Research Square

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Statistical Analysis and Predictive Modeling for Bridge Deterioration in Pennsylvania

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Abstract

With over 30,000 bridges, Pennsylvania ranks third in the number of bridges and sixth in the nation for bridges in poor condition, according to a 2023 analysis by the Transportation Advisory Committee (TRIP) [1]. The Pennsylvania Department of Transportation (PennDOT) handles supporting these structures. Given the essential role bridges play in supporting commercial, personal, and public transportation, the Pennsylvania Department of Transportation (PennDOT) handles supporting these structures. This involves activities such as painting, superstructure replacement, substructure repair, rehabilitation, bridge replacement, and scour protection.

PennDOT faces several factors, including the age of bridges, span length, material type, average daily traffic (ADT), and environmental factors. These factors contribute to the deterioration of bridge conditions and potential failure if no action is taken in the long term.

This paper will provide a detailed statistical analysis of bridge deterioration across Pennsylvania, examining the factors and also exploring statistical methods, including multiple regression and survival analysis, to assess bridge conditions and predict hazard and time of bridge failure. The paper aims to offer solutions for rehabilitating and improving the condition of Pennsylvania's bridges.

1. Introduction

Bridges are essential civil engineering structures designed to span obstacles without obstructing the features beneath them. To qualify as a bridge, the span must measure at least eight feet. Each bridge is evaluated by its key components (e.g., deck, superstructure, and substructure) and assigned a condition code. Table 1 outlines the Federal Highway Administration (FHWA) codes (zero to nine and N) adopted by PennDOT to classify structural health. For this study, ratings of seven to nine indicate *Good* condition, five to six represent *Fair*, and less than or equal to four denote *Poor*, consistent with PennDOT's Good/Fair/Poor system used to guide load rating, posting, maintenance, rehabilitation, or closure decisions. These standardized codes provide a common language for inspectors and engineers, forming the basis for all subsequent analysis. Inspectors collect condition data statewide, which structural engineers then use to perform load rating analyses, to compare findings with historical performance, and determine necessary actions to maintain safety and serviceability.

Table 1

Bridge Condition Coding[2]

Codes	Condition	Description
0	Failed	Bridge collapsed
1	Imminent Failure	The bridge is closed due to severe deterioration of critical structural components, including the deck, superstructure, and substructure.
2	Critical	The bridge must be closed due to significant structural concerns, advanced section loss in steel members, cracking in concrete elements, or scour holes affecting the substructure.
3	Serious	Failure of bridge elements due to advanced cracking and section loss. The bridge will be posted with weight restrictions.
4	Poor	Significant deterioration in multiple components, concrete cracking, wearing surface damage, section loss in beams, rust, exposed reinforcement, and scour near substructure elements.
5	Fair	Major components exhibit moderate deterioration, noticeable section loss and cracking, but remain functional.
6	Satisfactory	Minor deterioration is observed in some elements, with no immediate impact on structural performance.
7	Good	Only slight changes are present, with negligible effect on the bridge's serviceability.
8	Very Good	Inspection reveals no deficiencies; all components are in sound condition.
9	Excellent	Bridge is newly constructed or recently rehabilitated and meets current design standards.
N	NA	Not Applicable

Studies are done on bridge condition ratings and deterioration to investigate the performance of structural behavior during the service life of bridges. Environmental factors and challenges play a key role in substructure rating as debris jammed in the waterway and bedrock material. "The study of scour formed by the influence of Debris Jam Formed by Trees on Bridge Pier Scour has focused on how large trees (debris) were changing the stream shape and scour depth. A large tree and a camera are placed in the stream to record the changes in streambed material over time" [3]. Thus, the large tree blocked part of the stream, caused a change in the shape of the cross-sectional area, and enhanced the water velocity, leading to a deep scour hole. Many researchers found that ADT, materials, and weather influence the performance of bridge condition ratings. Understanding the impact of ADT on bridges allows stakeholders to oversee traffic closely and assign money for

maintenance activities. The study, which was conducted on daily traffic on multiple bridges, focused on how ADT in different states influences the bridge condition ratings. Collected ADT data on Bridge deck materials was taken from the NBI database to see the changes in bridge rating in the long run. Applying a non-linear regression model for ADT volumes on bridge deck ratings proved that large ADT volumes crossing concrete decks improve the superstructure condition in cold states" [4]. However, warmer states with large ADT volumes deteriorate faster from good to poor conditions.

PennDOT has faced a significant funding challenge in recent years. Vehicle-related revenue is declining as cars become increasingly fuel-efficient and the adoption of electric vehicles accelerates, including within public transportation fleets. At the same time, travel patterns have shifted due to online shopping, remote work, and broader technological changes, reducing fuel consumption and, consequently, fuel tax revenue, the primary source for infrastructure funding. PennDOT anticipates that this trend will continue, making it difficult to sustain bridge maintenance and rehabilitation across the state. A 2019 Transportation Advisory Committee (TAC) study identified six major risks to the transportation system, with fuel tax dependency and federal grant uncertainty ranking highest. TAC further noted that, following the COVID-19 pandemic, adapting to evolving travel behaviors and demands on an aging infrastructure network has become even more challenging [5].

The material used for a bridge's main span is a critical factor in assessing long-term durability and overall condition. The National Concrete Bridge Council (NCBC), in its *Market Use and Condition Report for U.S. Concrete Bridges*[6], analyzed 2023 NBI data to identify which materials correspond to the lowest incidence of poor-condition ratings. Their findings show that concrete bridges consistently outperform steel and timber in terms of condition, indicating superior durability and a longer service life. This reinforces the role of material selection as a key determinant of structural longevity and maintenance needs.

The NCBC Report supports the findings of this paper regarding main span material and bridge condition. NCBC report stated. PS concrete bridges exhibit the lowest cases of poor condition among all concrete bridges, which is consistent with the results shown in this study.

2. Results

All methods were generated using Statistical Package for the Social Sciences (SPSS) based on the data collected from the PennDOT website for bridge condition ratings for both local and state bridges. SPSS is one of the most used programs for directing and assessing research data. SPSS provides tools for managing, analyzing, and visualizing data, which helps the reader to understand statistical studies.

2.1 Survival Analysis Tables

Bridge condition ratings were recorded in SPSS to run the survival analysis method. The values for bridge condition ratings: Fair, Good, and Poor were assigned numerical values one, two, and three, respectively for this study, to answer which bridges reach poor condition first based on the material which had been used in the construction of the bridge. The Kaplan-Meier test was selected for the survival analysis run, and the Breslow test was selected as the default for testing the run. For a successful run, the defined value for this method is chosen to be three, which means the study will compare the bridge material at the moment of transfer of rating to poor condition. Also, a survival plot is checked to make the result easier for the reader to understand statistical analysis visually, and it has a significant conclusion.

2.1.2 Multiple Linear Regression

The multiple linear regression analysis in SPSS was conducted through a systematic process to ensure accurate modeling and interpretation. The first step was to determine the dependent and independent variables. The dependent variable in this study is the bridge condition rating, which reflects structural health. The independent variables are ADT, Year Built, Main Span, and Bridge Length.

The second step is selecting from the linear regression statistic window check the boxes for estimate and model fit. As a result, Linear Regression Chart, ANOVA, Coefficient, and Model Summary Tables were generated inside SPSS.

Further information regarding Multiple linear regression will be discussed in this paper to explain the information generated in SPSS to the reader.

2.1.3 Method

In Pennsylvania, bridge conditions are classified into three categories: Good, Fair, and Poor. This paper employs various statistical techniques to analyze these conditions and highlight the challenges faced by engineers in maintaining and improving bridge infrastructure. As illustrated in Fig. 2, approximately 32.38% of bridges are in good condition, 55.73% are in fair condition, and 11.75% are in poor condition. These proportions are influenced by several key factors, including the average age of the bridges, construction material, ADT, span length, and environmental conditions such as weather and exposure to corrosive elements. To better understand the relationship between these factors

and bridge condition, this study applies regression analysis to identify significant predictors and survival analysis to estimate the expected lifespan of bridges under varying conditions. These methods provide insights into how structural characteristics and external influences contribute to deterioration trends, enabling engineers and policymakers to prioritize maintenance and allocate resources effectively.

Survival analysis is a statistical method used to estimate the probability of an event occurring over time, compare survival distributions across different groups, and evaluate how long items or structures remain in a certain state. In this study, the “event” refers to a significant decline in bridge condition ratings during their service life. The analysis focuses on how the type of material used for the main span influences the rate of deterioration.

The summary table for survival analysis includes three key columns:

- Material Main Span: This column lists the material categories analyzed, including Aluminum, Concrete, Masonry, Steel, Timber, and other materials. Bridges with unspecified or uncommon materials were excluded due to insufficient data.
- Total N: This column represents the total number of bridges in each material group. For instance, there are 23,343 concrete bridges in the dataset.
- N of Events: This column indicates the number of bridges within each group that have reached a poor condition rating, serving as a measure of deterioration events.

X-axis: bridge condition categories (Good, Fair, Poor, and Not applicable)

Y-axis : percentage of bridges in each category

Figure 2: Bridge Conditions Across Pennsylvania

By comparing survival curves for these material groups, the analysis reveals which materials are associated with faster declines in condition ratings, providing valuable insights for maintenance planning and material selection in future bridge projects.

Table 2 summarizes these by using the Kaplan–Meier survival setup. Bridges were grouped according to their main span material—Aluminum, Concrete, Masonry, Steel, and Timber (with “Other” displayed but excluded from analysis due to insufficient data). For each group, the table reports Total N, representing the number of bridges in that category, and N of Events, indicating the count of bridges that transitioned to a Poor condition rating. Table 2 serves two purposes: (1) it shows the sample size balance across materials (e.g., Concrete and Steel dominate the inventory), and (2) it indicates the relative burden of deterioration events within each material group before any covariate adjustment. In conjunction with the survival curves, these counts support the finding that concrete bridges tend to remain in serviceable condition longer than timber and masonry, which exhibit earlier drops in survival probability.

Table 2
Survival Analysis Summary

Material Main Span	Total N	N of Events
Aluminum	151	26
Concrete	23,343	1,781
Masonry	608	181
Other	63	5
Steel	7,808	1,680
Timber	159	38
Overall	32,132	3,711

As seen in Fig. 3, the estimated survival of bridges remaining in good condition before requiring maintenance is categorized by the main span material. The survival chart begins with all bridges in good condition and tracks their deterioration over time. The curves reveal distinct patterns for different materials: Masonry and Timber exhibit the steepest decline early in the service life, indicating they deteriorate fastest. Steel and aluminum show a moderate drop during the second stage, while concrete demonstrates the slowest rate of deterioration, maintaining good condition for the longest period. This suggests that concrete bridges generally have the greatest durability compared to other materials analyzed.

Concrete bridges in the dataset include several construction types:

- Cast-in-Place Concrete: Concrete poured and cured directly on-site during construction.
- Prestressed Precast Concrete: Concrete elements manufactured off-site with steel reinforcement stressed before placement, enhancing strength and durability.
- Precast Concrete: Concrete components formed in a factory and transported to the site for assembly.
- Concrete-Encased Steel: Steel elements encased in concrete to improve structural integrity and corrosion resistance.

These variations in concrete construction methods contribute to its superior performance in survival analysis, making it a preferred choice for long-lasting bridge structures.

Among the concrete bridge types analyzed, 9,810 bridges are Cast-in-Place Concrete, 9,314 are Prestressed Precast Concrete, 4,219 are Precast Concrete, and 764 are Concrete-Encased Steel. As shown in Fig. 4, the majority of concrete bridges fall into the first two categories: Cast-in-Place and Prestressed Precast Concrete. These methods dominate bridge construction primarily because they offer a balance of durability, structural performance, and cost efficiency. Cast-in-Place Concrete is widely used for its adaptability to complex site conditions and strong monolithic structure, which enhances long-term durability. Prestressed Precast Concrete is favored for its ability to resist tensile stresses and minimize cracking, resulting in longer service life and reduced maintenance needs. Additionally, precasting components off-site accelerates construction schedules and lowers labor costs.

The prevalence of these two types reflects their proven reliability and economic advantages, making them the preferred choice for modern bridge projects.

X-axis: year built for bridges within Pennsylvania

Y-axis: survival range (A higher survival value reflects better bridge condition).

Note

This study tests bridge performance from 1800s to 2000s

X-axis: Total number of bridges within Pennsylvania

Y-axis: Methods used during their construction.

Figure 4: Concrete Bridges Material

The Concrete Bridges Survival Analysis Chart provides an estimate of how long bridges remain in good condition before requiring maintenance, based on the type of concrete material used for the main span. As shown in Fig. 5, all bridges begin in good condition, but their performance diverges over time. The survival curves indicate that Precast Concrete bridges experience the earliest decline, suggesting they deteriorate faster compared to other concrete types. In contrast, Prestressed Precast Concrete bridges maintain good condition for a significantly longer period, reflecting the benefits of prestressing, which enhances structural strength and reduces cracking underload. This extended lifespan makes prestressed concrete a preferred choice for high-traffic or long-span bridges, where durability and reduced maintenance costs are critical.

X-axis: year built for bridges within Pennsylvania

Y-axis: survival range (A higher survival value reflects better bridge condition).

Note

This study tested concrete bridge performance from 1800s to 2000s

Figure 5: Survival Analysis of Concrete Bridges

2.2.4 Multiple Linear Regression Analysis

Multiple linear regression was used to examine how several independent variables collectively influence a dependent variable. In this study, the goal was to determine whether factors such as ADT, Year Built, Main Span Length, and Overall Bridge Length significantly impact the bridge condition rating. The hypotheses are defined as follows:

- Null Hypothesis (H_0): There is no relationship between bridge condition and the selected predictors.
- Alternative Hypothesis (H_1): There is a significant relationship between bridge condition and the predictors.

The decision rule is based on the p-value:

- If $p < 0.05$, we reject the null hypothesis and accept the alternative, indicating a statistically significant relationship between bridge condition and the predictors.
- If $p \geq 0.05$, we fail to reject the null hypothesis, meaning no significant relationship exists.

The Model Summary Table provides key metrics for evaluating the regression model. The most critical measure is R-Square (Coefficient of Determination), which indicates the proportion of variance in the dependent variable explained by the independent variables. A higher R-Square value suggests a stronger model fit. Other important metrics include:

- R (Correlation Coefficient): Ranges from − 1 to 1, showing the strength and direction of the linear relationship.
- Adjusted R-Square: Adjusts the R-Square value to account for the number of predictors, providing a more accurate measure of model fit when multiple variables are included.

Table 3 reports the overall fit statistics for the multiple linear regression model with Condition as the dependent variable and ADT Total, Year Built, Main Spans, and Bridge Length as predictors. The R and R^2 values indicate the strength of the linear association; here, $R^2 \approx 0.364$ shows that roughly 36% of the variation in bridge condition is explained by the chosen predictors. The Adjusted R^2 matches R^2 (reflecting the large sample and four predictors), and the very large F Change with $p < 0.001$ confirms that the model improves significantly over a constant-only baseline. The Std. Error of the Estimate quantifies typical residual variation in the coded condition measure. Together, these statistics establish that the model is both meaningful and statistically robust for inferential purposes. By analyzing these coefficients, one can assess how well the predictors explain variations in bridge condition and identify which factors have the greatest influence.

The ANOVA Summary Results (Analysis of Variance) table is a critical component of regression analysis because it evaluates whether the overall model is statistically significant. That is, whether the predictors collectively explain variation in the dependent variable beyond random chance.

Key elements include:

- F (ANOVA Statistic): Indicates whether the regression model provides a better fit than a model with no predictors. A higher F-value generally suggests the model is statistically significant.
- df (Degrees of Freedom): Represents the number of values that can vary independently in the analysis. In regression, this relates to the number of predictors and observations used in the model.
- Sig (Significance Level): Corresponds to the p-value. A low significance value (typically less than 0.05) indicates that the model is statistically significant, meaning there is a strong relationship between the predictors and the dependent variable.

In short, the ANOVA table helps confirm whether the regression model is meaningful and worth interpreting further. Table 4 breaks down total variability in the dependent variable into Regression and Residual components. The Sum of Squares, df, and Mean Square entries culminate in an F statistic (≈ 4593) with Sig < 0.001, demonstrating that the predictor set (ADT Total, Year Built, Main Spans, Bridge Length) collectively explains a statistically significant share of the variance in bridge condition. This table is the formal omnibus test that justifies interpreting individual coefficients and effect directions in the next table.

Table 3
Model Summary Results

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.603	.364	.364	.505	.364	4593.136	4	32127	< .001
a. Predictors: (constant), ADT Total, Year Built, Main Spans, Bridge length									
b. Dependent Variable: Condition									

Table 4
ANOVA Summary Results

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig
Regression	4689.685	4	1172.421	4593.136	< 0.001b
Residual	8200.580	32127	.225		
Total	12890.264	32131			
a. Dependent Variable: Condition					
b. Predictors: (Constant), ADT Total, Year Built, Main Spans, Bridge Length					

2.2.5 Significance Value and Coefficients

The significance value (Sig.) is the most critical metric for interpreting the ANOVA results. In Table 5, the Sig. value is less than 0.05, which means the null hypothesis is rejected. This indicates that the regression model is statistically significant and that there is a strong relationship between the dependent variable (bridge condition) and the predictors. Table 5 provides detailed information about the contribution of each predictor in the multiple regression model. Key components include:

- Unstandardized Coefficients (B): These values represent the actual regression coefficients for each predictor, showing how much the dependent variable changes with a one-unit change in the predictor.
- Standardized Coefficients (Beta): These coefficients are standardized to allow comparison of the relative importance of each predictor, regardless of their original scale.
- t-values: These values test whether each coefficient is significantly different from zero. A higher t-value indicates a stronger impact of the predictor on the dependent variable.
- p-values: These determine whether each predictor is statistically significant. A low p-value (typically < 0.05) suggests that the predictor has a meaningful relationship with the bridge condition rating.

Together, these metrics help identify which factors most strongly influence bridge condition and guide decisions for maintenance and design priorities.

Table 5 presents the unstandardized coefficients (B), their standard errors, standardized betas, t-statistics, p-values, and 95% confidence intervals for each predictor. All four predictors are statistically significant ($p < 0.05$). The negative coefficient for Year Built implies that, holding other factors constant, newer construction years are associated with lower coded condition values (i.e., better condition), consistent with the expectation that older bridges are more likely to be in poorer condition. Positive coefficients for Main Spans, Bridge Length, and ADT Total indicate that increases in span count/length and traffic are associated with higher coded condition values (i.e., movement toward poorer condition), which is sensible given greater demand and structural exposure. The standardized betas allow comparing relative influence after unit scaling, and the confidence intervals corroborate the precision of these estimates.

Table 5
Coefficients Summary Analysis

Coefficients							
Model	Unstandardized Coefficient (B)	Unstandardized Coefficient (Std. Error)	Standardized Coefficients (Beta)	t	Sig.	95.0% Confidence Interval for B Lower Bond	95.0% Confidence Interval for B Higher Bond
Constant	23.318	.167		139.705	< .001	22.991	23.645
Year Built	-0.11	.000	– .603	-135.110	< .001	– .012	– .011
Main Spans	.006	.001	.026	4.216	< .001	.003	.008
Bridge Length	5.022E-5	.000	.017	2..732	.006	.000	.000
ADT Total	4.947E-7	.000	.011	2.403	.016	.000	.000
a. Dependent Variable: Condition							

3. Discussion and Results

Survival analysis was applied in this research to test the hypothesis that bridge condition ratings decline at different rates over time depending on the material used for the main structure. Figure 3 illustrates these results: Masonry and Timber bridges exhibit the fastest deterioration in the early stages, while Concrete and Aluminum bridges maintain good condition for a longer period.

PennDOT primarily constructs reinforced concrete bridges, which combine concrete (a mixture of cement, aggregate, and water) with steel reinforcement. This combination significantly enhances durability for several reasons:

- Strength in Compression and Tension: Reinforced concrete benefits from concrete's high compressive strength and steel's tensile strength, allowing it to carry heavy loads without cracking or losing structural integrity. This makes it more durable than Masonry, Aluminum, Timber, or plain Steel bridges, as confirmed by the survival analysis.
- High Compressive Strength: Reinforced concrete can achieve compressive strengths up to 10,000 psi, according to industry standards, enabling it to withstand substantial live loads before failure.

The survival results also show that Timber bridges last longer than Masonry bridges, primarily due to load design. Timber bridges in Pennsylvania are typically designed for light traffic only, prohibiting heavy vehicles, whereas Masonry bridges often carry both light and heavy loads. This difference in load capacity explains why Masonry bridges deteriorate faster under stress[7].

To further understand factors influencing bridge condition, a Multiple Regression Analysis was conducted using SPSS. The research question was: *"Do ADT, Year Built, Main Span, and Bridge Length impact the bridge condition rating?"* The hypotheses were:

- Null Hypothesis (H_0): No relationship exists between bridge condition and the predictors.
- Alternative Hypothesis (H_1): A significant relationship exists between bridge condition and the predictors.

The regression results rejected the null hypothesis because the significance value ($p < 0.005$) indicated a strong relationship between bridge condition and the predictors. Specifically:

- Higher ADT, longer bridge length, and greater main span are associated with lower condition ratings, reflecting increased stress and wear.
- Older bridges tend to be in poorer condition, as shown by the negative correlation between Year Built and condition rating.

Figure 5 visualizes these relationships, confirming that traffic volume, structural dimensions, and age are critical factors in predicting deterioration.

4. Conclusions, Implications, and Future Research

This paper highlights the significant challenges in maintaining Pennsylvania's bridge infrastructure, where a large proportion of bridges are currently rated as fair or poor. PennDOT faces multiple obstacles, including funding constraints, aging structures, span length, material type, ADT, and environmental factors, all of which accelerate deterioration and increase the risk of structural failure if not addressed proactively.

One of the most pressing issues is declining transportation revenue. PennDOT reports that fuel tax revenue, a primary source of funding for infrastructure, has been steadily decreasing due to several trends: the rise of fuel-efficient and electric vehicles, shifts in travel behavior driven by teleworking and e-commerce, and broader technological changes. These factors reduce fuel consumption, making it increasingly difficult to sustain traditional funding models for bridge maintenance and rehabilitation.

To address these challenges, this study employed statistical methods including linear regression, multiple regression, and survival analysis to evaluate bridge conditions and predict deterioration patterns over time. These models identified key predictors such as traffic volume, bridge age, span length, and material type, providing actionable insights for prioritizing maintenance and allocating resources effectively. While these methods offer robust tools for planning, natural hazards such as sinkholes and scour holes remain difficult to predict and mitigate due to their complexity and the specialized engineering techniques required.

The findings of this research are critical for engineering decision-making and policy development. They support more informed scheduling and planning of maintenance activities, enabling PennDOT to optimize limited resources. Furthermore, the results underscore the need for innovative funding strategies that account for the growing prevalence of fuel-efficient, hybrid, and electric vehicles. Engaging stakeholders and educating policymakers about these challenges will be essential to secure sustainable funding and foster collaboration for long-term infrastructure resilience.

Sinkholes and scour holes represent environmental challenges that are difficult to predict using traditional statistical methods. They occur when subsurface layers collapse over time, often due to chemical reactions between rainwater and soluble rock formations such as limestone. Pennsylvania is particularly susceptible to sinkholes because of its underlying geology. These formations often begin as small depressions with little immediate impact on bridge components but can expand significantly, ultimately compromising structural integrity and lowering bridge condition ratings[8].

Similarly, scour holes develop when fast-moving water erodes streambed material around bridge foundations, exposing and undermining structural supports. Contributing factors include fallen trees, debris accumulation, and bridge alignment, which can accelerate erosion. Scour holes pose a severe risk because they can form beneath foundations, creating hidden vulnerabilities that may lead to catastrophic failure if undetected [9].

To address these risks, specialized tools are essential. Ground Penetrating Radar (GPR) is effective for detecting subsurface anomalies by measuring variations in material depth beneath bridge structures, helping identify early signs of sinkhole formation. Fathometers, on the other hand, measure streambed elevation and depth changes [9,10], enabling engineers to monitor scour development and take preventive action. These technologies provide critical data for proactive maintenance strategies, complementing statistical models that cannot fully capture these unpredictable environmental hazards.

Abbreviations

ADT
Average Daily Traffic
FHWA
Federal Highway Administration
NCBC
National Concrete Bridge Council
NBI
National Bridge Inventory
PennDOT
Pennsylvania Department of Transportation
SPSS
Statistical Package for the Social Sciences
TAC
Transportation Advisory Committee

Declarations

Author Contribution

M.S. = data, statistical analysis, wrote manuscriptS.M.V. = advisor, guided research, checked data and analysis, wrote manuscript

Data Availability

The dataset is publicly available through PennDOT and is regularly updated to reflect any maintenance activities, inspections, or structural changes: https://data-pennshare.opendata.arcgis.com/datasets/PennShare::pennsylvania-bridges/about

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Figures

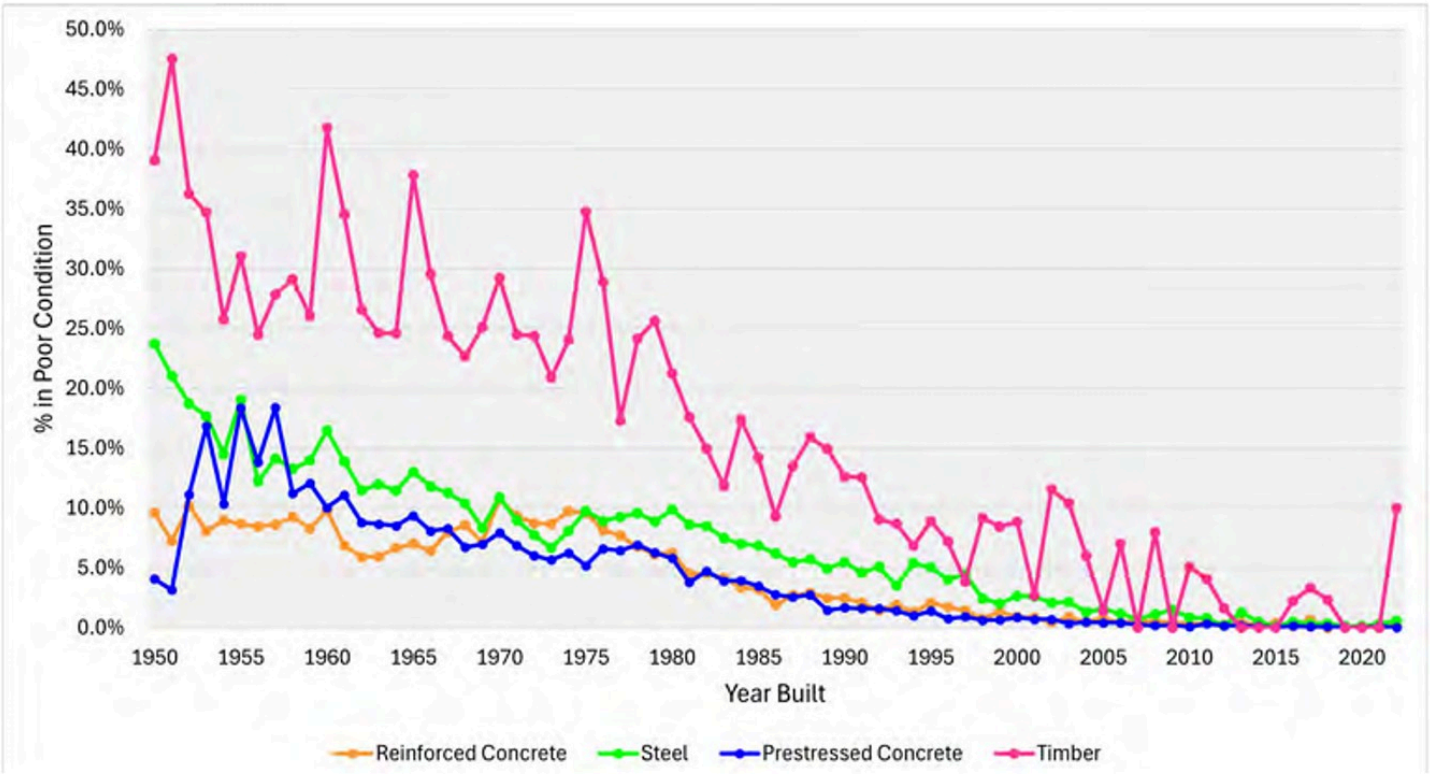
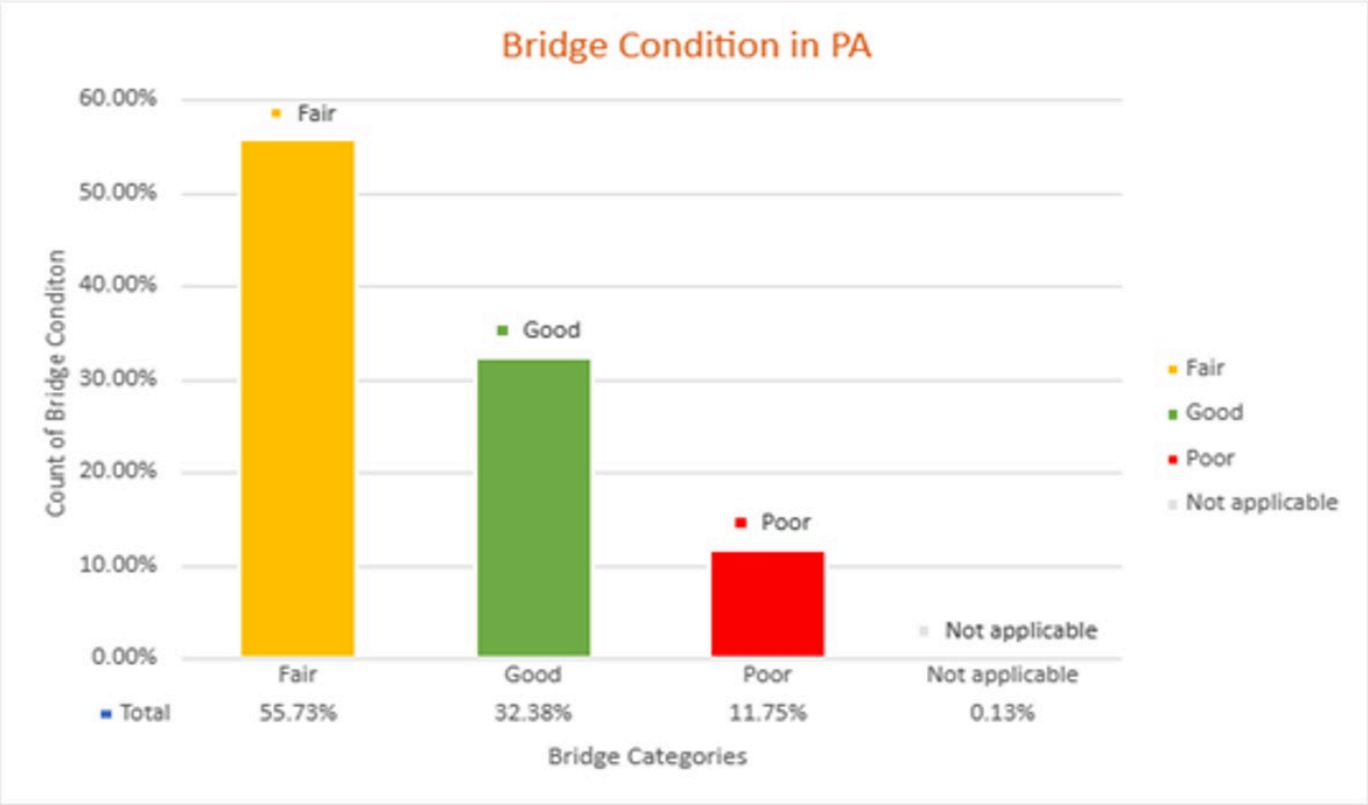


Figure 1

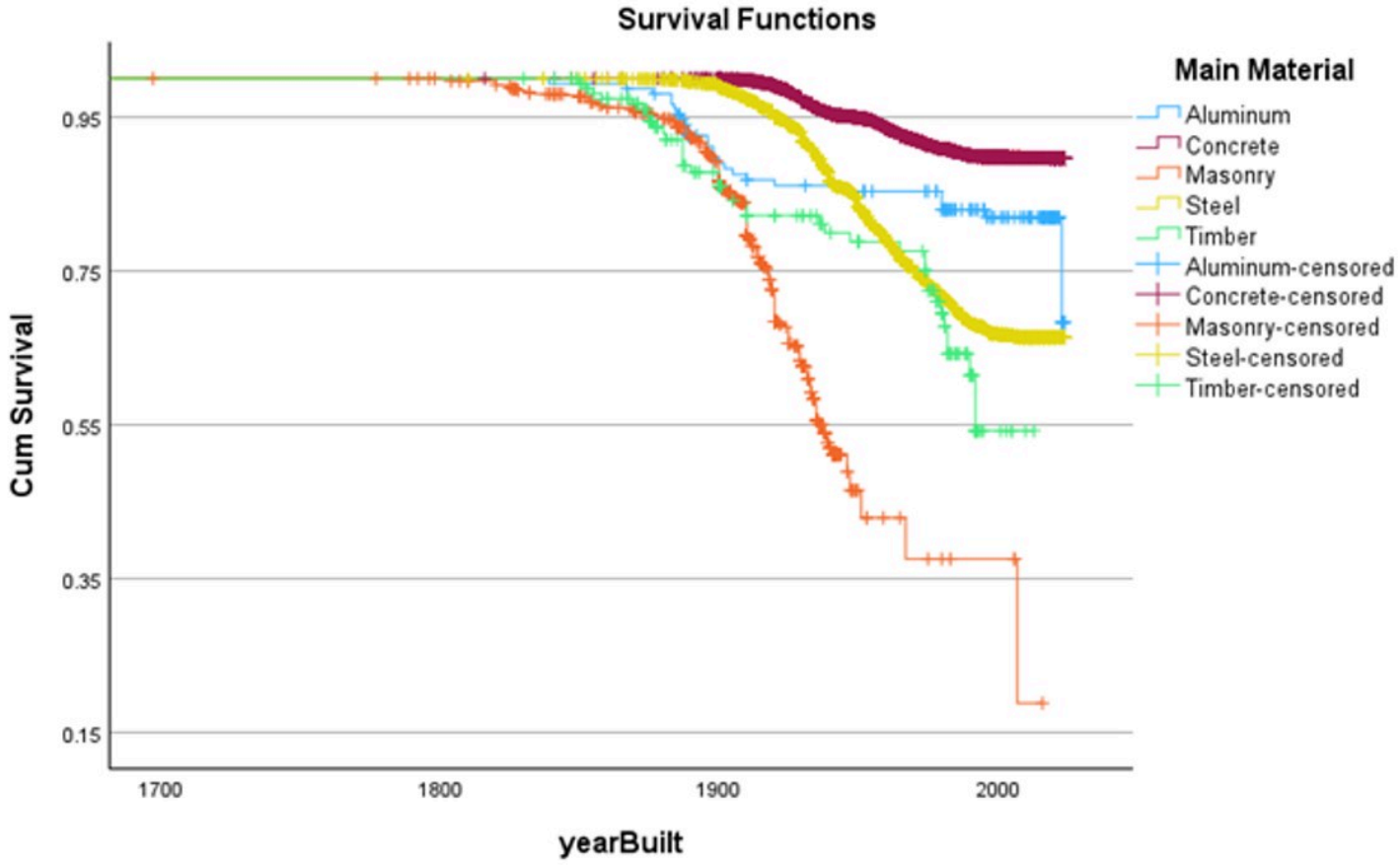
Lowest Rates of Poor Condition Bridges[6]



X-axis: bridge condition categories (Good, Fair, Poor, and Not applicable)
Y-axis : percentage of bridges in each category

Figure 2

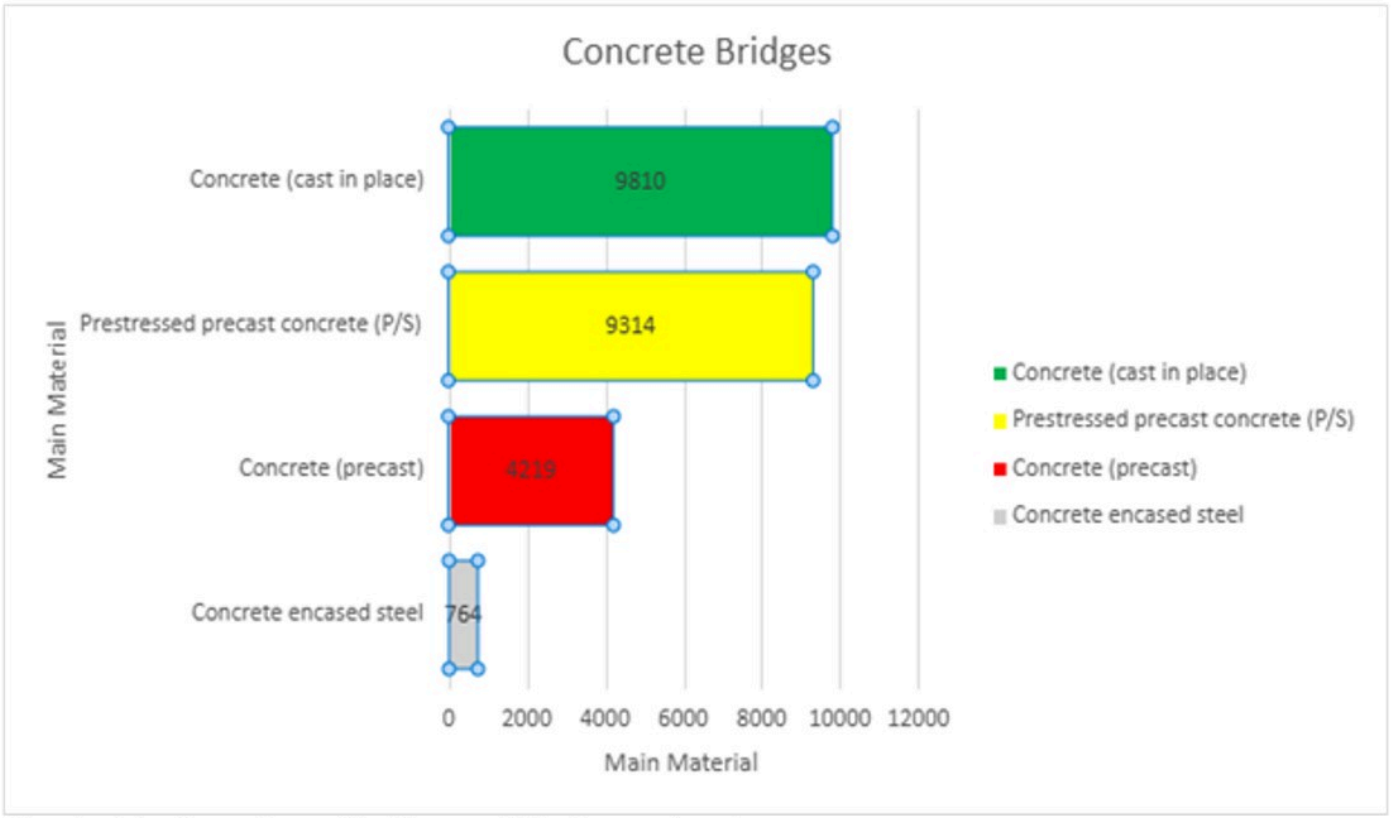
Bridge Conditions Across Pennsylvania



X-axis: year built for bridges within Pennsylvania
Y-axis: survival range (A higher survival value reflects better bridge condition).
Note: This study tests bridge performance from 1800s to 2000s

Figure 3

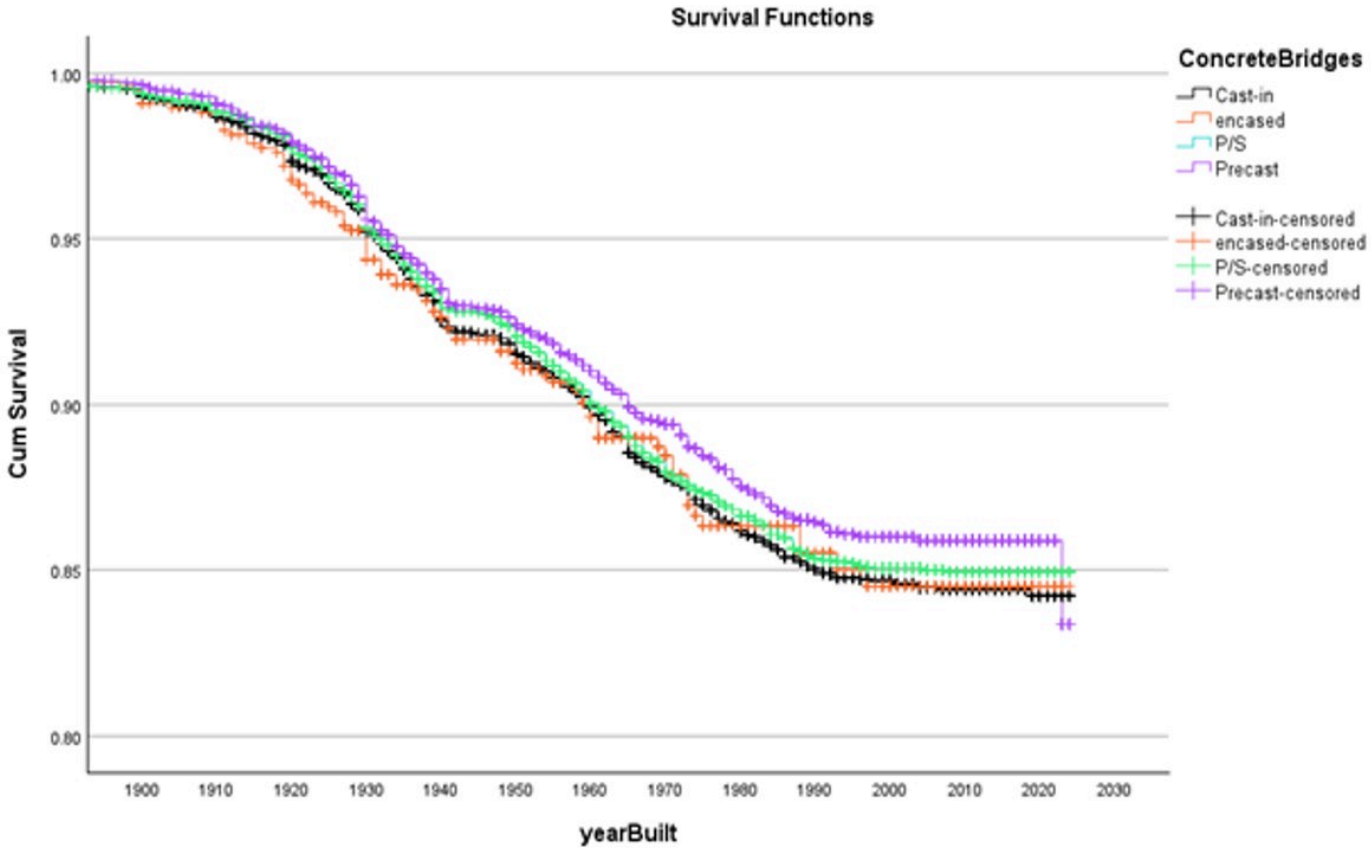
Survival Analysis of Main Bridge Materials



X-axis: Total number of bridges within Pennsylvania
Y-axis: Methods used during their construction.

Figure 4

Concrete Bridges Material



X-axis: year built for bridges within Pennsylvania
Y-axis: survival range (A higher survival value reflects better bridge condition).
Note: This study tested concrete bridge performance from 1800s to 2000s

Figure 5

Survival Analysis of Concrete Bridges