Developing a Nationwide Bridge Geodatabase to Investigate Flood Related Bridge Collapses

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Abstract

➢ **An analysis was to be done to build a database and perform important exploratory analysis on bridges vulnerable to flood events within the Continental United States (U.S.). This work has important implications for the economy, environment and human safety. In situ observations and measurements pertaining to both bridges and streamflow throughout the U.S. were obtained. Based on these data, an analysis was done to determine annual flood peaks for states containing bridges that have failed. Thirty-five cases of failed bridges were used in the analysis. The likelihood of floods in each state pertaining to these bridges were collected to help determine how likely it was that the flood was correlated with the failure of the bridges. More dimensions to this analysis were added by providing the age of the bridges, average daily traffic, design load, structural types, and material components. Plots were made to demonstrate bridges that are most likely to be affected by floods and other factors by the structural make up. Spatial plots, flood return period plots, and structural component graphs were developed from the sample of thirty-five failed bridges to provide visual interpretation of the data. This research can be further developed by applying these results to build predictive models to help manage bridges prone to damage due to floods in the future. These models can be used to sustain and protect the U.S. economy, environment, and human safety.**

Research Goals

- To analyze bridge failures do to floods and determine the likelihood that the flood event caused the failure.
- Determine areas that are prone to high level floods.
- Explore other possible reasons for bridge failure.

Statistical Computations

$$Bridge\ Damage = f(W, T, M, t)$$

where W = weather or climate related events (e.g. flooding), T = traffic volume and accidents,

M = material of structure, t = age of structure

$$Upper\ Quartile = Value\ of\ x\ that\ satisfies\ P(X \le x) = 0.75\ \ Median = Value\ of\ x\ that\ satisfies\ P(X \le x) = 0.50\ \ Lower\ Quartile = Value\ of\ x\ that\ satisfies\ P(X \le x) = 0.25$$

K-Means Clustering Formula

Given a set of d-dimensional observed vectors ($\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_n$), k-means clustering partitions the observations into k < n sets $\mathbf{S} = \{S_1, S_2, \ldots, S_k\}$ in order to find

$$\underset{S}{argmin} \sum_{i=1}^{k} \sum_{x \in S_i} \|x - \mu_i\|^2 = \underset{S}{argmin} \sum_{i=1}^{k} |S_i| Var(S_i)$$

Results

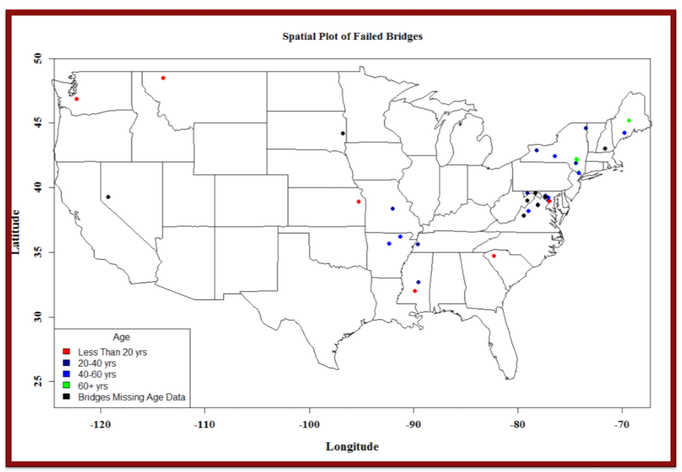

Figure 1: Spatial plot of thirty-five failed bridges in the US. In this plot spatial clusters can be observed.

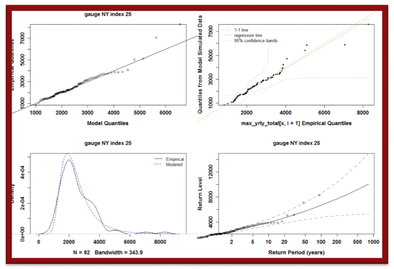

Figure 2:Annual max peak distribution for streamflow gauge in NY.

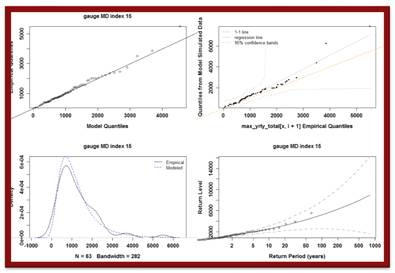

Figure 3:Annual max peak distribution for streamflow gauge in NY.

Table 1: Annual max flow for the year of bridge failure.

State	Flood Peak	Probability
ME	31700	0.0013
ME	3940	0.0176
NH	1540	0.0515
NY	1370	0.0071
NY	6630	0.0038
NY	2090	0.1334
NY	8200	0.0239
NY	1540	0.0039
MD	2580	0.0259
MD	2000	0.04
WV	8600	0.5387
WV	8010	0.5792
VA	2450	0.1114
MD	74000	6.00E-04
MD	5500	0.008
MD	5000	0.0043
MD	3500	0.0307
VA	1940	0.1419
VA	1780	0.0338
VA	4950	0.7132
SC	5400	0.0085
MS	14500	0.5055
MS	8610	0.4351
NY	680	0.3166
NY	1620	0.8164
NY	4850	0.0065
SD	9650	0.1059
KS	22600	0.0221
MO	3740	0.8724
TN	28700	0.2718
AR	34300	0.2417
AR	24100	0.1888
NV	13400	0.0174
WA	1670	0.7333
MT	92700	2.00E-04

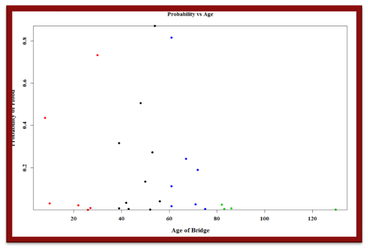

Figure 4: Plot of probability of flood occurrence vs. how old bridge was at failure.

Bridge Features

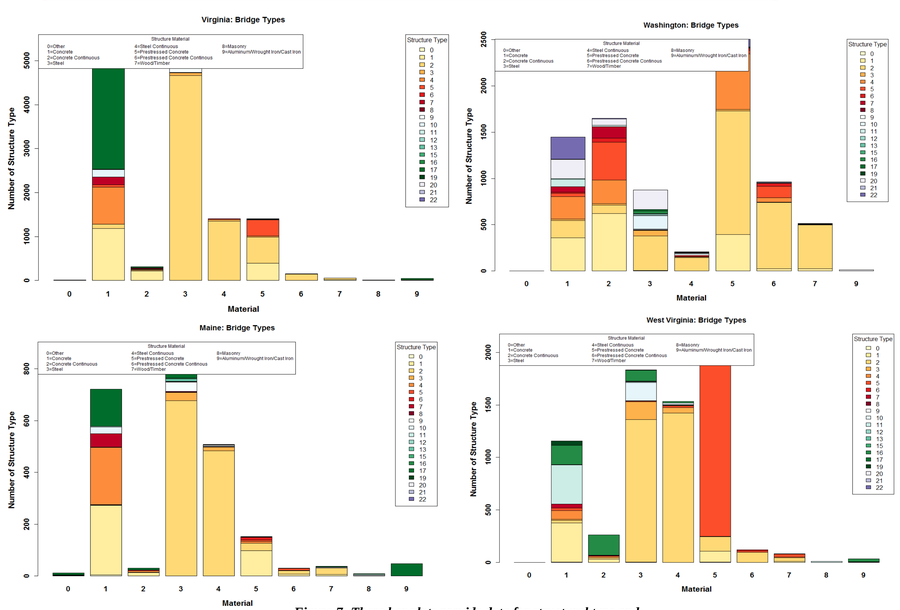

Figure 7: These bar plots provide data for structural type and material for all bridges over water in Virginia, Washington, Maine, and West Virginia, respectively.

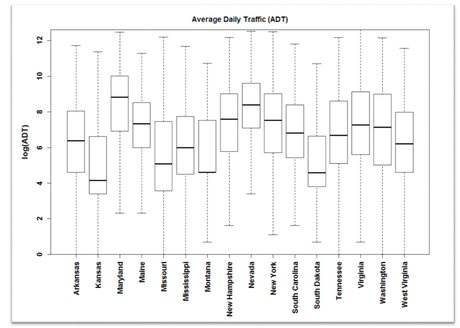

Figure 8: This box plot provides average daily traffic data from the sixteen states containing the 35 failed bridges to consider the average daily traffic for the thirty-five failed bridges.

Table 2: Average daily traffic of failed bridge.

State	ADT	Log(ADT)
ME	30	1.477121255
ME	1360	3.133538908
NH	6500	3.812913357
NY	4914	3.691435152
NY	732	2.864511081
NY	18	1.255272505
NY	3993	3.60129931
NY	6110	3.786041121
MD	500	2.698970004
MD	20	1.301029996
WV	5700	3.755874856
WV	970	2.986771734
VA	835	2.921686475
MD	200	2.301029996
MD	4392	3.642662331
MD	15000	4.176091259
MD	7712	3.887167021
VA	298	2.474216264
VA	621	2.7930916
VA	40	1.602059991
SC	1682	3.225825991
MS	1000	3
MS	20	1.301029996
NY	617	2.790285164
NY	103	2.012837225
NY	1015	3.006466042
SD	5760	3.760422483
KS	3571	3.55278985
MO	15	1.176091259
TN	10	1
AR	1460	3.164352856
AR	30	1.477121255
NV	6796	3.83225337
WA	20060	4.302330929

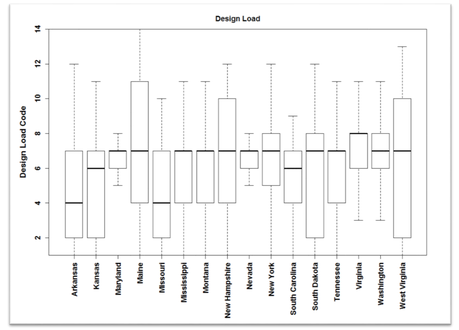

Figure 9: This box plot provides design load data from the sixteen states containing the 35 failed bridges to consider the design load for the thirty-five failed bridges

Table 3: Design load of failed bridges.

State	Design Load
ME	3
ME	6
NH	5
NY	1
NY	7
NY	1
NY	1
NY	4
MD	6
MD	4
WV	6
WV	1
VA	5
MD	1
MD	5
MD	4
MD	1
VA	4
VA	7
VA	1
SC	2
MS	4
MS	1
NY	4
NY	1
NY	6
SD	5
KS	4
MO	4
TN	4
AR	2
AR	4
NV	4
WA	4
MT	4

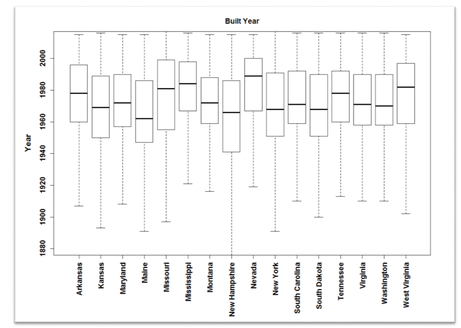

Figure 10: This box plot provides built year data from the sixteen states containing the 35 failed bridges to consider the year built for the thirty-five failed bridges

Table 4: Built year of failed bridges.

State	Year Built
ME	1857
ME	1926
NH	NA
NY	1925
NY	1928
NY	1955
NY	1929
NY	1936
MD	1900
MD	1940
WV	NA
WV	NA
VA	1935
MD	1920
MD	NA
MD	1929
MD	1962
VA	NA
VA	1953
VA	NA
SC	1968
MS	1941
MS	1991
NY	1950
NY	1920
NY	1959
SD	NA
KS	1929
MO	1950
TN	1936
AR	1915
AR	1910
NV	NA
WA	1916
MT	1938

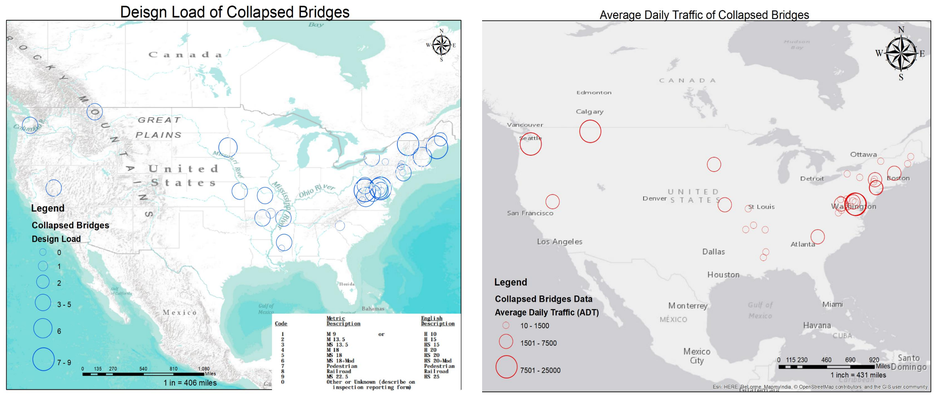

Figure 5: Map of failed bridges with the design load and average daily traffic density, respectively.

Summary

➢ For the thirty-five failed bridges most bridges were found to have experienced extreme flood conditions on the year of failure. An additional flood component that may be explored is flood duration. The age of the bridges varied from 20-80 years of age with a few outliers being younger and older (as young as 8 years and old as 120 years). From the exploratory analysis, plots and tables were obtained to consider the other components that may have contributed to the failure of the bridges. The average daily traffic, design load, built year, structural type, and material were considered and can now be used for further analysis to provide more information regarding the vulnerability of bridge failure in the future.

Acknowledgements

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