SIGNIFICANT FACTORS OF BRIDGE DETERIORATION

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INTRODUCTION

Bridge structures deteriorate over time due to various factors. Understanding the factors that affect bridge deterioration rates is necessary for state agencies to maintain the safety and functionality of bridges during their design service life. To improve deterioration modeling in Montana, factors affecting bridge deterioration were evaluated within the Montana Department of Transportation's (MDT) Bridge Management (BrM) software. The research improved the understanding of bridge deterioration by considering different bridge groups, variables, NBI component-level data, and maintenance activities. The overall objective of the research was to increase the confidence of deterioration prediction models by applying weighted factors to reflect different environments, traffic characteristics, and bridge types in Montana.

LITERATURE REVIEW

Several significant factors influencing the deterioration of bridges were identified from published research. A summary of factors considered or identified by at least two researchers is shown in Figure 1.

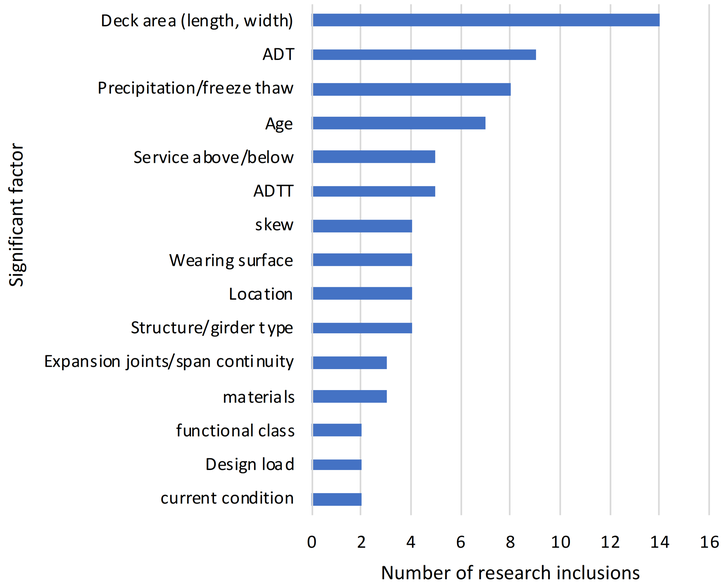

Figure 1. Significant factors identified by other researchers in published literature.

The three most identified significant variables from the literature review were deck area, ADT, and precipitation/freeze thaw.

STATISTICAL ANALYSIS

Two statistical regression models were used to investigate selected bridge groups and model variables.

- Analyses were conducted in the program R[1]
- 80% of the NBI deck ratings were randomly selected and used as a training dataset. The remaining 20% of the NBI deck ratings were used as a validation dataset.
- Three sources of maintenance data were investigated and Montana's Highline Route was used to evaluate the potential influence of relatively larger volumes of permitted (overweight, oversize) trucks.

Maintenance district, bridge age, and deck surface are the three most influential variables identified by both the GL and RF models. Lower rankings varied between the two analyses, which were averaged to approximate the influence of the remaining variables.

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

Table 1. Ranking of significant factors by Generalized Linear (GL) and Random Forest (RF) regression models.

GENERAL CONDITION RATING ANALYSIS

MDT's asset management software (BrM) was used to conduct zero-cost General Condition Rating (GCR) analyses to predict the number of bridges in Good, Fair, and Poor condition over a 100-year period. Two different deterioration profiles were used.

- BrM Time-in-State Reports (TSR) were used to identify median years for each NBI rating for each bridge group.
- The WTI profile used the average TSR transition time for each condition state plus one standard deviation.
- The MDT deck profile was created using professional experience and insight from MDT.

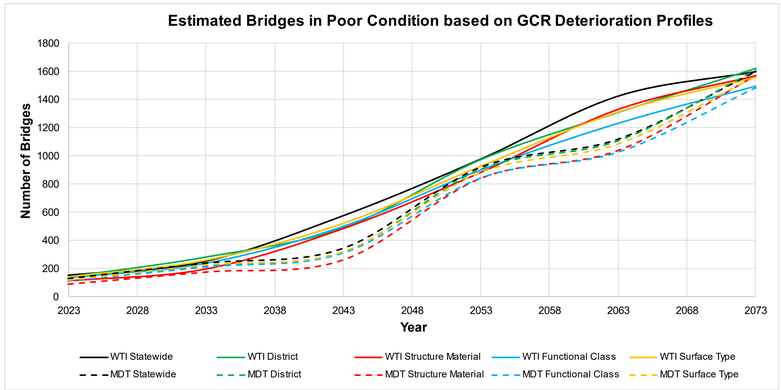

Figure 2. Estimated number of bridges in poor condition based on WTI and MDT deterioration profiles using no-cost optimizations.

- Figure 2 reveals differences in the profiles at 20 and 40 years and likely reflect maintenance activity that was generally accounted for through experienced selection of the profile transition times by MDT bridge engineers.

HIGHLIGHTED FACTS

- The top three factors influencing bridge deterioration in Montana are District/County (location), age, and deck surface.
- A procedure was established to estimate the number of bridges in good, fair, and poor condition over different time periods. Including engineering judgement and experience to select transition in each NBI rating improves the predictions.

CONCLUSIONS AND RECOMMENDATIONS

This research project explored different factors and variables that contribute to the deterioration of Montana bridges. Conclusions and recommendations of the research include:

1. A refined statistical analysis considering four bridge groups and 21 variables resulted in the same top three significant factors (location, age, deck surface) as the preliminary analysis.
2. A review of condition ratings after interstate maintenance activities indicates a larger number of improved NBI ratings in the year following maintenance activities.
3. The Random Forest regression model may be more reliable than the General Linear regression model because the largest number of bridges produced the highest described variance compared to the other smaller bridge groups using the same variables.

Future Research is needed to continue modeling within BrM using realistic cost and maintenance scenarios using the significant bridge groups and variables identified in this research to further support MDT's asset management decisions.

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[1]R Core Team (2023) 'R: A Language and Environment for Statistical Computing'. Vienna, Austria: R Foundation for Statistical Computing. Available at: http://www.R-project.org.