Time to Failure and Socioeconomic Analysis for Bridge Assessment

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CREATEs

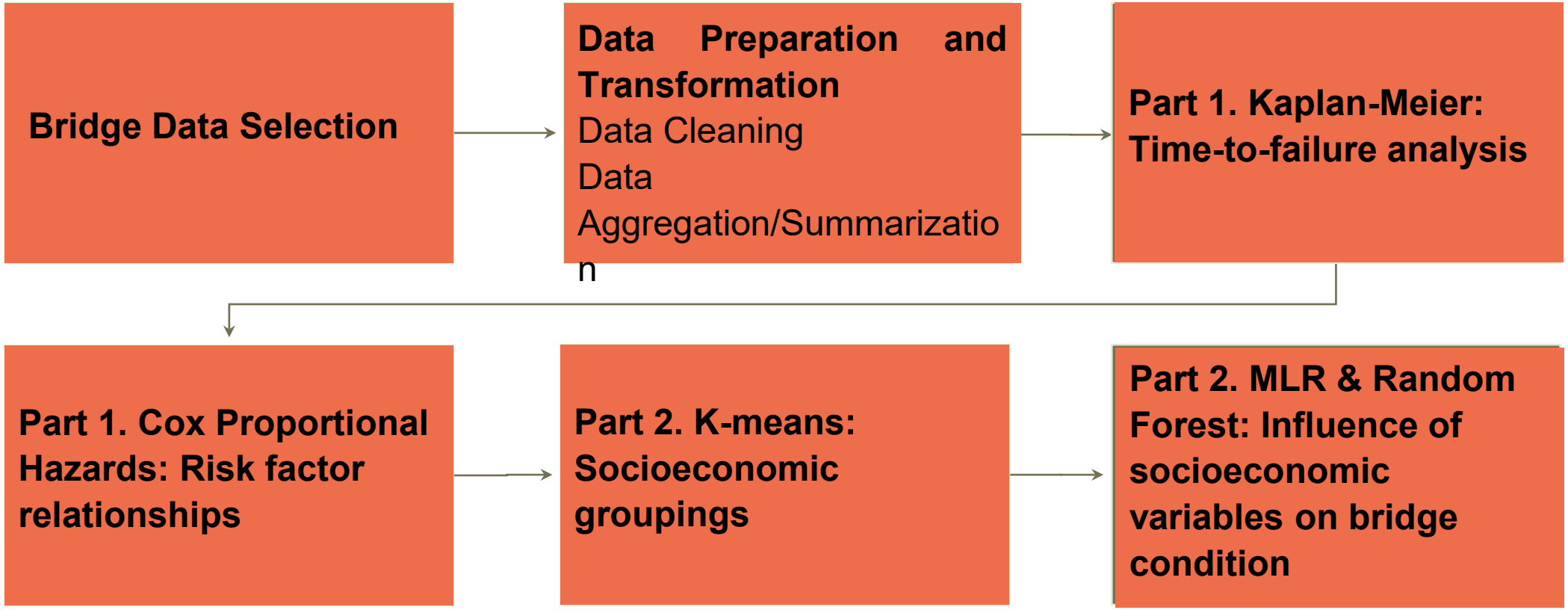
Research Purpose

- Examine how both structural and socioeconomic factors impact bridge condition
- Understand how structural and community variables affect bridge longevity
- Explore how funding decisions are influenced by more than just structural integrity

Introduction

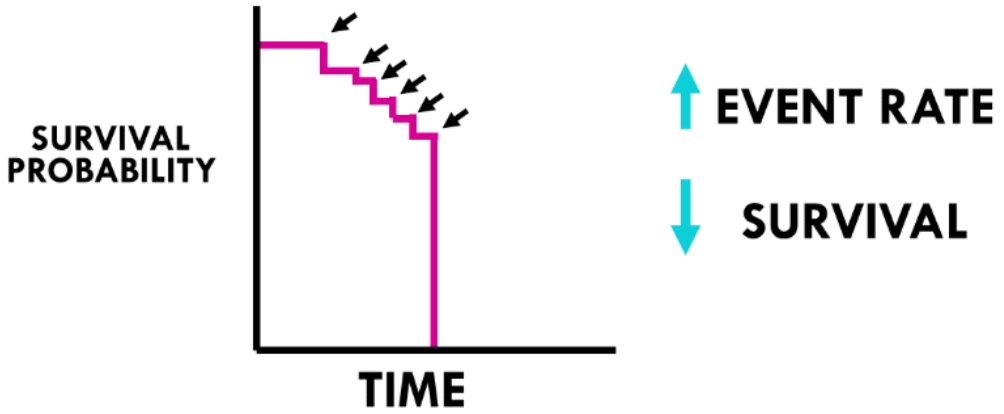
- 6,827 bridges in New Jersey analyzed
- Two-part study: structural and socioeconomic analysis
- Methods used: Kaplan-Meier, Cox PH, K-means, MLR, Random Forest
- Key factors: Part 1. Live Loads, Bridge Features, Environmental Loads/Conditions
  Part 2. AADT, Population, Business Density, Median Income

Methodology

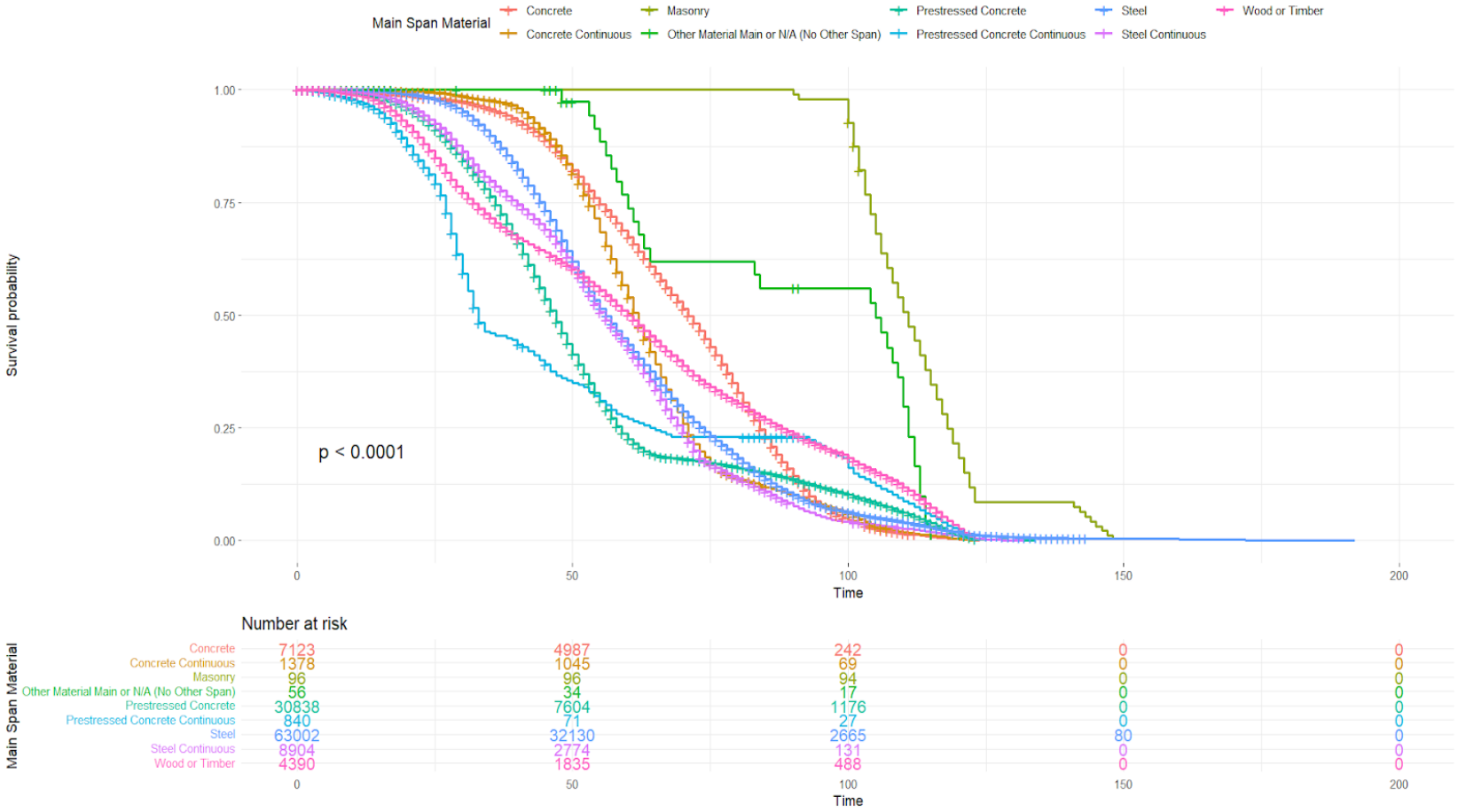


Kaplan Meier

- Non-parametric survival analysis method
- Estimates probability of survival (bridge condition) over time
- Accounts for censored data (bridges still in service)
- Used to compare survival across bridge material categories under different load scenarios.



Reliability and Failure Probability:



Main Span Materials	Number at risk				
Concrete	7123	4987	242	0	0
Concrete Continuous	1378	1045	69	0	0
Masonry	96	96	94	0	0
Other Material	56	34	17	0	0
Prestressed Concrete	30838	7604	1176	0	0
Prestressed Concrete Continuous	840	71	27	0	0
Steel	63002	32130	2665	80	0
Steel Continuous	8904	2774	131	0	0
Wood/Timber	4390	1835	488	0	0
Years of events	0	50	100	150	200

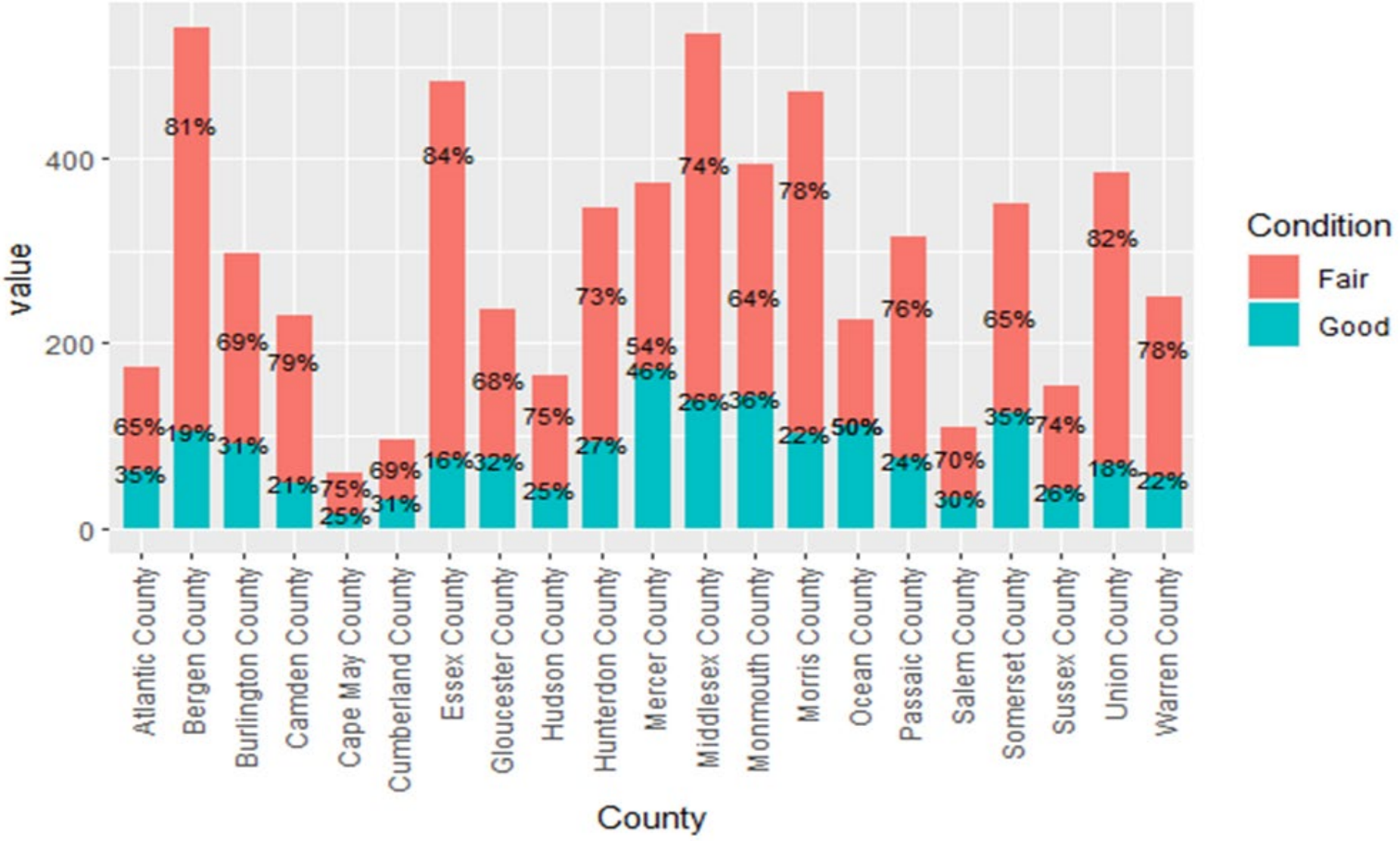
Cox Proportional Hazard

- Semi-parametric survival model. Estimates hazard ratios for covariates
- Interprets effect size: hazard ratio >1 means higher risk
- Adjusts for multiple factors simultaneously

COX Proportional Hazard Model Results

Column1	coef	exp(coef)	se(coef)	z	Pr(>|z|)
Average.Daily.Traffic	1.12E-06	1.000001122	1.04E-07	10.75854248	5.40E-27
factor(Main.Span.Material)Concrete Continuous	0.227588066	1.255568007	0.031927722	7.12822758	1.02E-12
factor(Main.Span.Material)Masonry	-1.073546183	0.341794301	0.104874512	-10.23648327	1.36E-24
factor(Main.Span.Material)Other Material Main or N/A (No Other Span)	-0.419894012	0.657116463	0.177352191	-2.367571605	0.017905255
factor(Main.Span.Material)Prestressed Concrete	0.623918939	1.866227362	0.015648213	39.8715775	<0.0001
factor(Main.Span.Material)Prestressed Concrete Continuous	0.655727327	1.926543234	0.06696245	9.792463173	1.21E-22
factor(Main.Span.Material)Steel	0.222473329	1.249162502	0.014464156	15.38100984	2.19E-53
factor(Main.Span.Material)Steel Continuous	0.305130612	1.356802206	0.020723414	14.72395478	4.52E-49
factor(Main.Span.Material)Wood or Timber	0.185420413	1.203724395	0.023171325	8.002149841	1.22E-15
Number.of.Spans.in.Main.Unit	0.004920736	1.004932863	0.000305721	16.09551025	2.74E-58
Skew.Angle..degrees.	0.007056249	1.007081202	0.000156592	45.06147868	<0.0001
Structure.Length..ft..	0.000174657	1.000174672	1.80E-05	9.678232289	3.73E-22
Deck.Area..sq..ft..	-2.14E-06	0.999997857	2.51E-07	-8.526713285	1.51E-17
Length.of.Maximum.Span..ft..	0.000530985	1.000531126	3.73E-05	14.25028683	4.46E-46
Average.Daily.Truck.Traffic..Percent.ADT.	0.027851974	1.028243466	0.000766762	36.32412075	6.73E-289
Number.of.Freeze.Thaw.Cycles	-0.006757174	0.993265604	0.000228534	-29.56743887	3.92E-192
Total.Precipitation	-0.000103613	0.999896392	1.48E-05	-6.982071767	2.91E-12

Socioeconomic Impacts on Bridge Conditions



K-means Clustering

- Unsupervised machine learning
- Groups bridges with similar characteristics
- Identifies patterns without predefined categories
- Helps target interventions for similar bridge clusters

	75 K	100 K	150 K
Good	26% (441)	**36% (607)**	38% (643)
Fair	**29% (1293)**	33% (1503)	38% (1697)

Random Forest

- Ensemble machine learning method
- Builds multiple decision trees and aggregates results
- Provides variable importance ranking
- Captures nonlinear relationships between predictors and bridge condition

Results:

Socioeconomic Factor	Importance Ranking
Business	16.55%
Population	21.26%
Average Annual Daily Traffic	31.37%
Median Income	1.03%
Business and AADT	13.08%
Population and AADT	16.70%

Multiple Linear Regression

- Predicts bridge condition rating using multiple predictors
- Provides coefficients to measure contribution of each factor
- Controls for multicollinearity between socioeconomic variables
- Supports policy recommendations with quantitative evidence

Socioeconomic Factors	Coefficient	Pvalue
Business	0.32432	0.00216*
Median Household Income	0.05758	0.09569
Population	-0.29066	0.01729*
Average Annual Daily Traffic	0.07707	0.02025*
Business:Median Household Income	-0.36691	0.01337*
Business:AADT	1.02211	3.74e−07*
Median Household Income: Population	0.23296	0.27219
Median Household Income: AADT	−0.30220	3.92e−05*
Population : AADT	−0.96037	1.17e−06*
Business : Median Household Income: Population	-0.01940	0.35348
Business: Median Household Income: AADT	-0.16318	0.04204*
Business:Population:AADT	-0.03741	0.05050
Median Household Income :Population: AADT,	-0.27221	0.06600
Business:MedInc:Population:AADT	-0.13805	0.00936

Reliability Analysis and Socioeconomic Analysis Results

Socioeconomic factors and Bridge Conditions

The study investigates the relationship between different socioeconomic factors in each county and the condition of bridges within those areas.

Integrated Insights

By combining the reliability analysis with the understanding of socioeconomic impacts, the study provides a comprehensive framework for optimizing bridge infrastructure management. This holistic approach enables policymakers and transportation planners to make informed decisions that address both structural integrity and social equity considerations.

Thank You