A Correlation Network Model for Managing Safety and Performance Issues in Bridges and Civil Infrastructures

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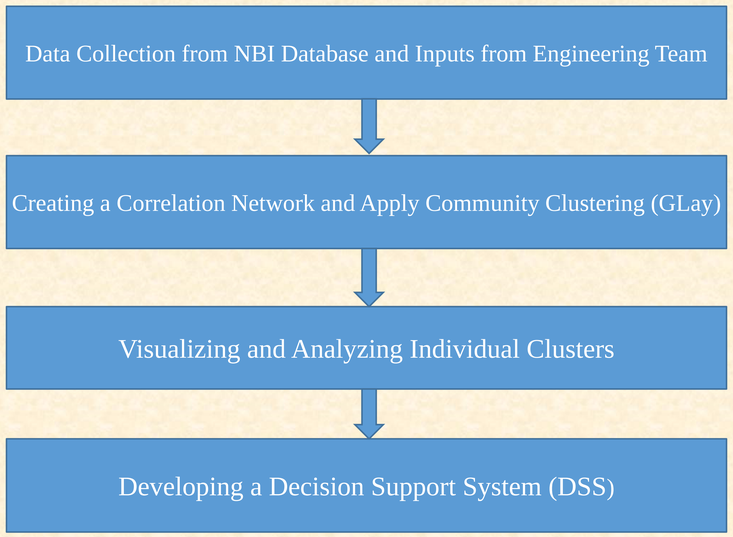
ABSTRACT

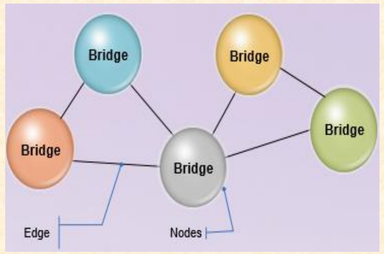
Many recent studies have shown that a large percentage of bridges in many parts of the world have low safety rating. National Bridge Inventory (NBI) database contains the information of more than 600,000 bridges, where each bridge has 116 parameters. Current safety inspections require bridge inspectors to manually inspect each bridge every few years. Manpower and budget constraints limit such approach from inspecting the bridges more frequently. Clearly, more efficient approaches need to be developed to improve the process of bridge inspection and increase the overall safety of bridges and civil infrastructures. In this study, we propose a Correlation Network Model (CNM) to analyze and visualize the big-data associated with more than 600,000 bridges of NBI database. We use Correlation Networks based on various safety parameters (deck rating in this case), then apply community clustering algorithm such as GLay to analyze a population of 8,712 Nebraska non-culvert bridges. Our results show that out of top5 clusters, two clusters have highly negative correlations with average deck ratings and one cluster have highly negative correlation with the average daily traffic. So these clusters need more attention than other cluster as these clusters are sensitive to the age and average daily traffic.

MAIN HYPOTHESIS

The main idea behind this work is to use population analysis to assess the health level of each bridge and predict potential health hazards of bridges before they happen. Our main hypothesis is that bridges with similar deck ratings are included in a common cluster in the correlation network model and have similar behavioral pattern.

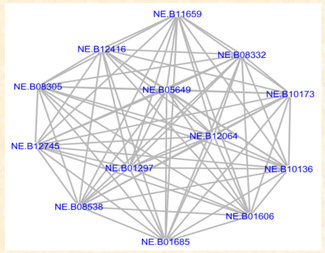
METHODOLOGY

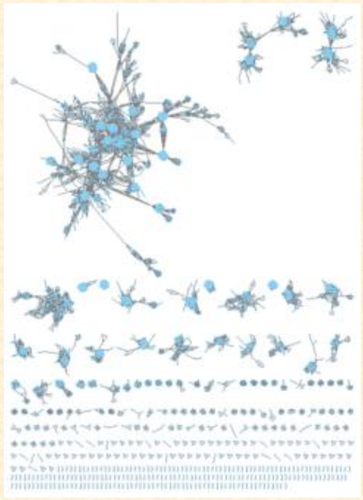




- Correlation Network Model (CNM) is a Graph Theoretic Model
- Each bridge is represented by a node
- Bridges with high correlation (ρ >= 0.96) in Deck Rating are connected by edges

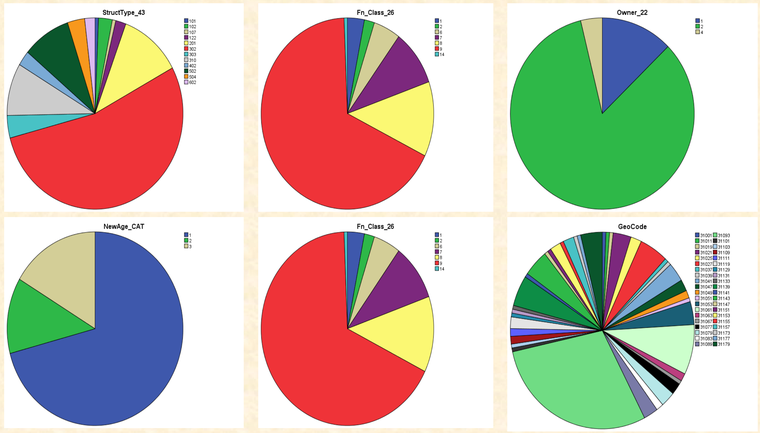
- Correlation Network of 6,401 Nebraska non-culvert bridges., with 161428 edges and 410 Connected Components
- Top-5 clusters with high density (density:1.0, which is in fact a complete graph) were selected for further analysis





RESULTS

# Cluster	#Nodes	#Edges	Avg.Deg	Diameter	Density	Avg.Clust.Coeff
CL1	158	12398	156.9	2	1.00	1.00
CL2	144	10295	142.9	2	1.00	1.00
CL3	117	6786	116.0	1	1.00	1.00
CL4	117	6786	116.0	1	1.00	1.00
CL5	115	6755	114.0	1	1.00	1.00



Highly enriched (or highly influential) parameters of cluster 1.

#Cluster (#Nodes)	Item_43	Item_26	AGE_CAT	ADT_CAT	Owner_22
CL1 (158)	302(53.8%) 201(11.4%)	9(67.1%) 8(12.7%)	1(70.9%) 3(16.5%) 2(12.7%)	1(72.2%) 2(17.7%)	2(83.5%) 1(12.6%)
CL2 (144)	302(62.5%) 201(6.9%)	9 (72.9%) 8 (11.1%)	1(72.2%) 2(15.3%) 3(12.5%)	1(75.57) 2(16.0%)	2(87.5%) 1(9.7%)
CL3 (117)	302(47.0%) 201(13.7%) 504(10.3%)	9(57.3%) 7 (27.4%)	1(78.6%) 3(15.4%)	1(70.1%) 2(24.8%)	2(88.0%) 1(5.9%)
CL4 (117)	302(51.3%) 702(11.1%)	9(70.9%) 8 (16.2%)	1(67.5%) 3(20.5%) 2(12.0%)	1(80.3%) 2(12.8%)	2(89.7%) 1(8.5%)
CL5 (115)	302(65.2%) 201(6.9%)	9(60.0%) 7(27.0%)	1(72.2%) 2(15.7%) 3(12.2%)	1(72.2%) 2(23.5%)	2(93.0%) 1(5.2%)

- **Item_43: Structure Type Main (Kind of Material (1st digit) and Type of Design (last 2 digits)** (201: Concrete continuous with slab design, 302: Steel with Stringer/multi-beam or Girder design, 402: Steel continuous with Stringer/multi-beam or Girder design, 504: Prestressed concrete with Tee beam design, and 702: Wood or Timber with Stringer/multi-beam or Girder design)
- **Item_26: Functional classification of inventory route**
- **AGE_CAT: represents different age categories. it has 3 categories** (Age 1 to 50 years: category 1, Age 51 to 100 years: category 2, and Age >100 years: category 3)
- **ADT_CAT: represents Average Daily Traffic categories** (ADT <100: category1, 100 <=ADT<1000: category2, 1000<=ADT<5000: category 3, and ADT >=5000: category 4)
- **Owner_22: Represents the maintenance responsibility** (01: State highway agency, 02: County highway agency)

CONCLUSION

- Correlation Network Model (CNM) with population analysis is appropriate to the traditional Structural Health Monitoring (SHM) methods to identifying which bridges need to be serviced first.
- In clusters 1 and 4, deck rating is highly negatively correlated with age, and in case of cluster-5, deck rating is highly negatively correlated with deck rating. Hence these clusters need more attention in terms of considering the age growth and controlling the average daily traffic . Our highly enriched parameters also show this.
- Post Hoc tests for multiple comparisons show that cluster-1's coefficient of variation (CV) for the last 25 years deck ratings is high and significantly different with all the remaining clusters. So these bridges are deteriorating fast.
- CNM provides a Decision Support System(DSS) to predict the health of the civil infrastructures so as to save many human lives.

REFERENCES

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