Final Presentation and Implementation Meeting

Significant Factors of Bridge Deterioration

December 9, 2024

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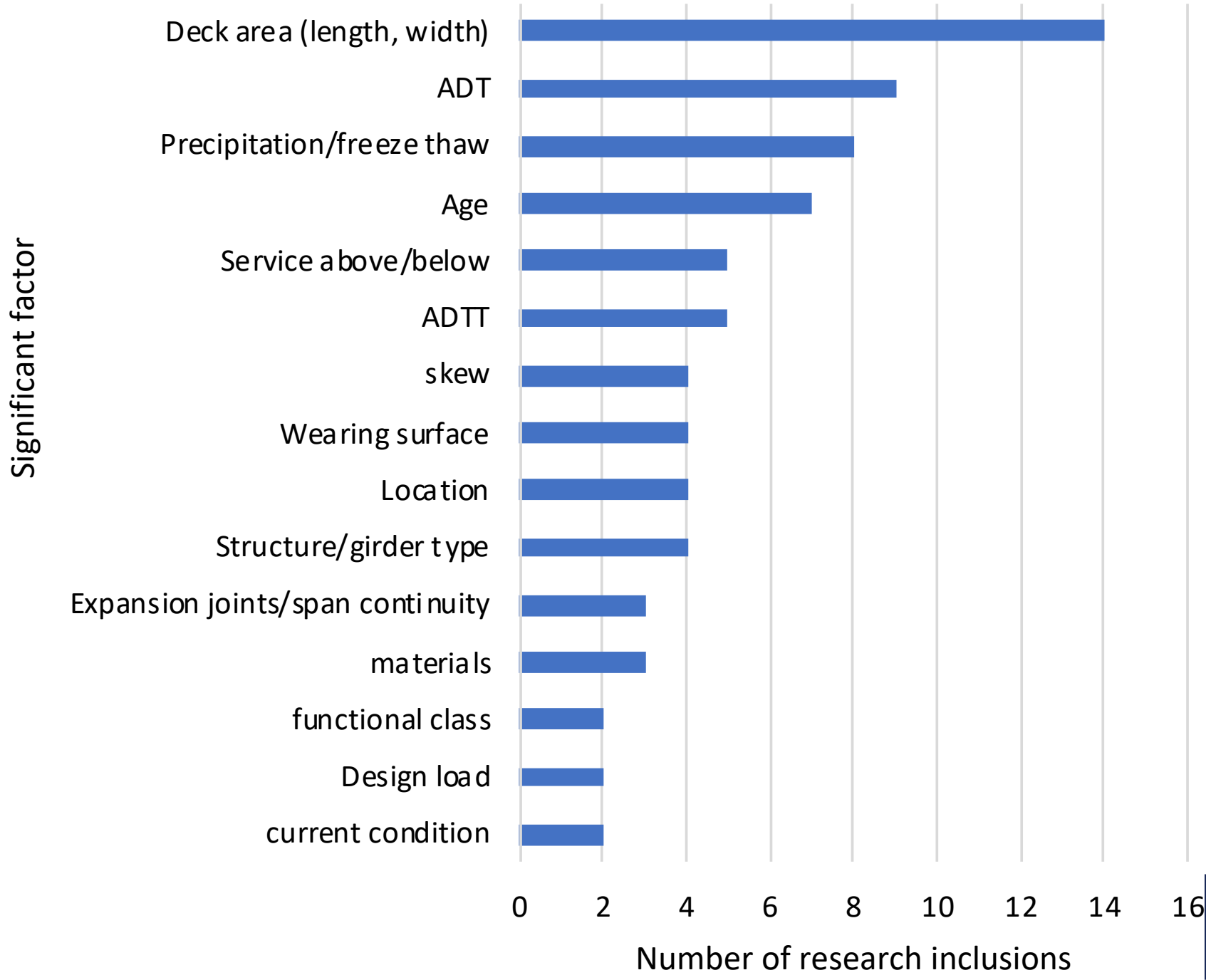
Outline

- Research Presentation
  - Literature review (Task 1)
  - Bridge groups, maintenance data, statistical analysis (Task 2)
  - General Condition Rating Analysis (Task 3)
- Implementation Discussion

Literature review summary



Research questions (5/4/23)

- What significant factors are influencing deterioration rates in Montana?
- What are the impacts of maintenance activities on deterioration?
- Do permitted trucks effect deterioration rates?

Task 2 bridge groups considered

1) Statewide
2) Maintenance District
3) Main-span material (concrete, steel, wood)
4) Functional class (interstate, major-, minor- arterial, collector)
~~5) Highline route~~
~~6) Highline control~~

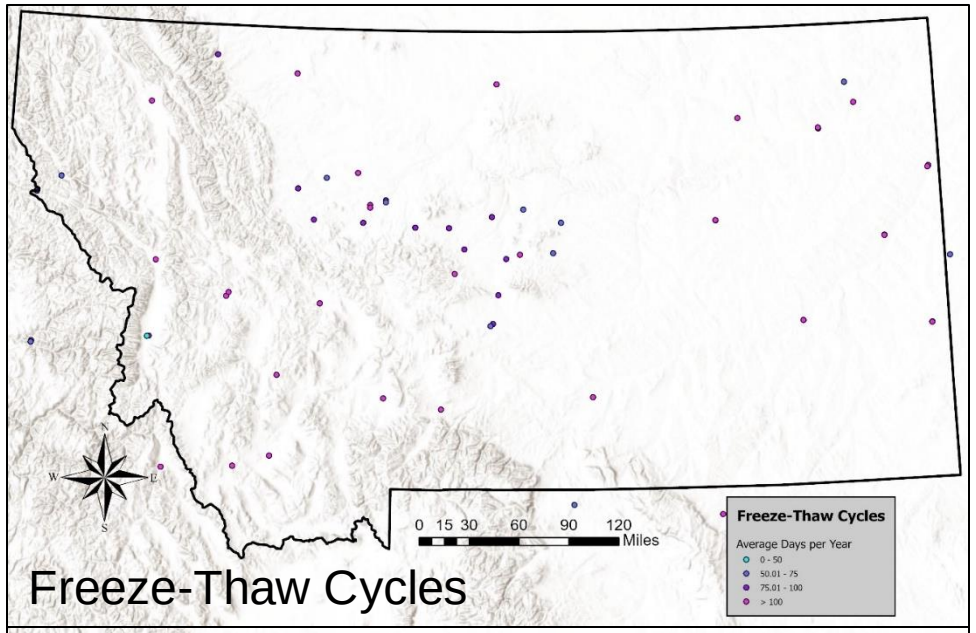
5) Bridge deck overlay

Task 2 revised variables considered

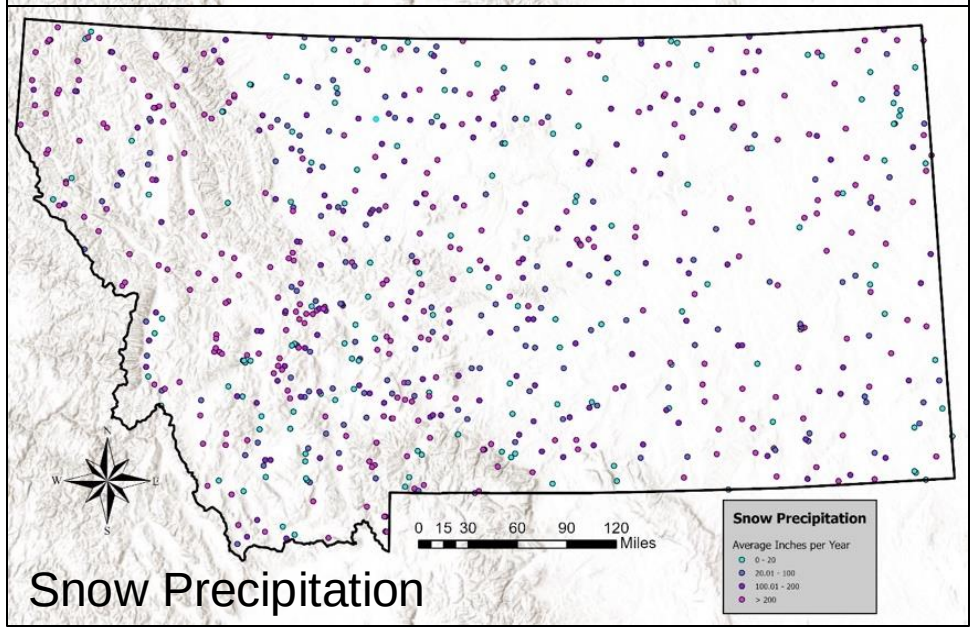
Low statistical significance

1) ~~Number of lanes~~
2) ~~Number of spans~~
3) ~~Urban areas~~
4) ~~NHS highway~~
5) ~~Road surface type~~

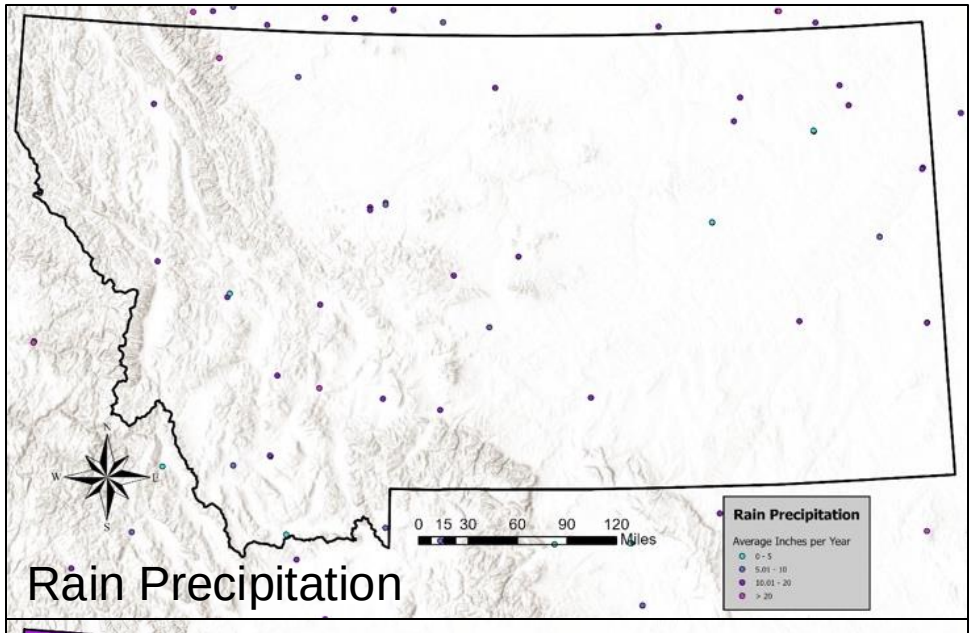
1) Freeze-thaw cycles
2) Rain precipitation
3) Snow precipitation
4) Deicer application



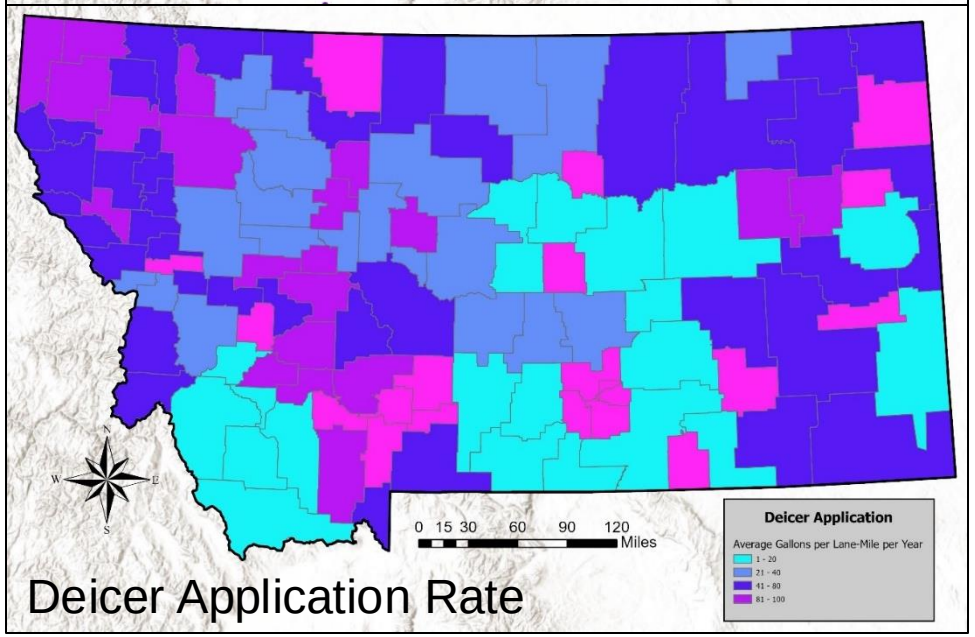
Freeze-Thaw Cycles



Snow Precipitation



Rain Precipitation



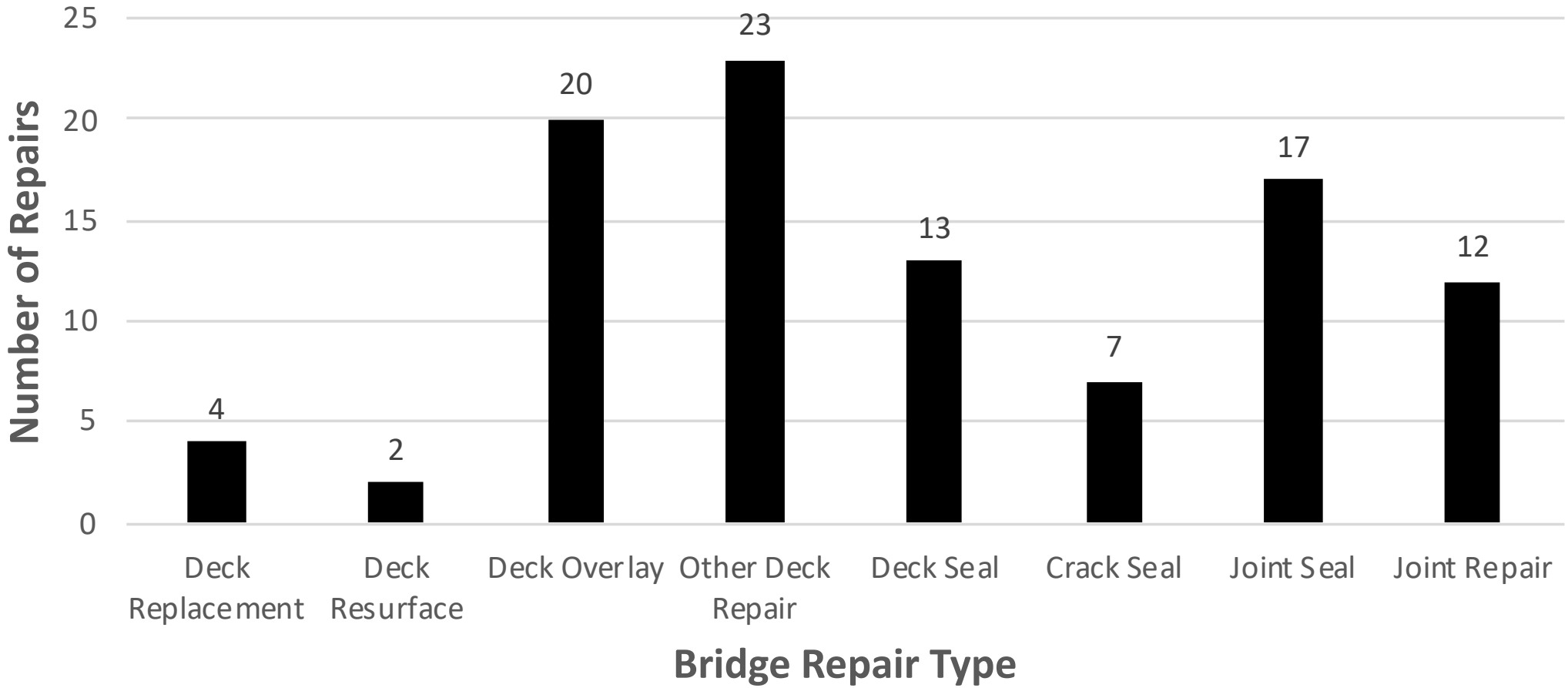
Deicer Application Rate

Maintenance Data Review

- 1 in 5 bridges had maintenance documented in BrM, most were rail and approach work, incomplete data
- Some bridge maintenance is managed by roadway projects – difficult to isolate
- Douglas McBroom provided 6 years of maintenance work records from MMS in Excel format.
- Conclusion – little maintenance documentation found on Highline route

A review of 50 Interstate bridge repairs

(10 in each district)



NBI rating change following repairs

District	**Billings**													
Rehab Year	2015	2015	2001	1999	2001	2014	2015	1999	2014					
District	**Butte**													
Rehab Year	2009	2016	2014	1993	2003	2012	1993	2003	2012	1995	2005	2013		
District	**Glendive**													
Rehab Year	1991	2016												
District	**Great Falls**													
Rehab Year	1980	1998	2020	1993	2021	1994	2011	2000	1995	2002				
District	**Missoula**													
Rehab Year	2004	1991	1994	2018	1985	1994	2018	1995	2017	1994	1999	2012	1999	2004

Legend	-2	-1	-	+1	+2	NBI rating change

Future Research/Recommendations

- Create a single-source database for bridge maintenance
- Bridge Rehab in BrM could support maintenance data, but currently used for upgrades
- Decouple bridge maintenance from other activities
- Add more maintenance detail to MMS

Statistical Models

Generalized Linear Model

- All variables initially considered; variables with p-value > 0.5 were removed during subsequent analyses.
- Evaluated by adjusted R^2 and root mean squared error (RMSE)

Random Forest Model

- Machine learning algorithm
- All variables considered to build 500 decision trees for each group
- Evaluated by pseudo- R^2 and mean of squared residuals (MSR)

Significant factor ranking

Preliminary analysis

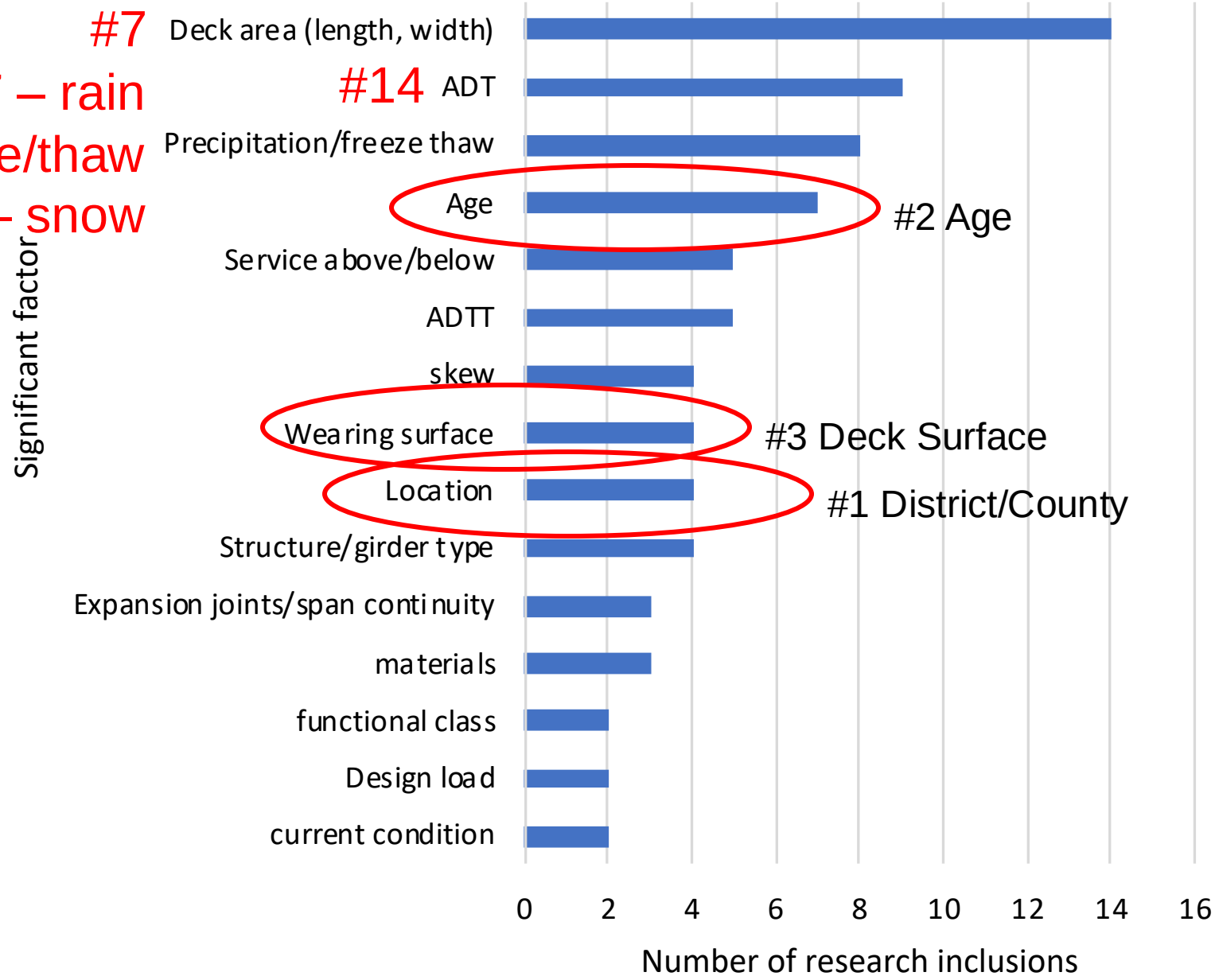
Model	District/County	Age	Deck Surface	Deck Area	AADTT	Structure Length	Functional Class	Design Load	AADT	Deck Width	Max Span Length	Bridge Over	Speed	Bridge Material	Deck Material	Bridge Design	Bridge Skew	Urban Area	# of Lanes
GLM	1	2	3	5	7	10	4	6	9	13	12	8	11	17	14	16	15	19	18
RF	1	2	3	4	8	6	13	11	9	5	7	12	14	10	15	16	18	17	19
Average Ranking	1	2	3	4.5	7.5	8	8.5	8.5	9	9	9.5	10	12.5	13.5	14.5	16	16.5	18	18.5

Final analysis

Model	District/County	Age	Deck Surface	Max Span Length	Bridge Over	Snow	Deck Area	Structure Length	Deicer	Deck Width	Freeze/Thaw	Functional Class	Bridge Material	AADT	AADTT	Speed	Rain	Bridge Design	Design Load	Bridge Skew
GLM	1	2	3	7	6	4	10	11	9	13	8	5	14	16	15	12	19	17	20	18
RF	1	2	3	4	6	12	6	5	8	7	13	17	10	9	11	18	14	19	16	20
Average Ranking	1	2	3	5.5	6	8	8	8	8.5	10	10.5	11	12	12.5	13	15	16.5	18	18	19

Results compared with other researchers

#7
#17 – rain
#11 – freeze/thaw
#6 – snow

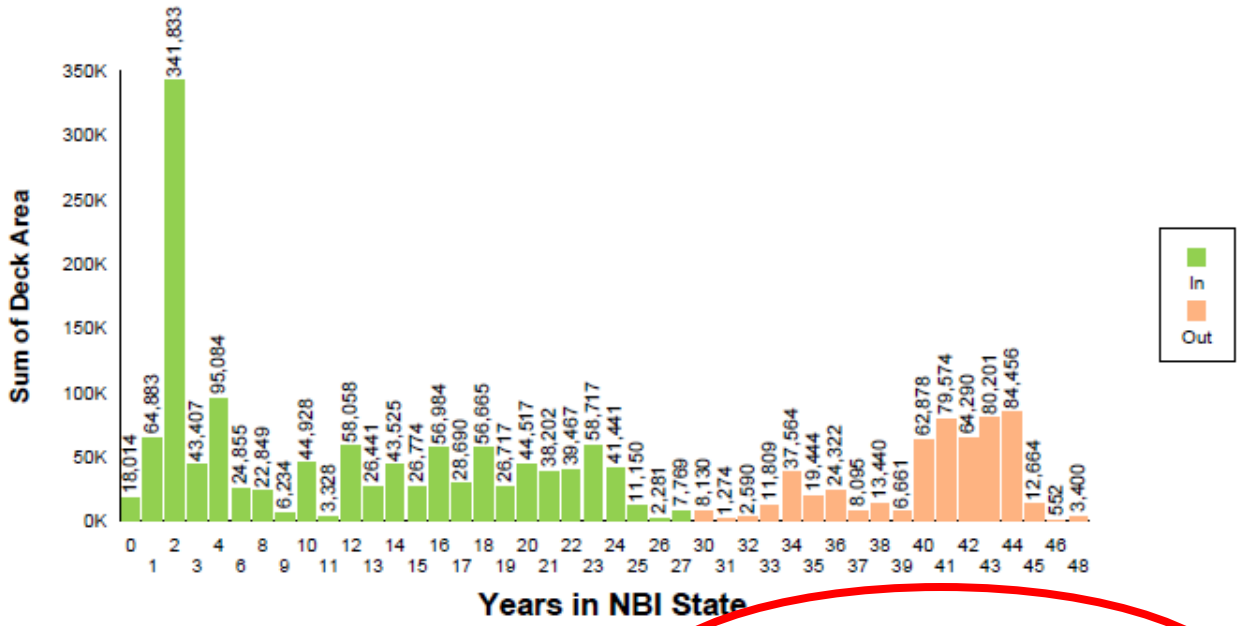


General Condition Rating Analysis (Task 3)

- Uses NBI component level data
- Requires transition times between NBI ratings (1-9) to conduct analysis
    1) Time-in-State Reports
    2) Deterioration Profiles, and
    3) % Good, Fair, Poor forecasts

Time-in-State Reports

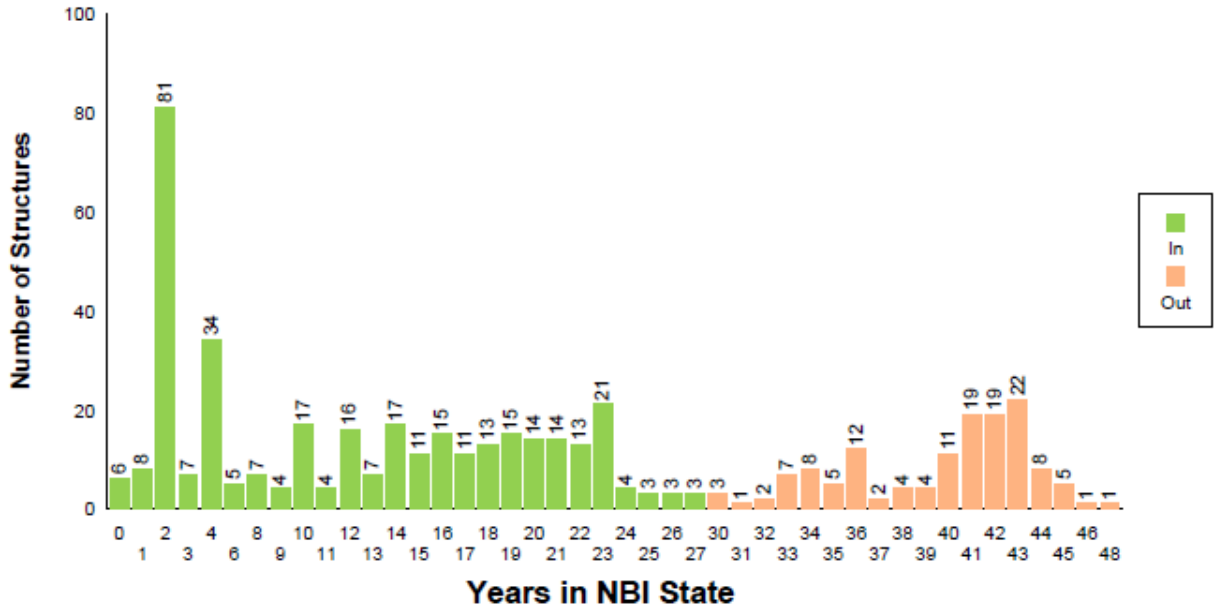
For 7 By Deck Area



Total Deck Area:	1,754,154
Weighted Avg Time in State:	19.17
Weighted Std Deviation:	15.57

wAvg + 1 w St Dev:	34.74
wAvg + 2 w St Dev:	50.31

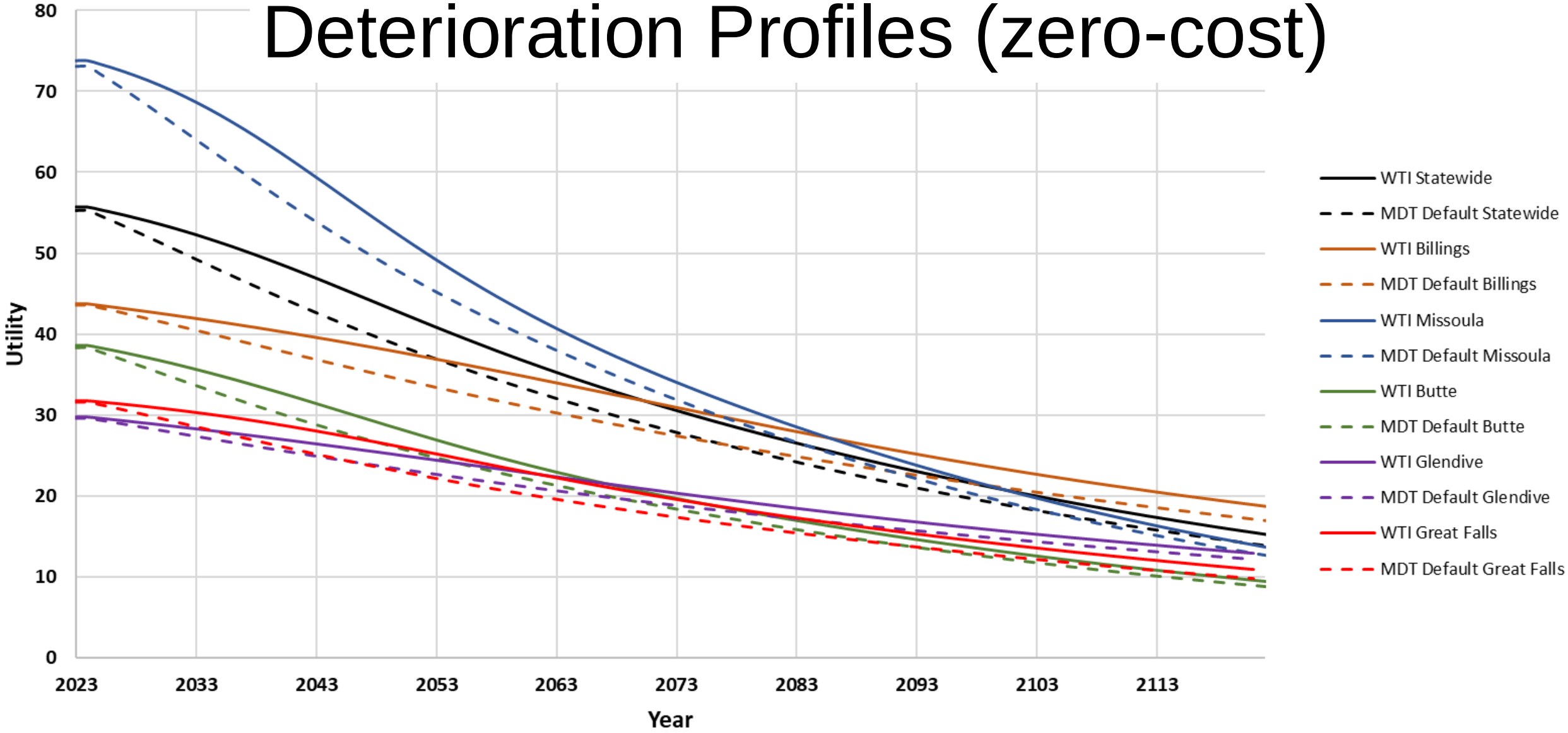
For 7 By Count



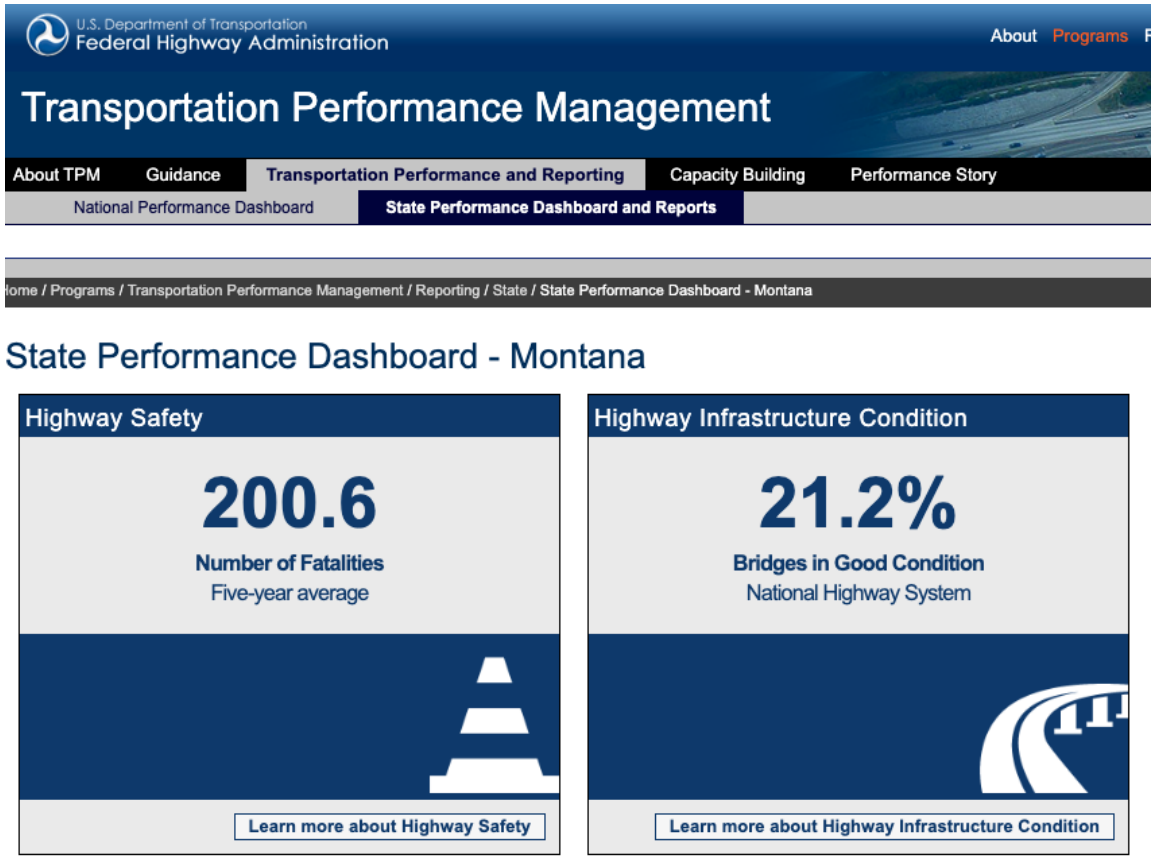
Structure Count:	487
Average Time in State:	19
Standard Deviation:	14.60

Avg + 1 St Dev:	33.60
Avg + 2 St Dev:	48.20

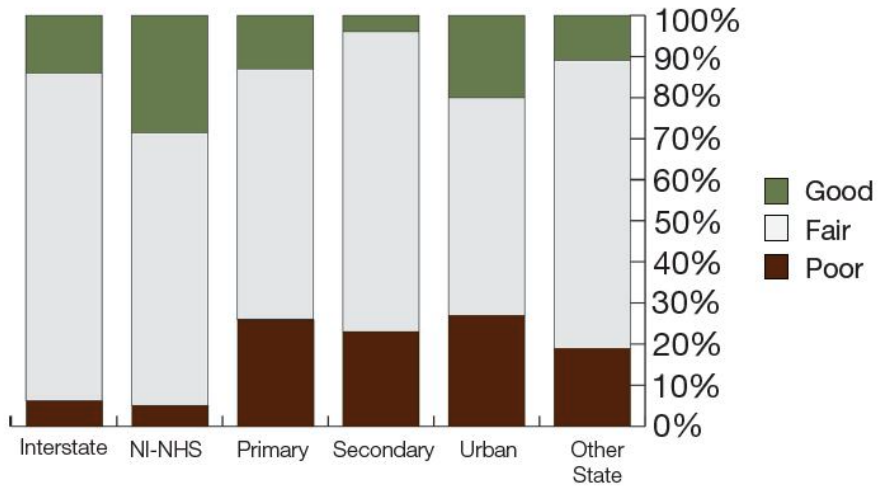
Deterioration Profiles (zero-cost)



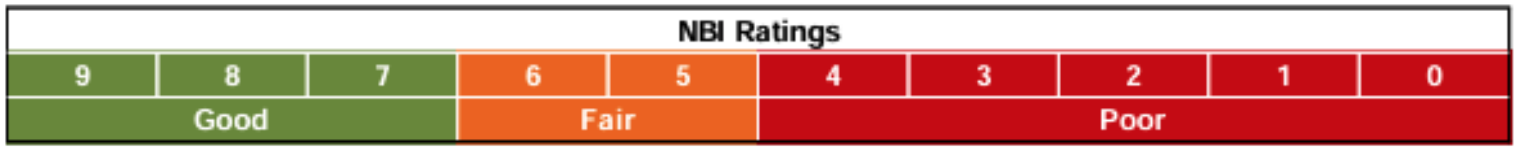
% Good, Fair, Poor Forecasting



https://www.fhwa.dot.gov/tpm/reporting/state/state.cfm?state=Montana

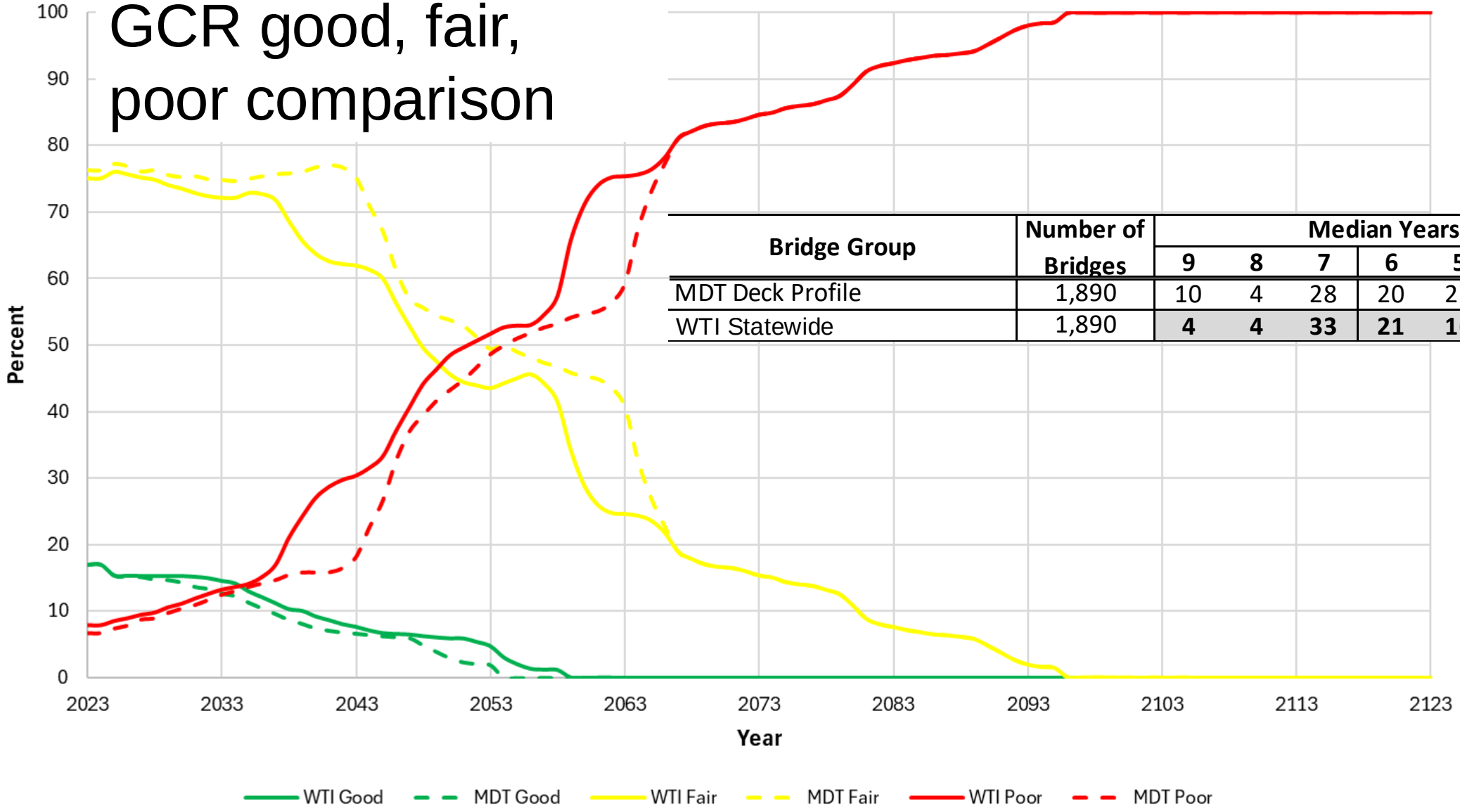


https://mdt.mt.gov/publications/reports/performance-measures.aspx



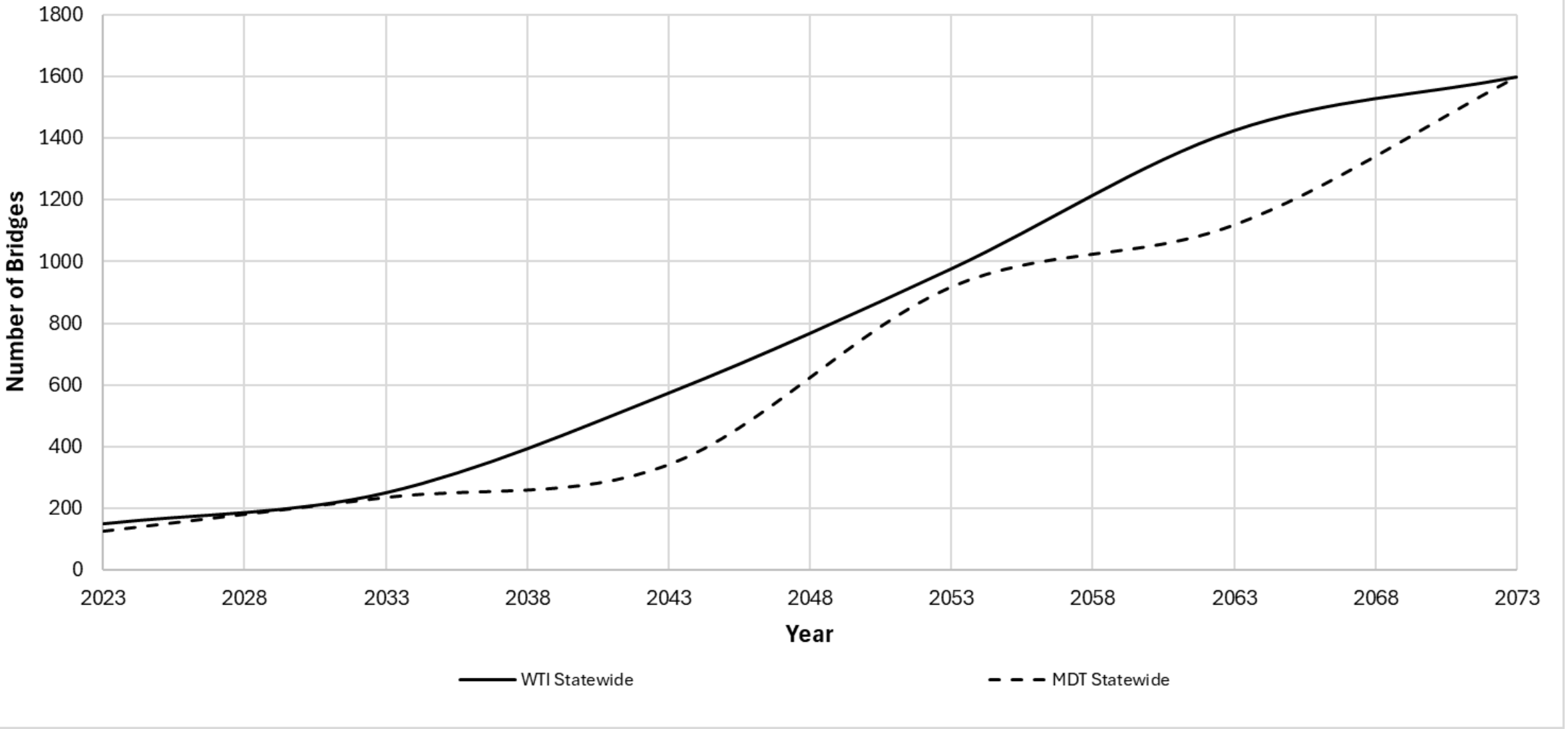
https://www.mdt.mt.gov/publications/docs/plans/MDT-TAMP-2022.pdf

GCR good, fair, poor comparison



Bridge Group	Number of Bridges	Median Years in NBI Rating								
		9	8	7	6	5	4	3	2	1
MDT Deck Profile	1,890	10	4	28	20	22	11	10	10	10
WTI Statewide	1,890	**4**	**4**	**33**	**21**	**16**	**16**	**10**	1	1

Estimating Poor Condition Bridges



Summary and Conclusions

- A refined statistical analysis identified district/county, bridge age, and surface type as the top-3 significant variables
- In general, considering the number of iterations and their adaptability to multiple datasets, the RF regression model may be a better representation of the performance of NBI deck rating predictor models and hold a higher weight to variable selection.
- A procedure was established using BrM's general condition rating (GCR) analysis to estimate the number of bridges that are in good, fair, and poor condition over selected time periods.

Future Research

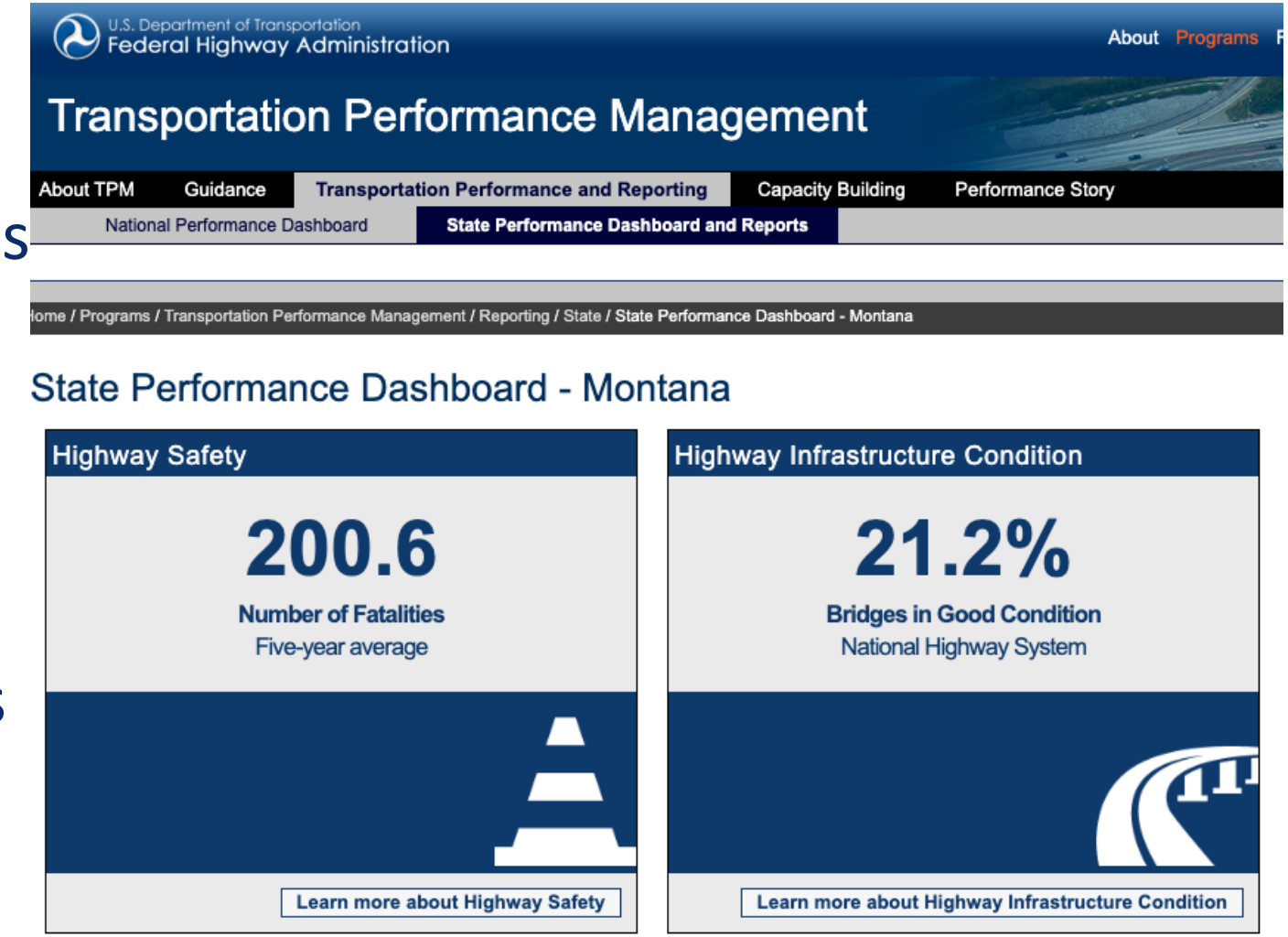
- Maintenance data recording criteria
    - Develop a methodology to record data for efficient BrM implementation
- Continue modeling in BrM
    - Apply life-cycle costs to bridges to compare long-term benefits of different maintenance/construction practices and bridge group profiles

Implementation Recommendations

Implementation Recommendation #1

Continue modeling in BrM

- Create maintenance scenarios and targets
- Focus on most-significant variables and bridge groups
- Incorporate deterioration curves/environmental factors from Phase 1 research



Implementation Recommendation #2

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 #3

Continue recording and prioritize NBI component-level data using a scale of 0 to 9. BrM's GCR optimization strategies are improved over less-granular element-level ratings from 1-4.

Implementation Recommendation #4

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.

Questions and Comments