MONTANA
Department of Transportation
Research

February 2025

Project Summary Report
FHWA/MT-24-005/10336-933

SIGNIFICANT FACTORS OF BRIDGE DETERIORATION

https://www.mdt.mt.gov/research/projects/bridge-deterioration.aspx

Introduction

Bridges 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 existing deterioration curves established in Phase I of this research 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. Specific objectives were to:

1. Identify significant factors affecting bridge deterioration in Montana.
2. Establish a procedure for performing a general condition rating analysis within MDT's Bridge Management software (BrM) using National Bridge Inventory (NBI) for bridges with reinforced concrete bridge decks.
3. Identify effective data collection, processing, and future research opportunities for improving the accuracy and efficiency of Montana's ability to forecast bridge deterioration.

What We Did

To accomplish the research objectives, the following three tasks were completed for this project: 1) Literature, standards, bridge specification, and maintenance activity review, 2) significant factors data analysis, and 3) general condition rating analyses. The first sub-task of the literature review summarized the span types, bridge types, and materials included in the new Specification for National Bridge Inventory (SNBI). The second sub-task identified significant factors and methods used by other departments of transportation and researchers that influence the deterioration rates of bridges. The papers reviewed focused on, 1) statistical methods and analyses used to evaluate and identify deterioration factors, 2) factors that caused overall bridge deterioration, and 3) studies that focused on the deterioration of a single bridge element.

The maintenance record review section of Task 2 investigated three sources of data: (1) BrM, (2) the National Bridge Inventory (NBI) inspection data, and (3) electronic sources available through MDT's Maintenance Management System (MMS). The Highline route was selected for an initial review of maintenance data because of the large number of permitted trucks that travel the route and the relatively comprehensive electronic data available in BrM. A second search of maintenance data information was performed on 10 interstate bridges randomly selected from each maintenance district (50 total bridges).

The significant factor data analysis component of Task 2 used two statistical regression models (General Linear and Random Forest) to identify hidden relationships between the NBI deck ratings and different variables. The preliminary analysis considered five bridge groups and 28 variables to characterize their influence on bridge deterioration in Montana. Based on the results of the preliminary analysis and input from bridge engineers at MDT, a refined analysis was performed. Statistically insignificant bridge groups and variables were removed, and one new group and four new variables were added. The final analysis considered four bridge groups and 21 variables.

The first revision to the data was to limit the bridge dataset to bridges with reinforced concrete decks. Due to the low number of bridge decks made with precast concrete, corrugated steel, and the relatively low traffic volumes and maintenance expenditures on wood and timber bridges, the statistical analysis included only bridges with concrete cast-in-place decks.

The second refinement made to the data groups was to remove the Highline route and Highline control route based on the inconclusive results obtained during the preliminary analysis. A new bridge group, deck overlay material (i.e. epoxy, bituminous, latex concrete), was added to the analysis.

The third revision made was the removal of insignificant variables identified in the preliminary analysis and the inclusion of four new variables: freeze-thaw cycles, rain precipitation, snow precipitation, and deicer application rate.

The final task of this research was to establish a procedure for using the General Condition Rating (GCR) analyses within the Bridge Management (BrM) software. The overall objectives accomplished in this task included: 1) quantifying the influence of selected variables for predicting National Bridge Inventory (NBI) deck ratings, 2) using the results as input variables for a GCR analyses, and 3) exploring alternatives to integrate the results within the larger BrM optimization framework.

What We Found

Several significant factors influencing the deterioration of bridges were identified from published research. Some of the research focused on statistical methods and analyses to evaluate and identify deterioration factors, while other researchers focused on historical condition ratings using NBI data.

The studies summarized in this review considered the general deterioration of bridge components in addition to specific deterioration of steel coatings, concrete bridge decks, concrete bridges, and the deterioration of superstructure members. The analytical tools used by researchers included data-driven approaches, machine learning frameworks, data mining techniques, and statistical analyses. A summary of the factors considered or identified by at least two of the researchers included in this literature review are shown in Figure 1.

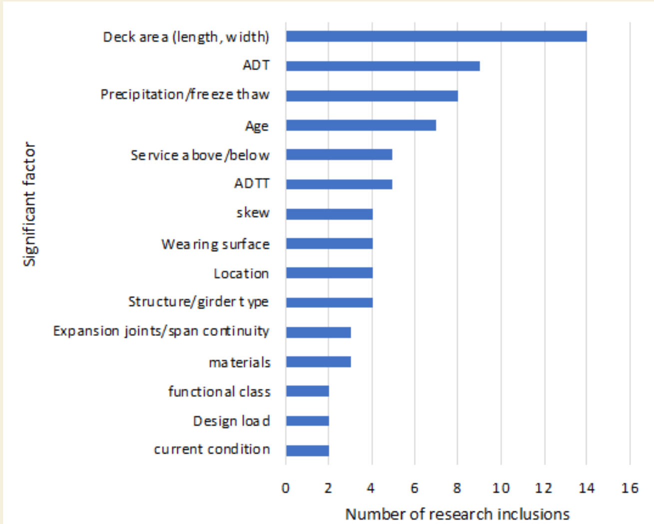

Figure 1: Significant factors considered by researchers.

The refined significant factor data analysis that included the additional variables (e.g., snow, rain, freeze-thaw, and deicer) and removed non-significant variables from the preliminary analysis did not meaningfully change the results of the final analysis nor did it change the significance of the top three previously identified variables.

The significance ranking of the variables from both regression models in the final analysis can be seen in Table 1. Despite the revision to the bridge dataset, groups, and variables considered in the refined analysis, the same top three significant variables were identified as those from the preliminary analysis: district/county, age of the bridge, and surface type.

Table 1: Significant variable ranking for generalized linear and random forest models.

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

The procedure established using BrM's general condition rating (GCR) analysis estimated the number of bridges that are in good, fair, and poor condition over selected time periods. Zero-cost optimizations were completed using two different deterioration profiles.

The WTI profile used the average 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 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.

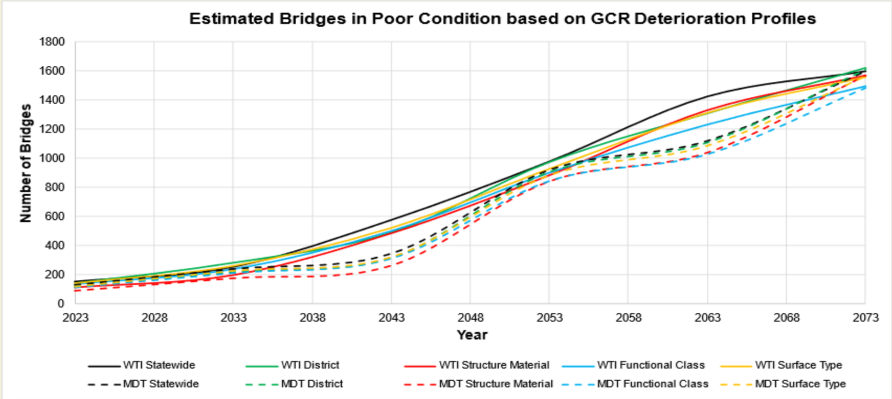

Figure 2: Estimated number of bridges in poor condition based on WTI and MDT deterioration profiles using a no-cost optimization.

What The Researchers Recommend

Future research is needed to continue modeling within BrM to identify analytical tools that use the significant bridge groups and variables to help MDT bridge engineers make reliable and efficient maintenance decisions. The researchers recommend implementing a 3rd phase of research when MDT bridge engineering staff become available, to collaboratively identify bridge repair, maintenance, and construction cost and timing data. When these scenarios are established, continued BrM modeling and implementation will complement the existing research knowledge base (deterioration curves, significant factors) to complete a well-documented basis for efficient and economical resource allocation to reduce deterioration and increase the service life of Montana's transportation infrastructure.

More Info:

The research is documented in Report FHWA/MT-24-005/10336-933

Principal Investigator:

Damon Fick, damon.fick@montana.edu, 406.404.4454

MDT Technical Contact:

Andy Cullison, acullison@mt.gov, 406.444.9221

MDT Research Project Manager:

Vaneza Callejas, vcallejas@mt.gov, 406.444.6338

To obtain copies of the final report, contact MDT Research Programs, 2701 Prospect Avenue, PO Box 201001, Helena MT 59620-1001, mdtresearch@mt.gov, 406.444.6338.