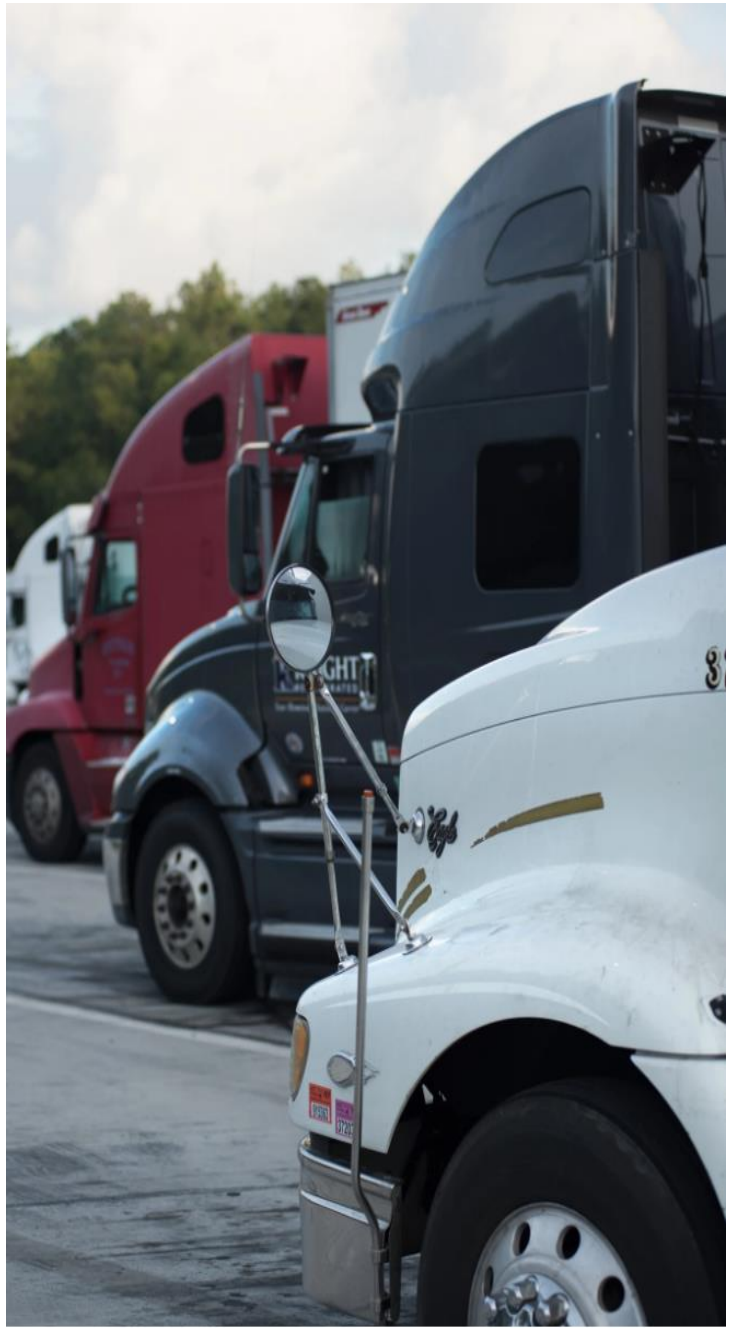

Impact of Truck Load on Bridge Decks based on WIM Data

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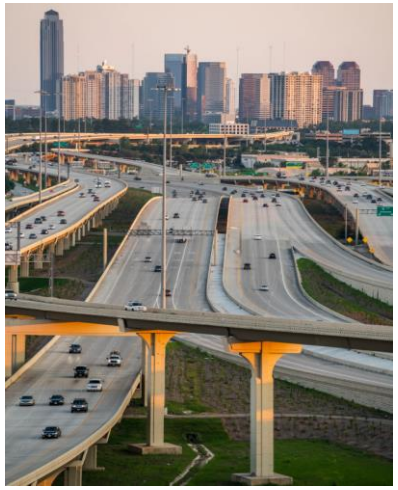

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Specialty

- Bridge live load analysis using weigh-in-motion (WIM) data
- Bridge reliability-based calibration

Education History

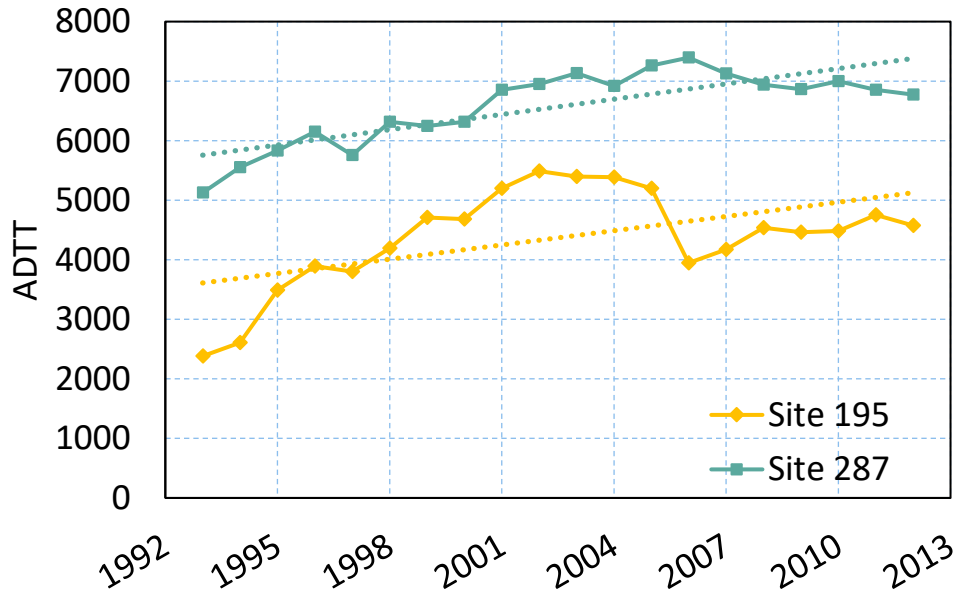
2014 – 2018	2018 – 2019	2019 – 2023
B.S.	M.S.	Ph.D.
Rutgers University	Rutgers University	Rutgers University

Selected Publication Related to WIM Data

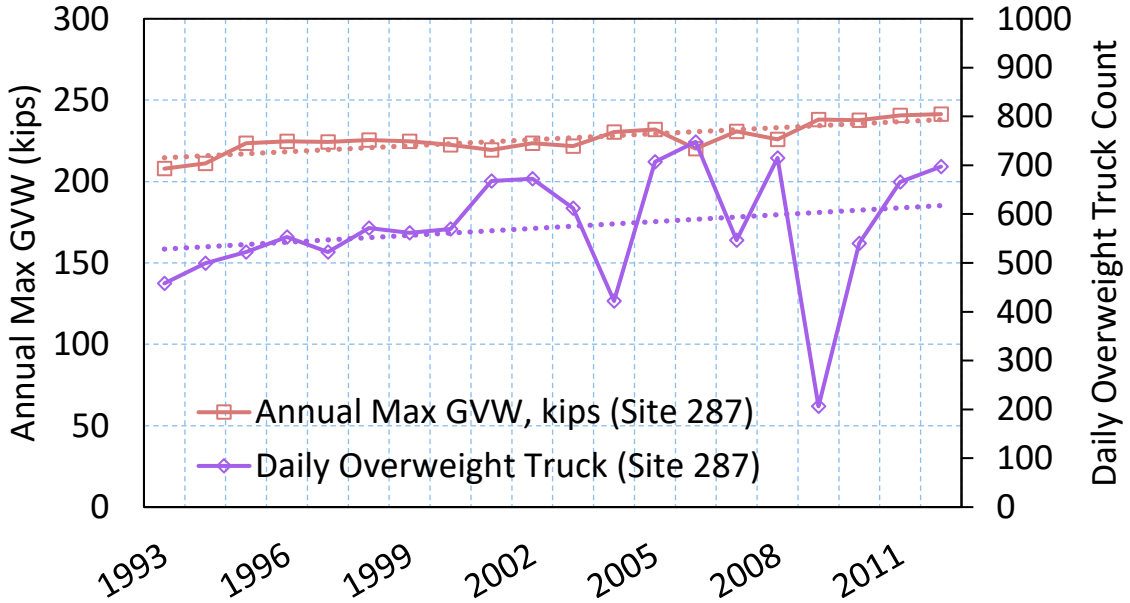
- Yang, C., Lou, P., & Nassif, H. (2024). *Correlation of Bridge Deck Deterioration With Truckload Spectra Based on NBI Condition Rating and Weigh-In-Motion Data* (No. FHWA-HRT-24-032). United States. Department of Transportation. Federal Highway Administration. Office of Research, Development, and Technology.
- Yang, C., Lou, P., & Nassif, H. (2022). Reliability-Based Assessment of Concrete Decks Designed Using Approximate Method at the Strength I Limit State. *Transportation Research Record*, *2676*(10), 695-707.
- Lou, P., Yang, C., & Nassif, H. (2024). Prediction of Maximum Live-Load Effects for Bridges Based on Weigh-in-Motion Data. *Transportation Research Record*, 03611981241265690.
- Lou, P., Yang, C., & Nassif, H. (2024). Prediction of Maximum Live-Load Effects for Bridges Based on Weigh-in-Motion Data. *Transportation Research Record*, 03611981241265690.

Introduction

- Bridge decks are observed to have premature deteriorations.
- Load-driven factors:
  - Increasing truck volume
  - Increasing truck weight and overweight truck traffic



Reference: Lou, P., Nassif, H., Su, D., & Truban, P. (2016). Effect of overweight trucks on bridge deck deterioration based on weigh-in-motion data. Transportation Research Record, 2592(1), 86-97.



Reference: Lou, P., Nassif, H., Su, D., & Truban, P. (2017). Impact of overweight trucks on the service life of bridge girders. Transportation Research Record, 2642(1), 103-117.

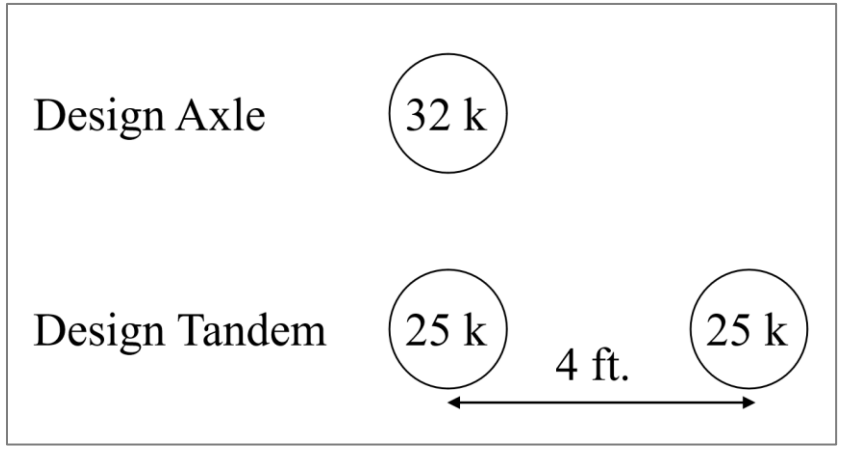
3

Introduction

- AASHTO LRFD adopted the Approximate Method for the RC deck design. This design method assumes the bridge deck fails by flexure.

- The design loads may be inadequate and not representative of the actual truck load spectrum.
  - Heavy single axle and tandem axle
  - Tridem axle (e.g., specialized hauling vehicles)

- The current LRFD code for deck design was calibrated by a series of bridge girders.
  - Lack of statistical live load model
  - Lack of resistance database



AASHTO LRFD Deck Design Load

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Objectives

1. Obtain actual truck load spectra on bridge decks, including truck volume, axle weight, and overweight vehicle statistics.
2. Examine the load effect of axle groups and assesses the adequacy of current LRFD bridge deck design.
3. Identify the correlation between truck traffic loading and bridge deck service life.

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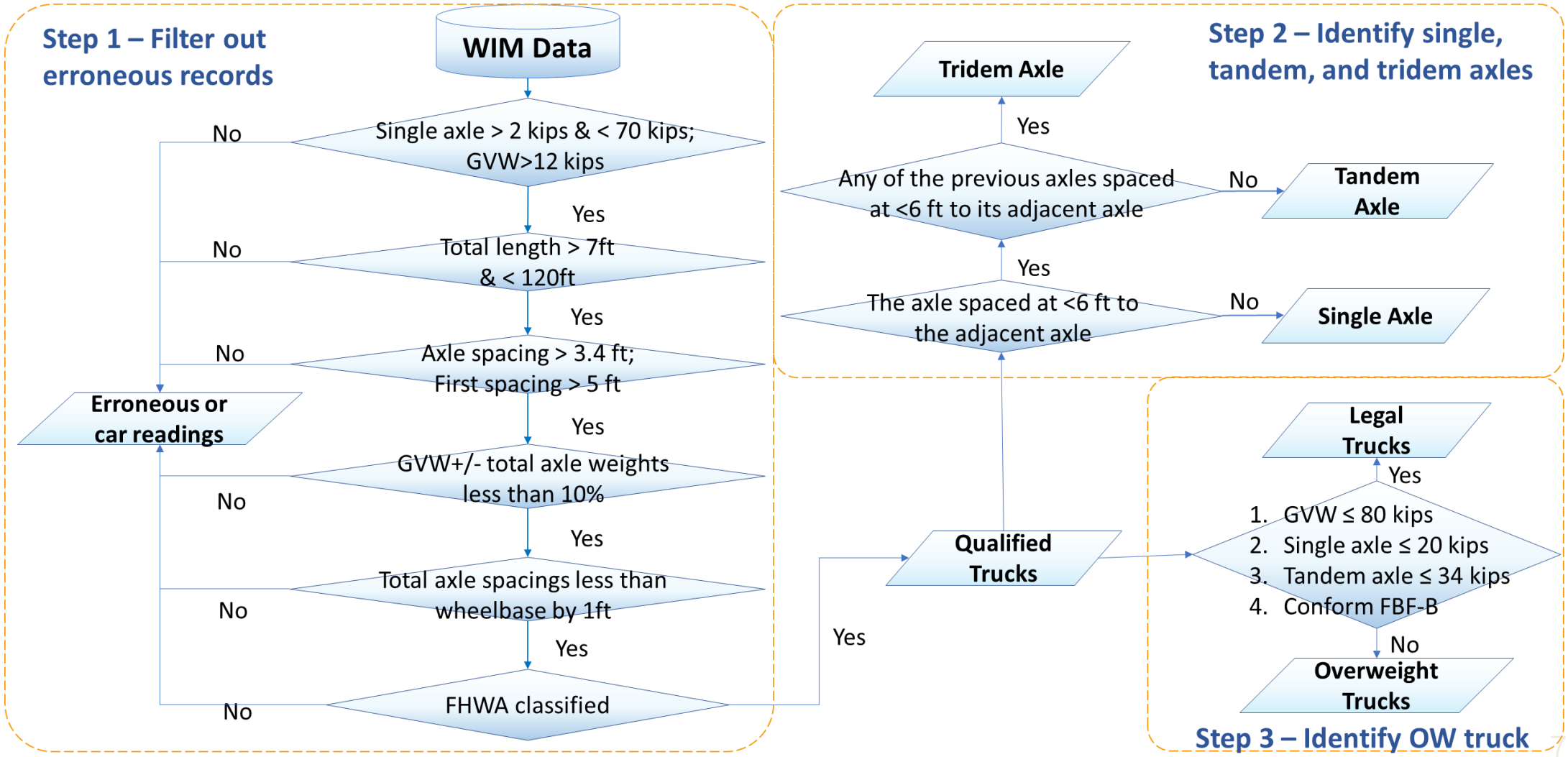
WIM Data Processing

Data Source

- Source 1: WIM Sites from NCHRP 12-83 Project
  - ➢ 32 WIM sites from 19 states
- Source 2: LTPP InfoPave Ancillary Data
  - ➢ 684 downloadable WIM sites in total
    - Incompatible data format
    - Missing WIM site information
    - Unreliable data quality
  - ➢ 203 appliable and reliable WIM sites nationwide

Climate Region	Interstate Highway	U.S. Highway	State Highway
Northeast	9	5	7
Upper Midwest	8	11	3
Ohio Valley	20	12	7
Southeast	6	14	2
Northern	3	2	4
South	5	13	3
Southwest	8	1	1
Northwest	4	7	7
West	18	4	5

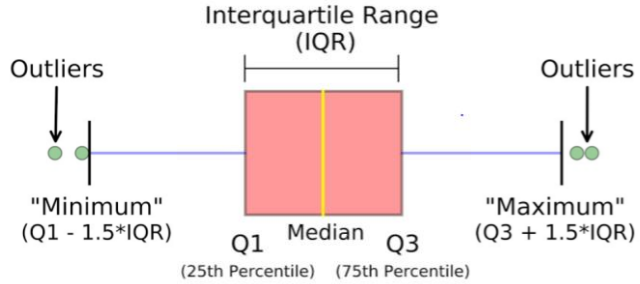
WIM Data Processing

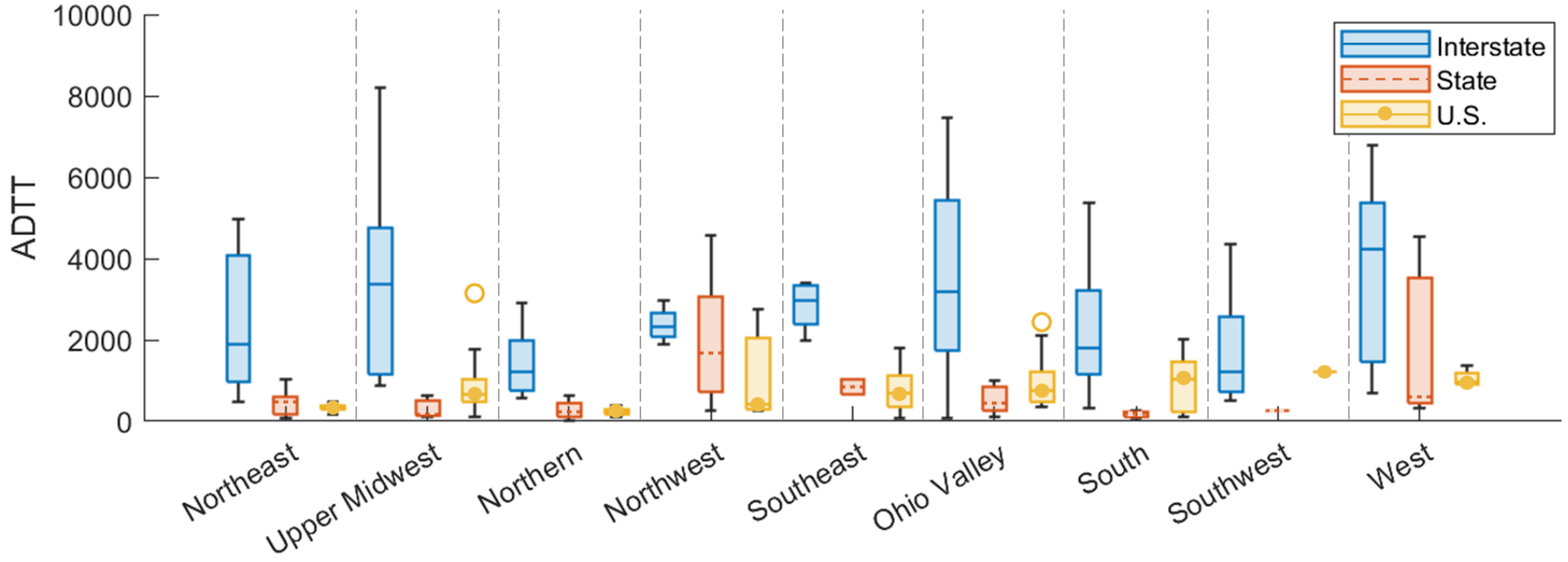


WIM Data Processing

Average Daily Truck Traffic (ADTT)

- Interstate highways carry the highest truck volume





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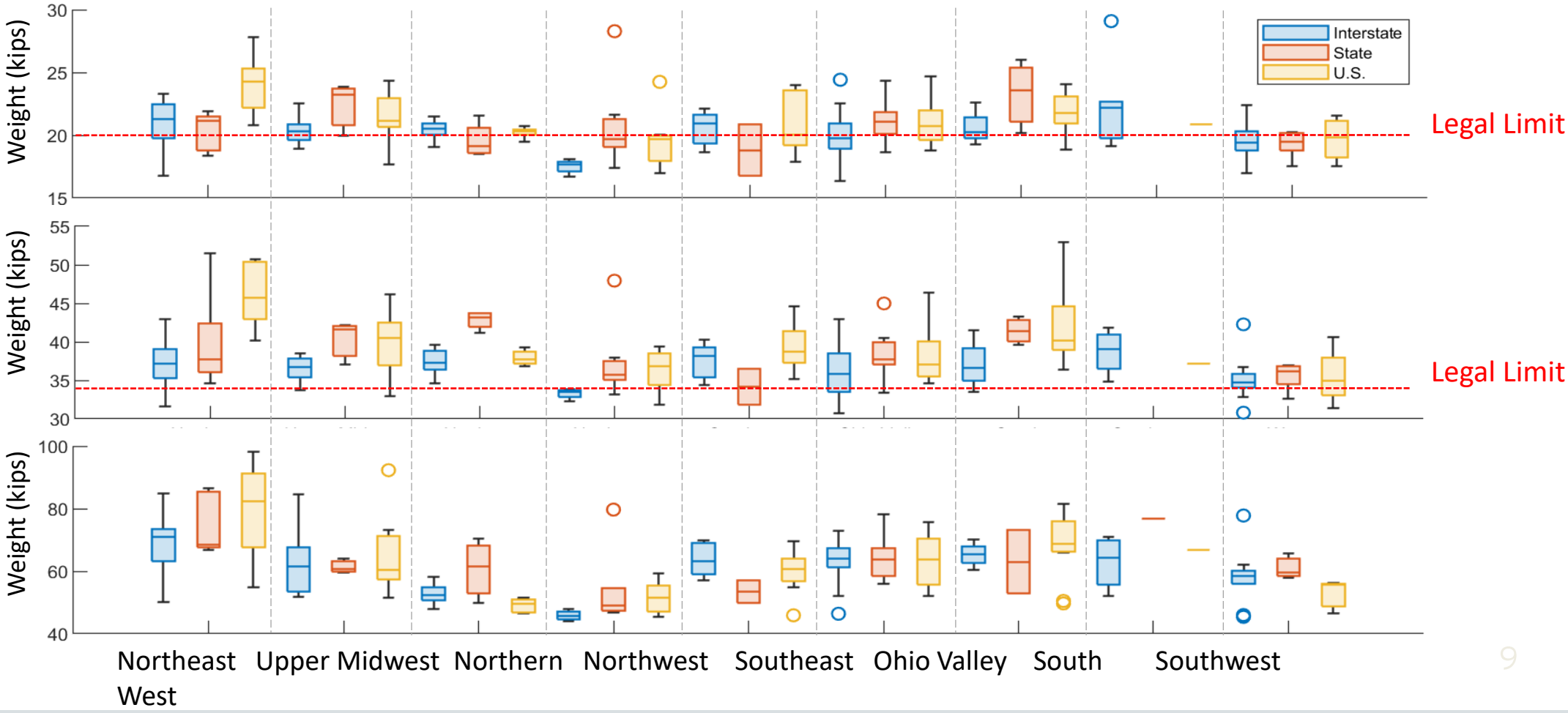
WIM Data Processing

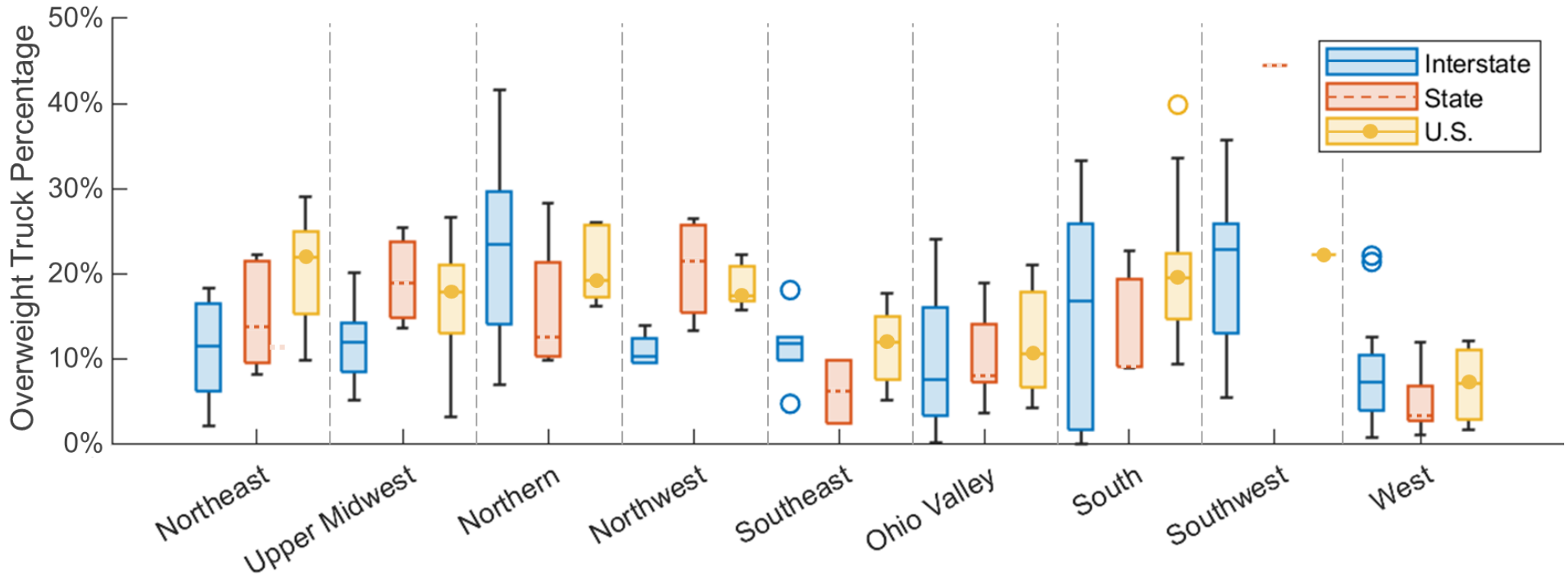
Weight of Axle Groups



WIM Data Processing

Overweight (OW) Trucks

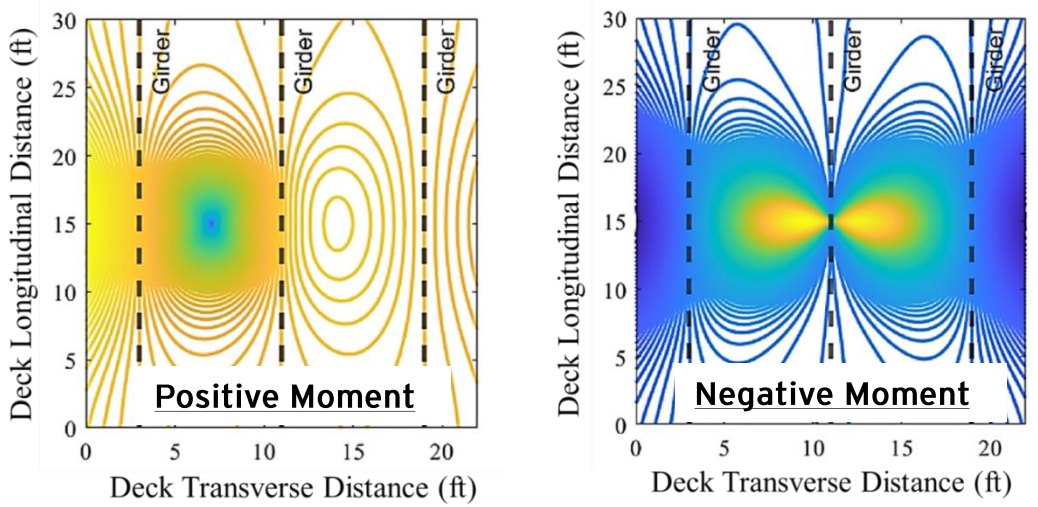
- Percent of overweight trucks exhibits big fluctuation across the country and is 15% on average.



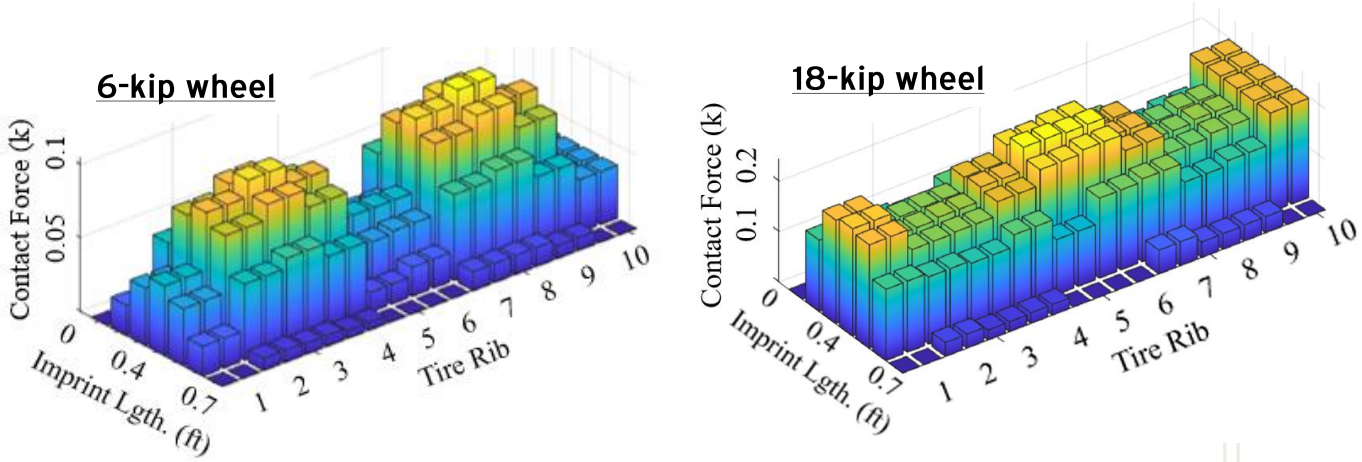
Flexure Effects of Axle Groups on Bridge Decks

Finite Element Model (FEM)

- FEM of a series of slab-on-girder bridges were developed in Abaqus to obtain the influence surface of bridge decks.
  - ➢ Deck was modeled as shell element
  - ➢ Girder was modeled as beam element with pin-roller boundary condition
  - ➢ Different girder spacings were considered: 6 ft, 8 ft, 10 ft, 12ft
- The effect of non-uniform tire contact force was considered.
  - ➢ Contact force of light wheel concentrates in the middle.
  - ➢ Contact force of heavy wheel spreads over the edges.



Bridge Deck Influence Surface

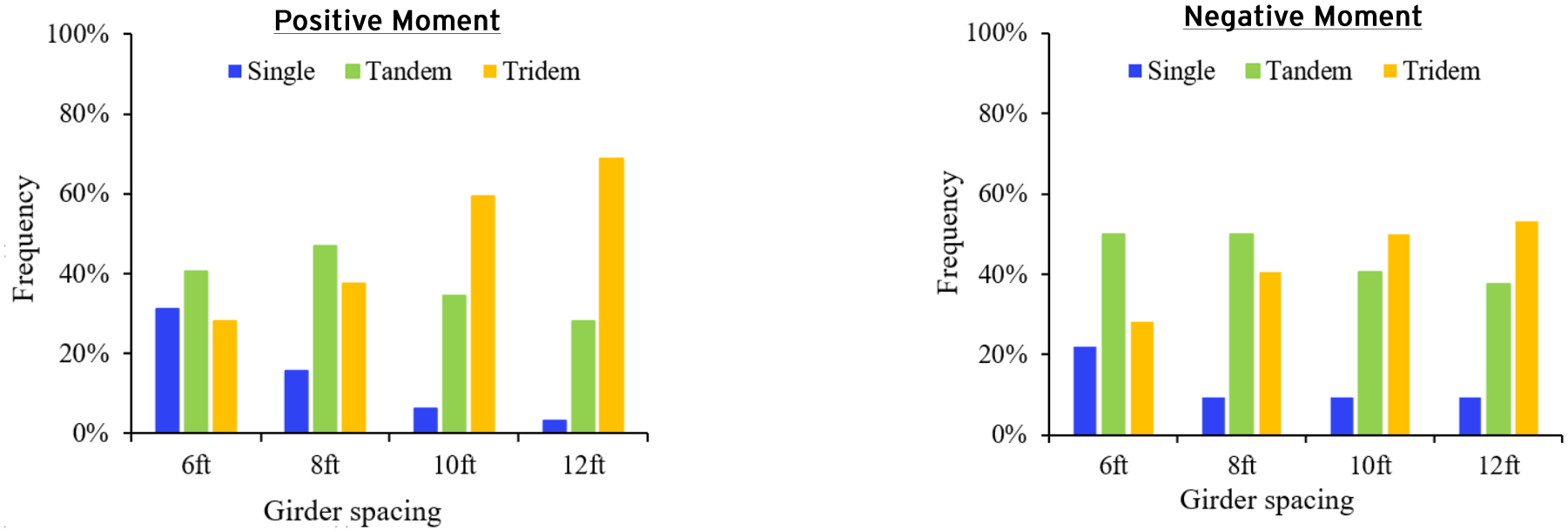


Tire Contact Force

Flexure Effects of Axle Groups on Bridge Decks

Flexure Effect of Axle Groups

- Axle groups from WIM data were analyzed in FEM influence surface to determine their flexural effects.
- These effects were then extrapolated to the design life of 75 years.
- Tandem and tridem axles often dominate the 75-year load effects, whereas the current design load does not account for tridem axles.



Frequency of Each Axle Group Governing the Load Effects

Correlation of Truck Load Spectra and Bridge Deck Service Life

Bridge Inspection Data

- Data source: National Bridge Inventory (NBI)
- Extracted parameters:
  1. State
  2. Structure number
  3. Signing prefix
  4. Deck structure type
  5. Deck condition rating (CR)
  6. Inspection date
  7. Year of built
  8. Year of reconstruction.

CR	Condition
9	Excellent
8	Very Good
7	Good
6	Satisfactory
5	Fair
4	Poor
3	Serious
2	Critical
1	Imminent Failure
0	Failed

A condition rating of 4 generally indicates the end of the service life for a bridge component.

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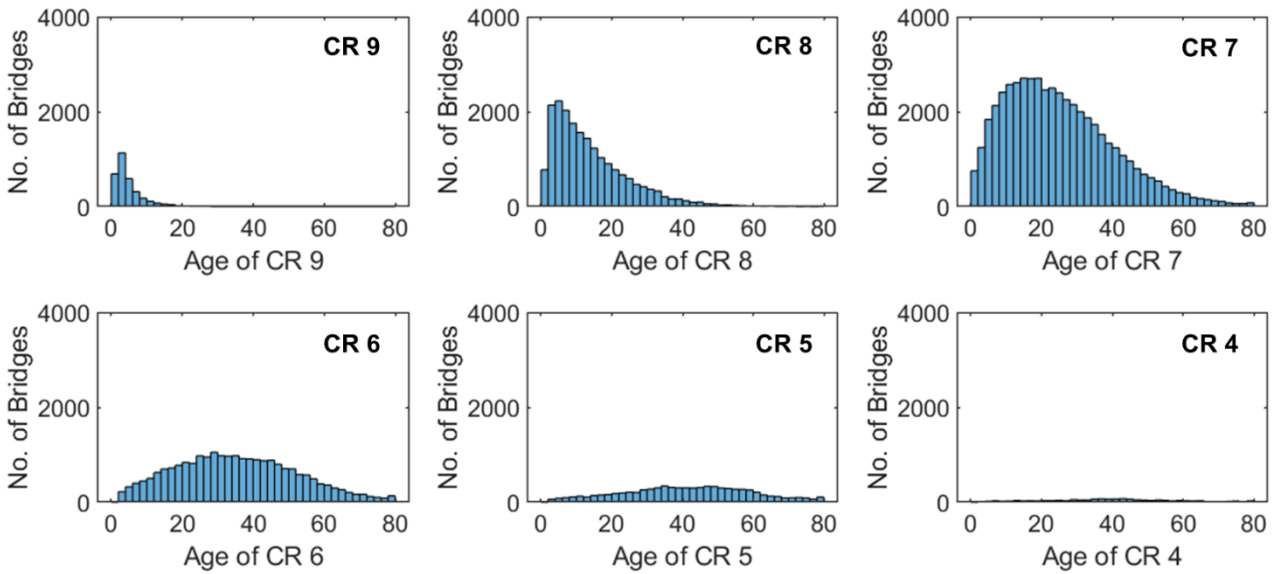
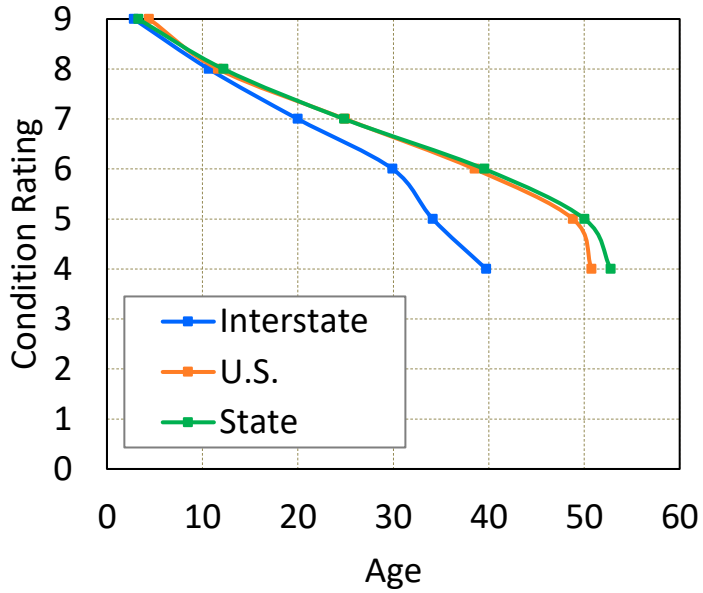
Correlation of Truck Load Spectra and Bridge Deck Service Life

Bridge Inspection Data Processing

- Data Filters
  1. Non-integer CR or CR > 9
  2. Negative bridge age
  3. Improved CR
- The filtered data display a smoothly shaped age histogram.



Frequency Distribution of Bridge Age at Different Conditions (Southeast Region – Interstate Highway Bridges)

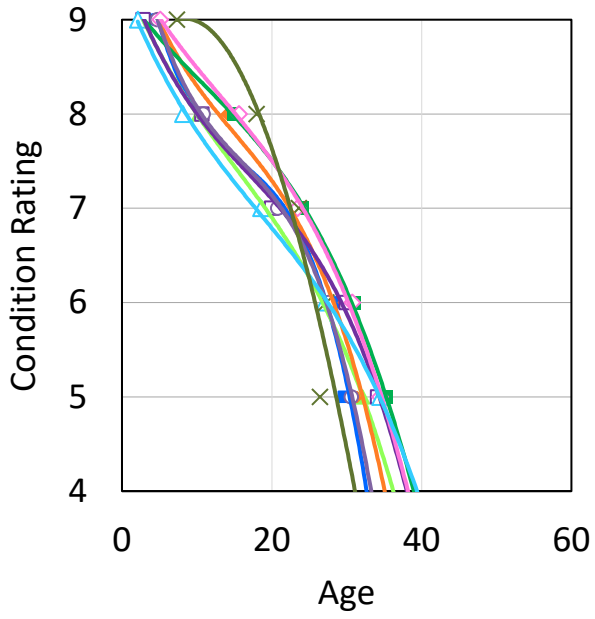


Average Age at Different CR (Southeast Region)

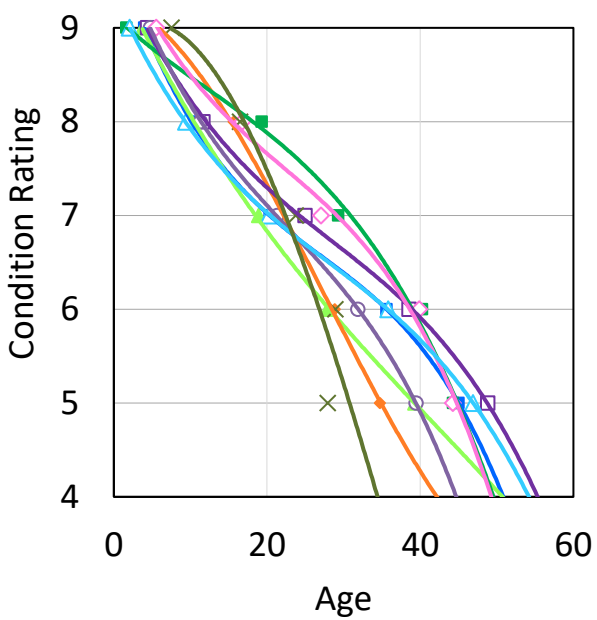
Correlation of Truck Load Spectra and Bridge Deck Service Life

Deterioration Model

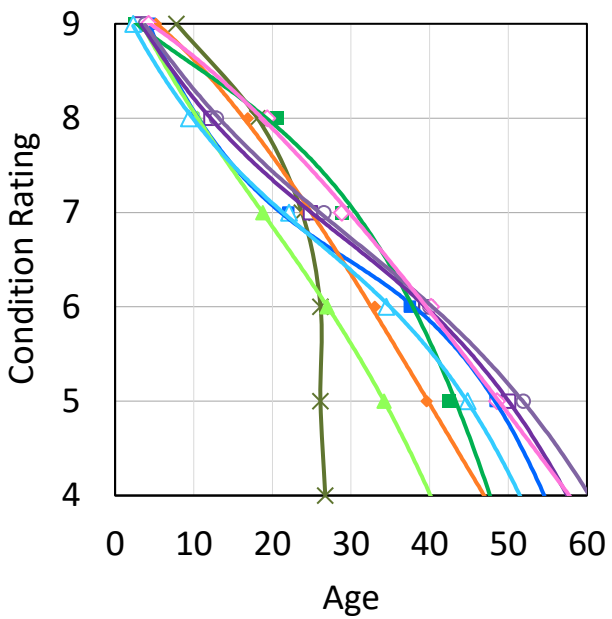
- 3rd order polynomial is used to fit the deterioration model
- The age when the bridge deck downgrade to CR4 is defined as the service life



Interstate Highway



U.S. Highway

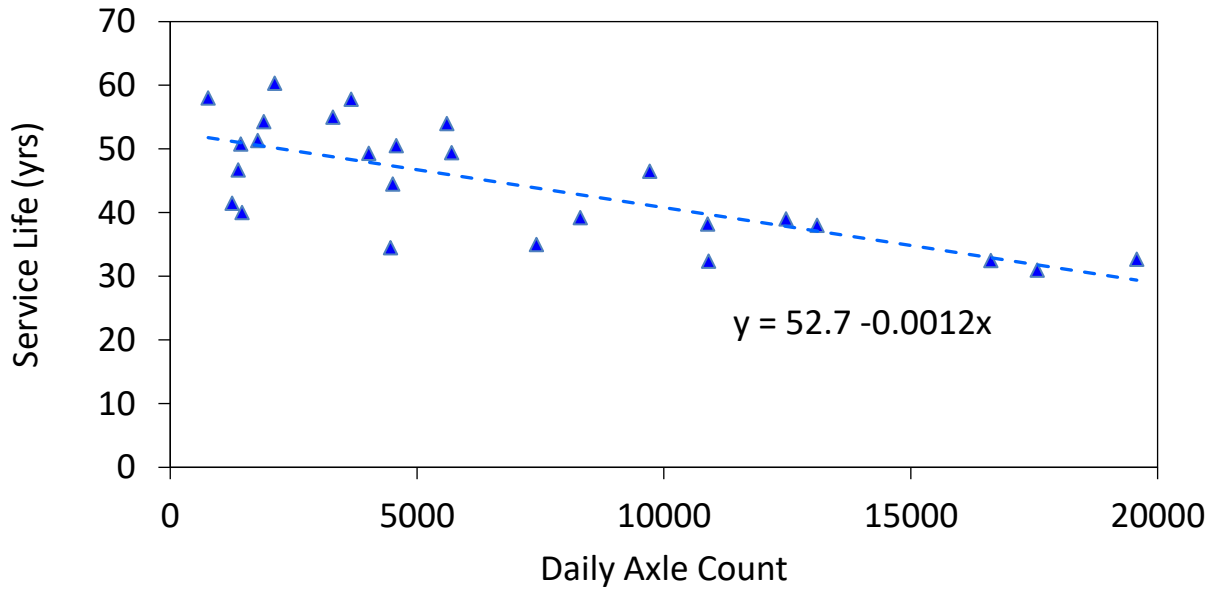


State Highway

Correlation of Truck Load Spectra and Bridge Deck Service Life

Deck service life vs. Truck Volume

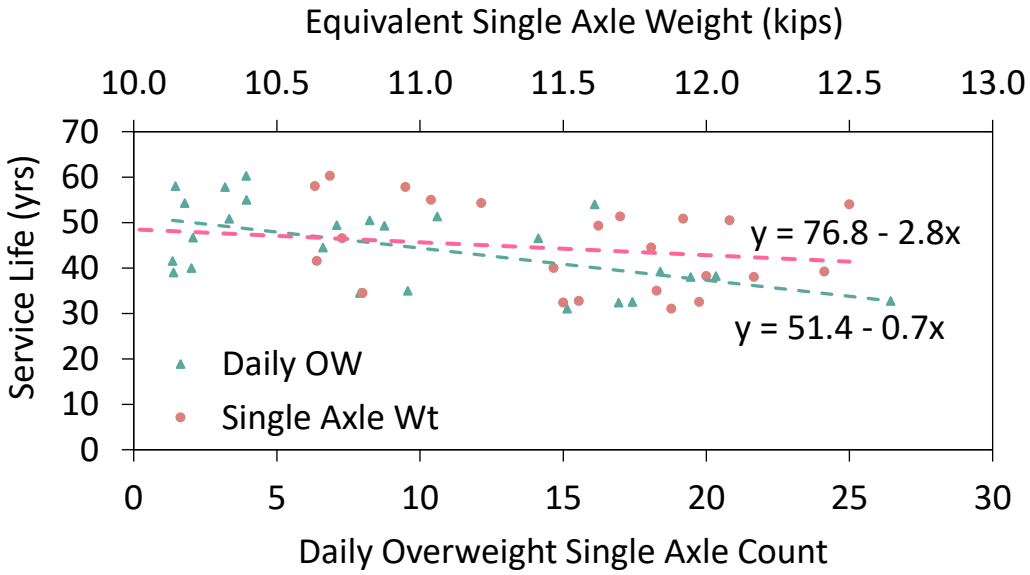
- Negative relationship was observed between service life and truck volume.
- Based on the linear regression analysis, an increase of 1,000 in the daily axle count can reduce the service life by 1.2 years.



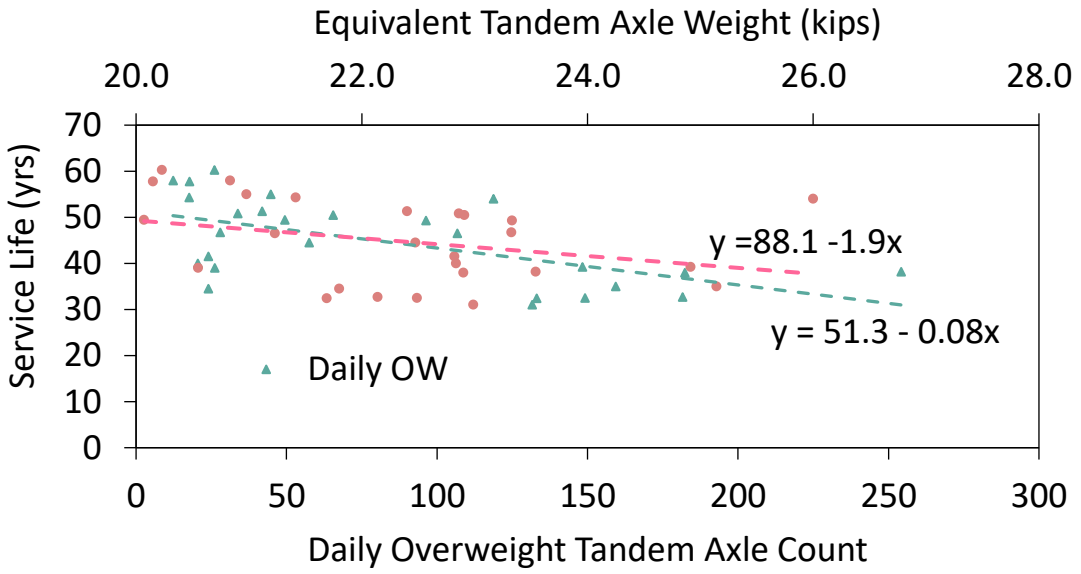
Correlation of Truck Load Spectra and Bridge Deck Service Life

Deck service life vs. Truck Weight

- Single and tandem axle equivalent loads negatively impact service life.
- Overweight axle counts also show a negative relationship with service life.
- Tridem axle load spectra do not exhibit a strong correlation with deck service life, possibly due to the limited occurrence of tridem axles in the dataset.



Single Axle Load Spectra



Tandem Load Spectra

Conclusions

- Bridge decks are subjected to single and tandem loads that are heavier than the design load as specified in the AASHTO LRFD Bridge Design Specifications.
- Interstate highways are subjected to more truck volume, resulting in the shorter service life.
- All the highway systems are subjected to a great portion of overweight trucks.
- Bridge deck deterioration rate shows an accelerating trend as the condition get worse.
- Truck load spectra are closely correlated with bridge deck service life, as indicated by the negative relationship between service life and both truck volume and weight.

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The contents of this paper reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents of the paper do not necessarily reflect the official views or policies of the agencies.