Clustering of Bridges for Vulnerability Assessment from Combined Debris and Scour

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Introduction

- **Bridge failure** during hurricanes and other severe weather events impact emergency vehicles, local residents, and commercial shipping companies.
- **Scour** is a leading cause of bridge failure during floods and can be significantly affected by the buildup of large woody debris (LWD) during flood conditions.
- Expounding upon previous work, models must account for LWD and other factors increasing scour and **risk** of bridge failure.
- Representative **clusters** of bridges are used to create a tailored approach to reliability of bridges in Vermont.
- A physics-based **fragility model** for bridges during extreme events can help inform when a bridge should be closed.

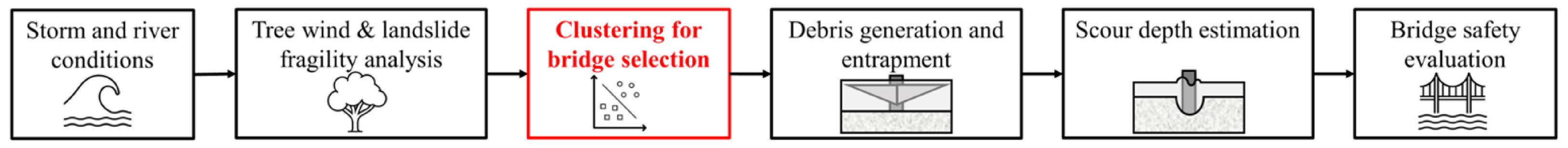
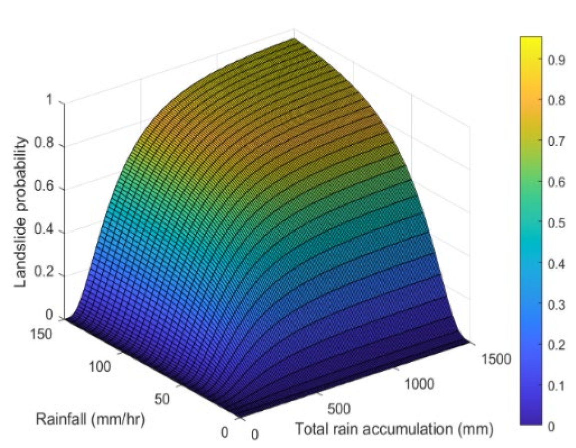


Figure 1. Flowchart of project goals highlighting current clustering focus

Fragility Models

- Past research focused on the fragility of nearby trees and embankments for landslides which can increase the presence of LWD.
- Future research will measure the **fragility of bridges against severe weather** events to determine the risk of keeping the bridge open.
- One such measure will account for scour which reaches beneath the foundations of the pier and causes a bridge to fail.



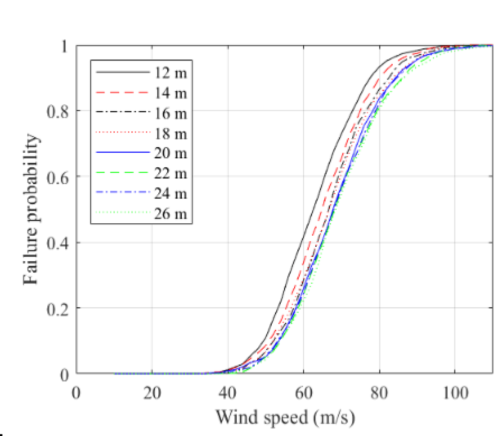


Figure 2. (Top) Fragility for landslide
Figure 3. (Bottom) Fragility for maple tree windthrow

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Clustering

- Clustering is used to group the bridges based on **key features.**
- From all Vermont bridges, to consider those at highest scour risk, only multi-span bridges crossing water were considered.
- The features used for clustering, representing key structural parameters for modeling the bridge, are **structure material, type, total length and average span length.**
- The typical *k*-means clustering was not suitable as it cannot handle both numerical and categorical features.
- Therefore, ***k*-prototypes** algorithm was used. This algorithm takes the mean for numerical variables and mode for the categorical variables
- Three different methods, Elbow method, Average Silhouette Criterion, and Bayesian Information Criterion (BIC), were compared to find the optimal number of clusters. The **BIC** results were used because of its robustness and ease of interpretation.

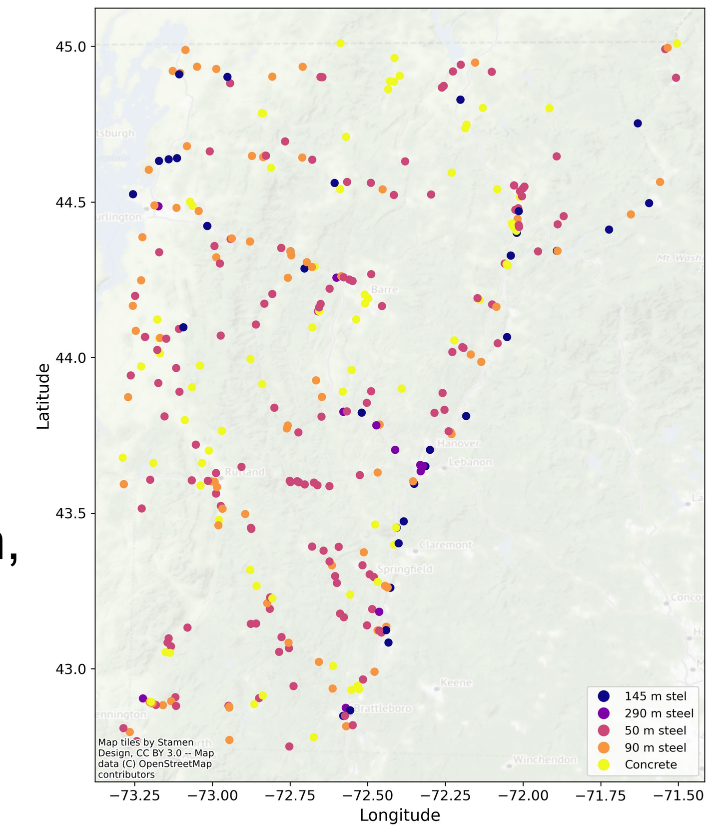
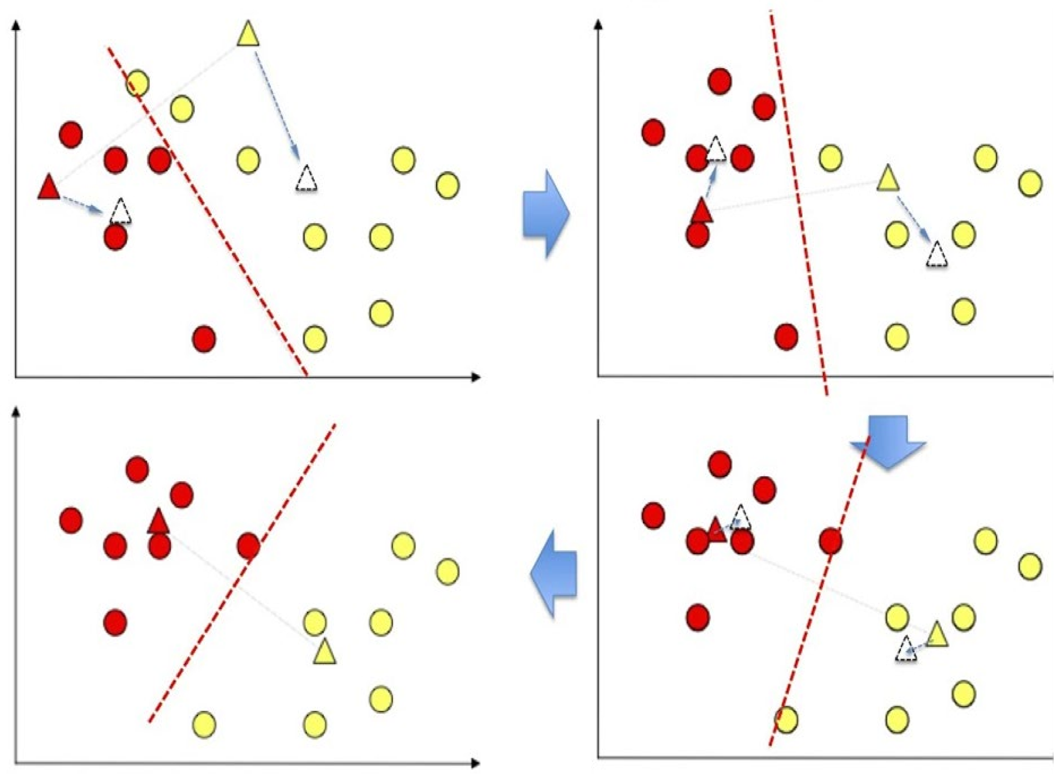


Figure 4. Map of different bridge types



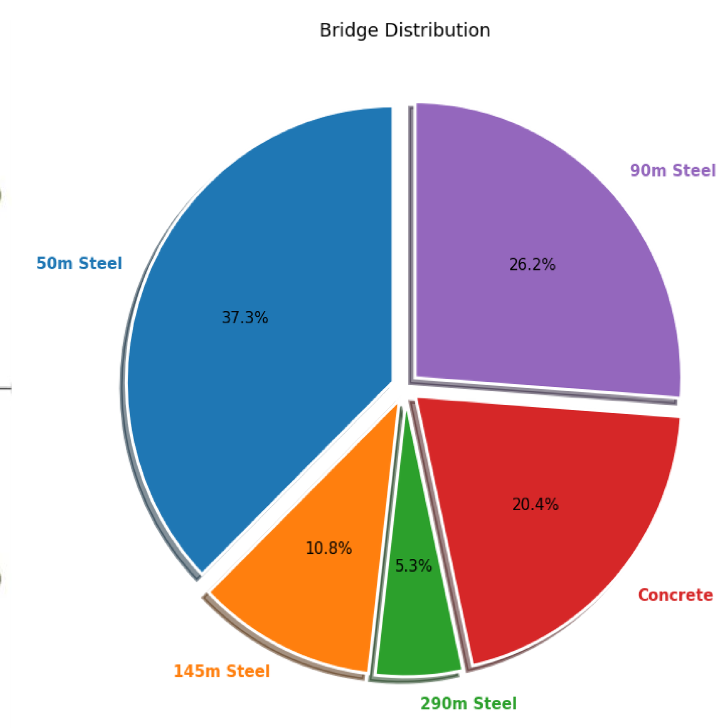


Figure 5. (Left) shows the steps involved in forming clusters. The red and yellow triangle in top left shows the initial centroid chosen by the algorithm. Then the algorithm tries to move to a new centroid represented by the white triangle. This step of choosing new centroids are repeated until a centroid is found which is able to better represent the observations.
Figure 6. (Right) Shows the percentage of data available in each cluster.

Bridge ID	Material	Structure type	Mean span length (m)	Total span length (m)
200028010203112	Concrete	Culvert	8.55	17.1
100122000701221	Steel	Stringer/Multi-beam or Girder	16.47	49.4
200089048S12182	Steel	Stringer/Multi-beam or Girder	30.57	91.7
200196B00109072	Steel	Stringer/Multi-beam or Girder	50.1	150.3
200089026S14162	Steel	Stringer/Multi-beam or Girder	46.58	279.5

Table1. The Most representative bridges along with their features in each cluster

Conclusions + Future Work

- The clustering result enlightens **common characteristics and key differences** of the studied bridges in Vermont
- 5 major bridge groups were identified, differentiated primarily based on their material and span length.
- The concrete bridges are generally similar while there is a large variability in the steel bridge designs
- Based on the key features from clustering, bridge fragility models will be developed to predict risk under storm events
- The **bridge fragility model** will be used to inform decisions related to closure of the bridge to minimize loss of lives
- A tool, **user interface**, or lookup table will be developed to quickly relate information related to the bridge risk

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