint seal	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
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B5- Open expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
B6- Other expansion joint	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
C1- Uncoated metal rail	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C2- Coated metal rail	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C3- Reinforced concrete railing	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
C4- Timber railing	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	100%	100%
C5- Other railing	100%	0%	0%	0%	0%	0%	50%	0%	0%	0%	0%	50%	30%	0%	0%	0%	0%	70%	100%	100%
D1- Unpainted steel super/substructure	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100%	100%
D2- Painted girder/floorbeam/cable/p&h	100%	50%	0%	0%	0%	0%	50%	100%	50%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	100%
D3- Painted steel stringer	100%	50%	0%	0%	0%	0%	50%	100%	50%	0%	0%	0%	0%	50%	0%	0%	0%	0%	0%	100%

Example rationale for migration probabilities

- For certain elements, there is minimal change in definitions, so old models can be used unchanged
  - Metal and concrete railings
  - Many of FDOT's agency-defined elements
  - Concrete elements mostly unchanged except exposed rebar moved from state 3 to state 2

Example rationale for migration probabilities

- For joints and bearings, spread 3 states probabilistically to 4 states
  - State 1 unchanged
  - For bearings, new state 4 equivalent to old state 3
  - Spread remaining old states equally or probabilistically among the remaining new states

Example rationale for migration probabilities

- Old painted steel elements, with 5 states, are divided into a new coating element and new steel element
  - Coating probabilities based on old states 1 thru 4
  - Steel element probabilities based on old states 2 thru 5

Conclusions

- You can develop bridge element deterioration models using your old CoRe Element data …
- … then easily convert the models for use in AASHTOWare Bridge Management 5.2.2 or above using a migration probability matrix

It's a quick, viable interim solution to develop statistically valid models for bridge management use