Quantification of Rail Displacement under Light Rail Transit Field Loading Conditions

Joint Rail Conference 2017

Philadelphia, PA

April 6th 2017

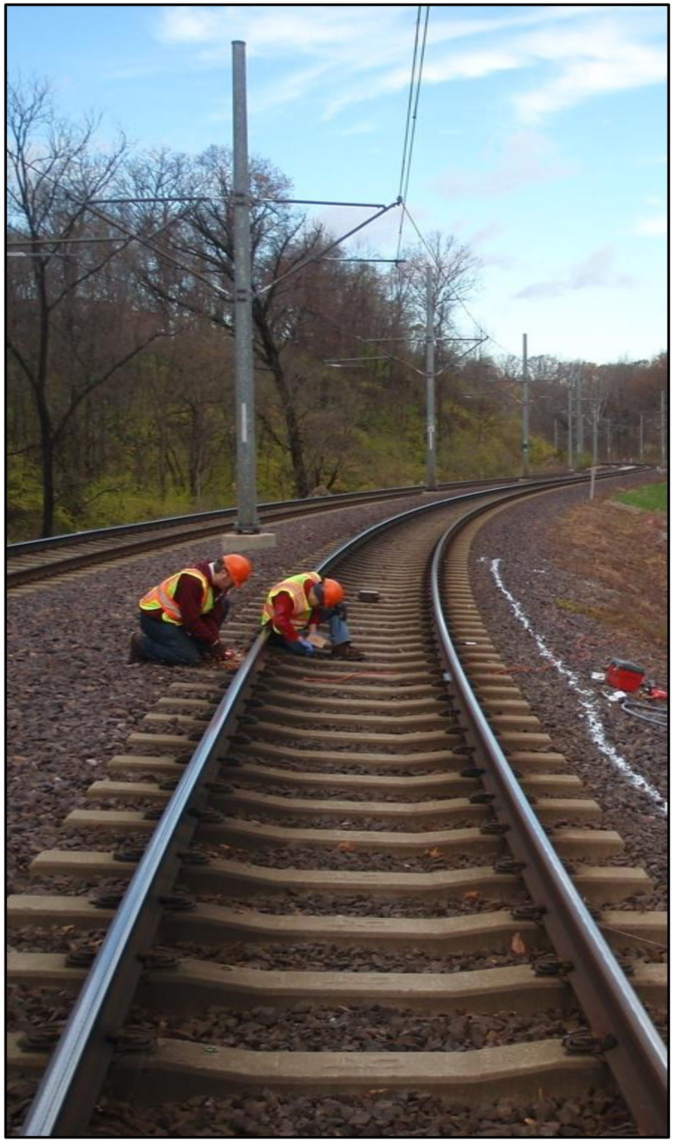
Alvaro E. Canga Ruiz, Matthew V. Csenge,
J. Riley Edwards, Yu Qian, and Marcus S. Dersch

U.S. Department of Transportation
Federal Transit Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

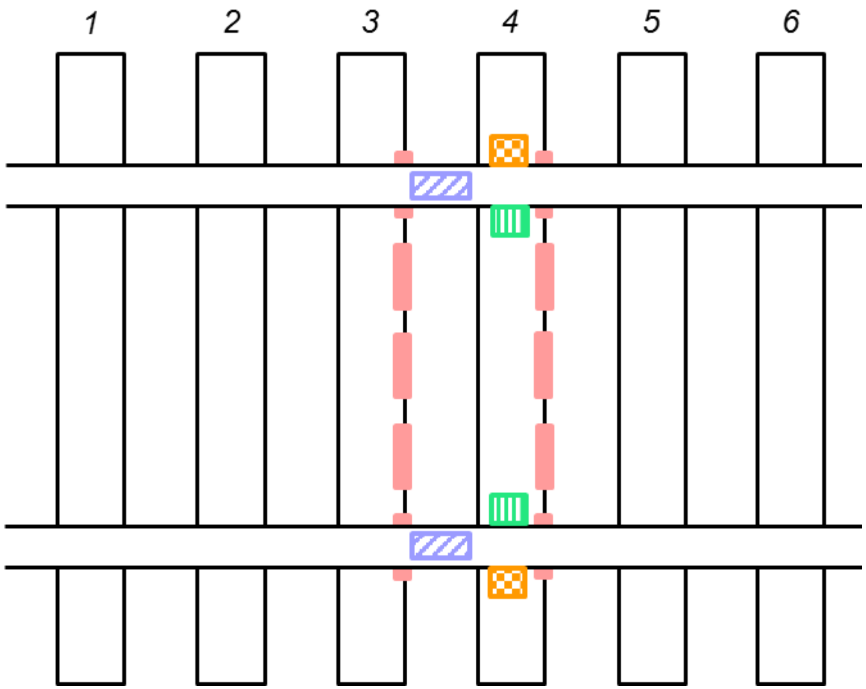
- Objective and Approach
- Data Collection Overview
- Rail Displacement Results:
  - Curve Site
  - Tangent Site
- Conclusions
- Future work



Objectives and Approach

- **Objectives:**
  - *Determine rail displacements under rail transit loading conditions using field data*
  - *Evaluate performance of fastening system:* combine field data, developed models and technical specifications of the fastening system provided by manufacturer to asses its level of usage
- **Approach:**
  1. **Field Data Collection**
  2. **Processing of Collected Data**
  3. **Analysis of Field Results**
  4. Comparison with Analytical and Finite Element Models
  5. Evaluation of Fastening System Behavior in Terms of Rail Restraining

Generic Field Instrumentation Map



Crosstie Bending Strain

Vertical and Lateral Load (Wheel Loads)

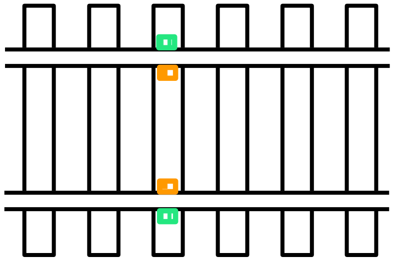
Rail Displacement (Base Vertical, Base Lateral)

Rail Displacement (Base Vertical)

- Metrics to quantify:
  - Crosstie bending strain (crosstie moment design)
  - **Rail displacements** (fastening system design)
  - Vertical and lateral input loads (crosstie and fastening system design, and load environment characterization)
  - Crosstie temperature gradient

Data Collection Overview

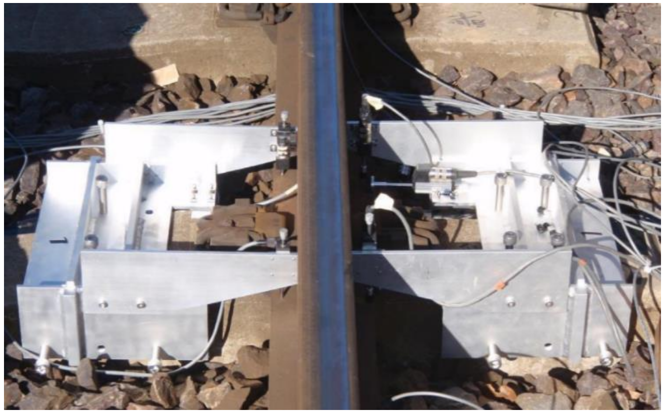
Rail Restraint



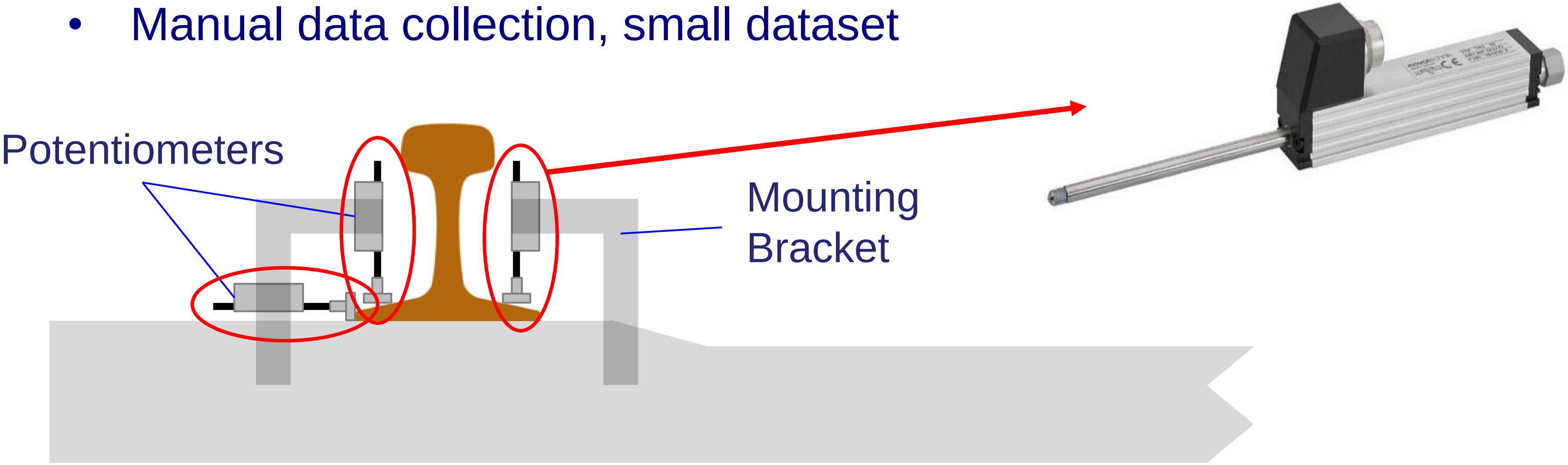
- **Desired data**:
  - Relative vertical and lateral displacement of rail base with respect to crosstie
- **Results:**
  - Capture displacement and rotation of rail under each wheel
  - Analyze load and speed effect on rail displacement
  - Curve sites allow more meaningful study: compare results for high and low rail
  - Have a better understanding of train dynamics

Instrumentation Insight

Portable Displacement Measurement Device (PDMD)



- Linear potentiometers fixed to manufactured rapidly-deployable brackets that affix non-permanently to crosstie
- Novotechnik TS-0025 potentiometers
- 6 potentiometers per rail on rail base: horizontal, vertical field and vertical gauge
- Stroke length: 1.1811 ± 0.000079 in (30 ± 0.002 mm)
- Manual data collection, small dataset



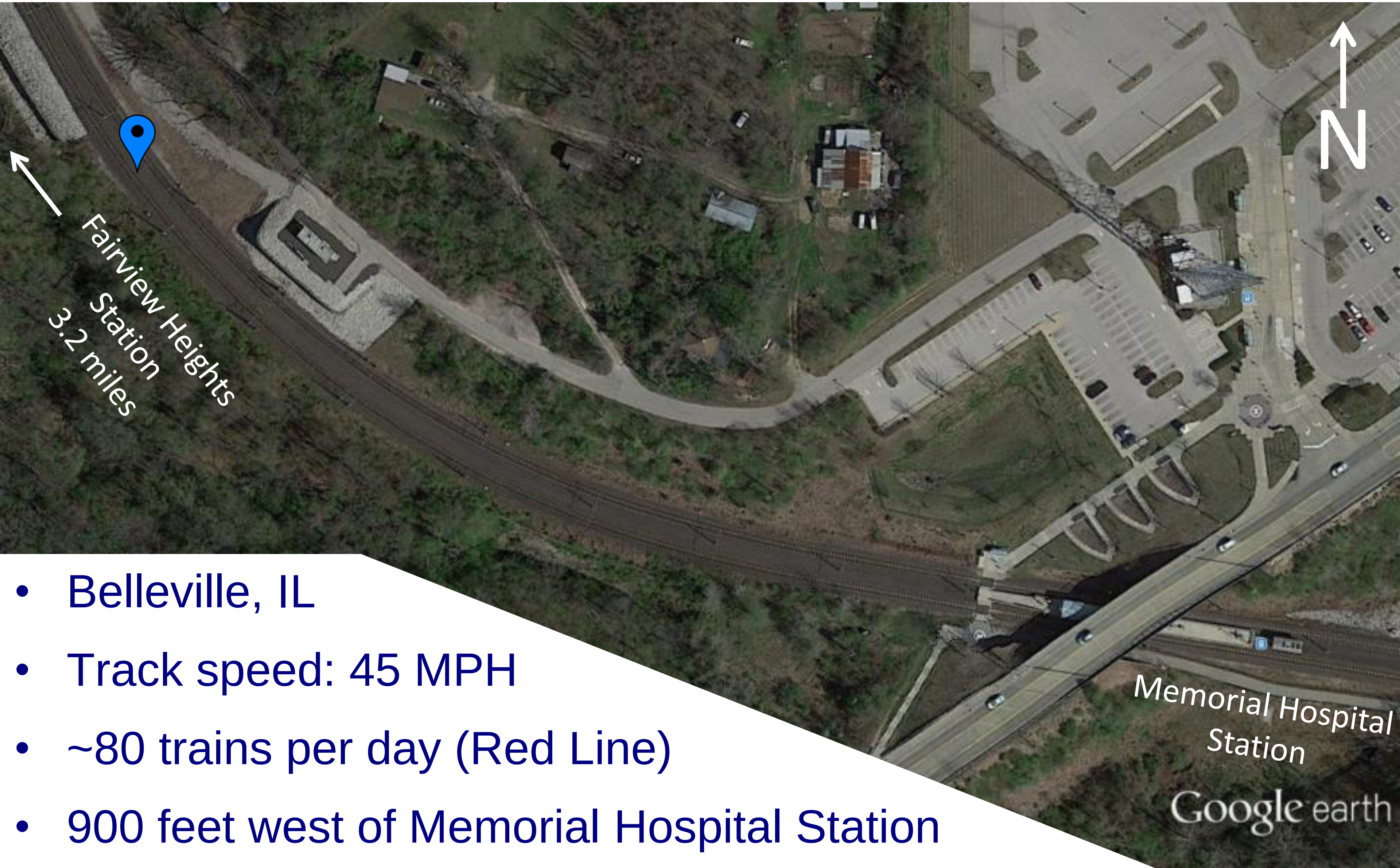
Partner Agencies

Light Rail Curve Data

Trains in Dataset: 36
18, 19, 20 November 2015
and 17 March 2016

(Curve Site)

MetroLink Curve Location

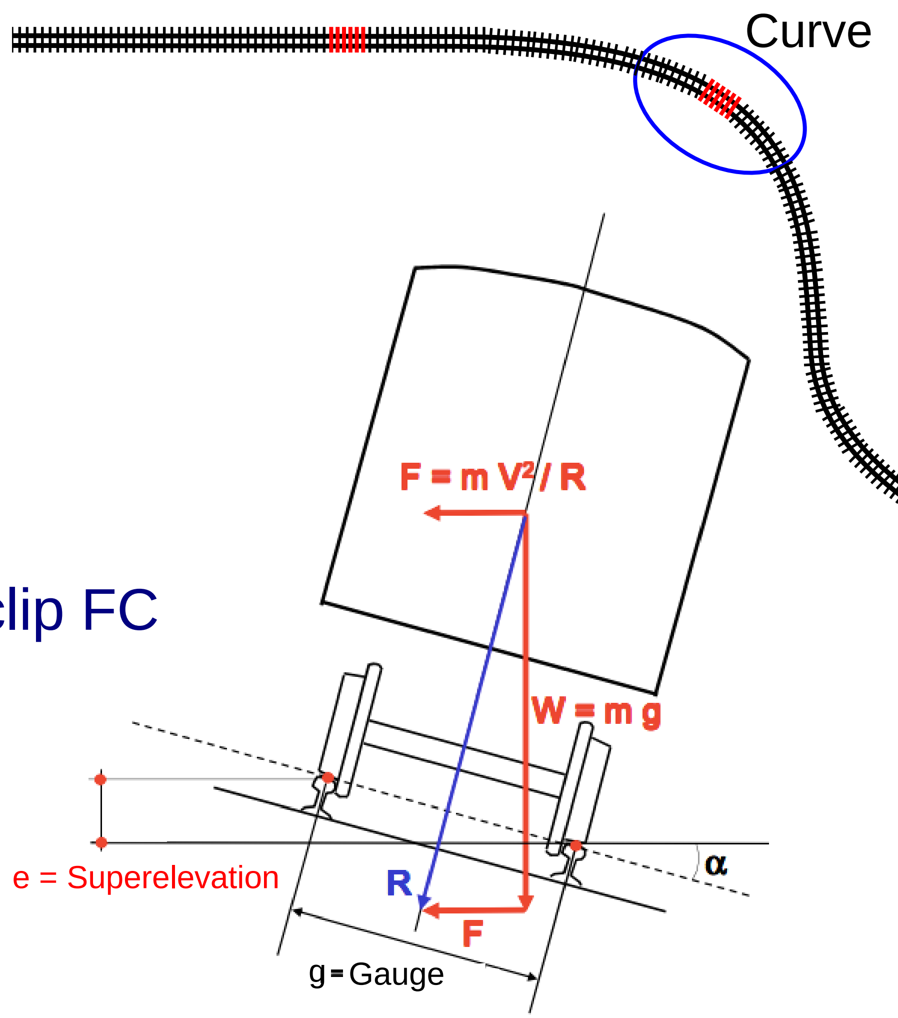


- Belleville, IL
- Track speed: 45 MPH
- ~80 trains per day (Red Line)
- 900 feet west of Memorial Hospital Station

Curve Geometry

St. Louis MetroLink Curve Site

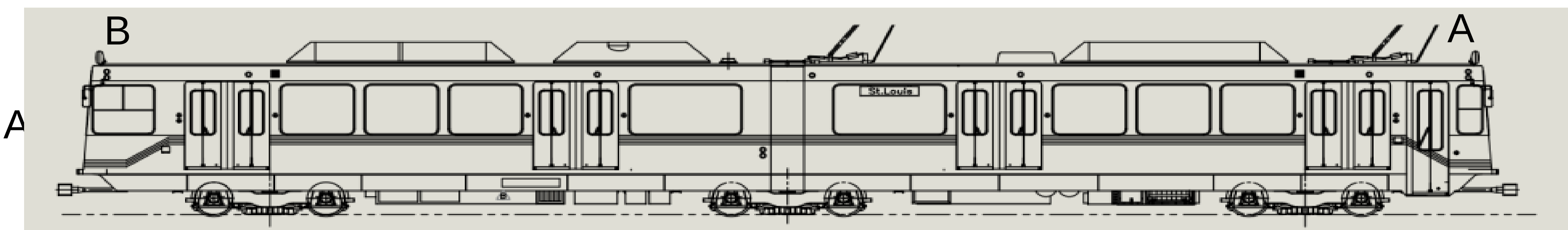
- Characteristics:
  - Curve: 6°00’
    (955 ft. (291 m) radius)
  - Superelevation:
    5.25 in. (133 mm)
  - Balance speed:
    35.4 mph (57 km/h)
- Fastening system: Pandrol Fastclip FC
- Measured speeds
  - From 15 mph (25 km/h)
    to 46 mph (74 km/h)
- High and low rail instrumented



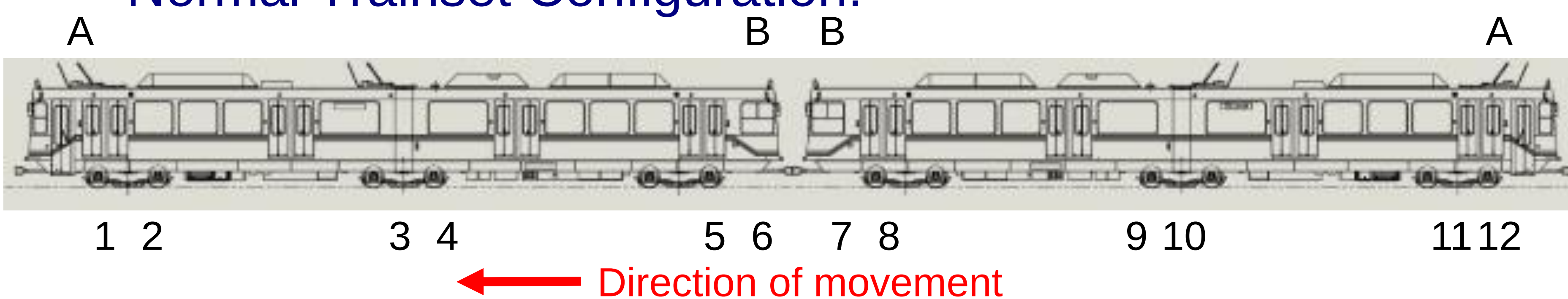
MetroLink Light Rail Vehicles (LRVs)

Siemens SD-400 & SD-460

- 2-vehicle (12 axle) trainsets
- Static loads provided by MetroLink engineering staff
- Middle truck unpowered
- AW0 (Unloaded) wheel weights at delivery (kips, one car):



- Normal Trainset Configuration:



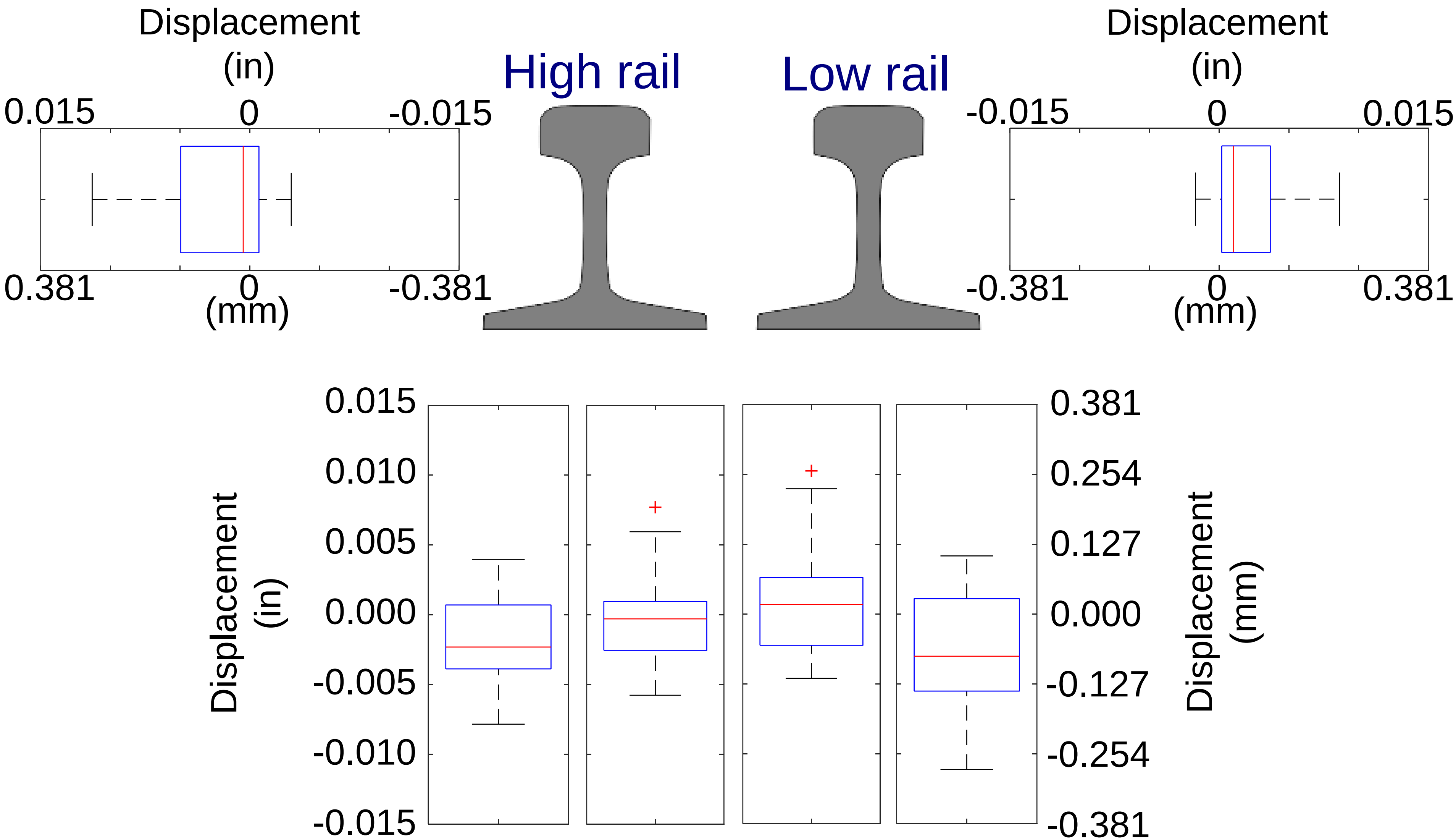
Results

St. Louis MetroLink Curve Site

- The following results were obtained:
  - Horizontal and vertical displacements were analyzed for high and low rail considering displacement due to wheel loads
  - Rail displacement by axle for 12-axle light rail rolling stock

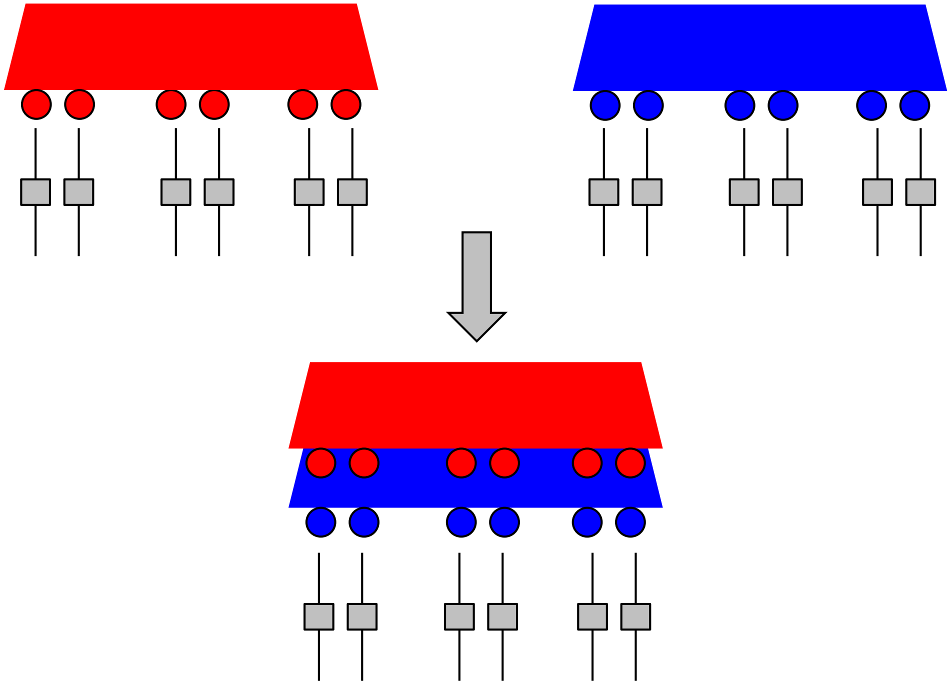
Rail Displacement

St. Louis MetroLink Curve Site



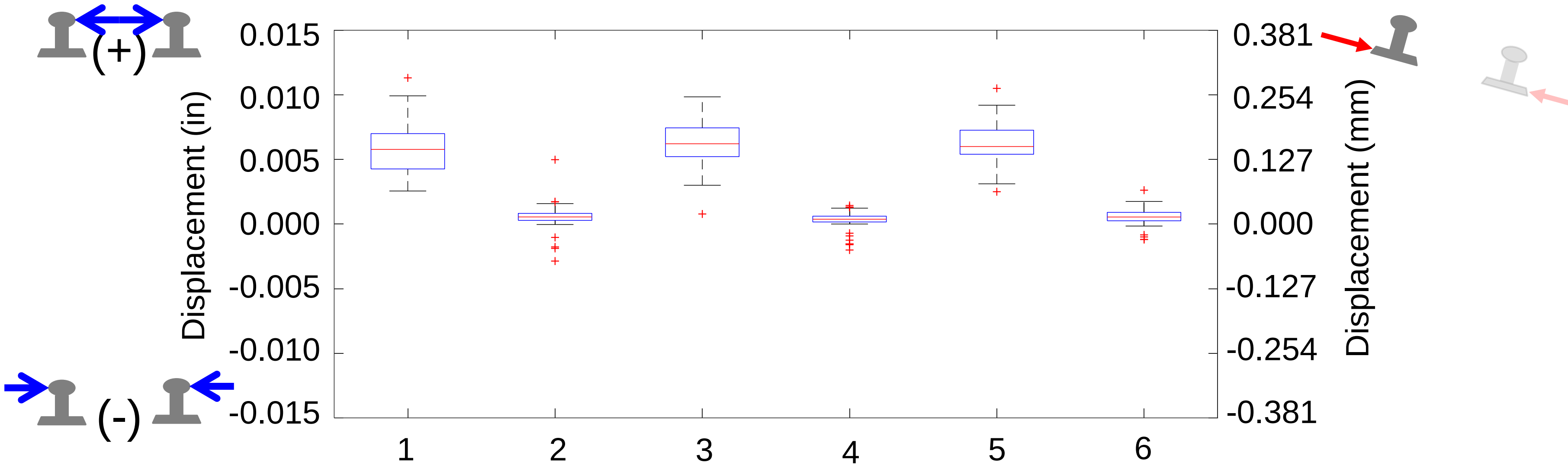
Presentation of Results by Axle

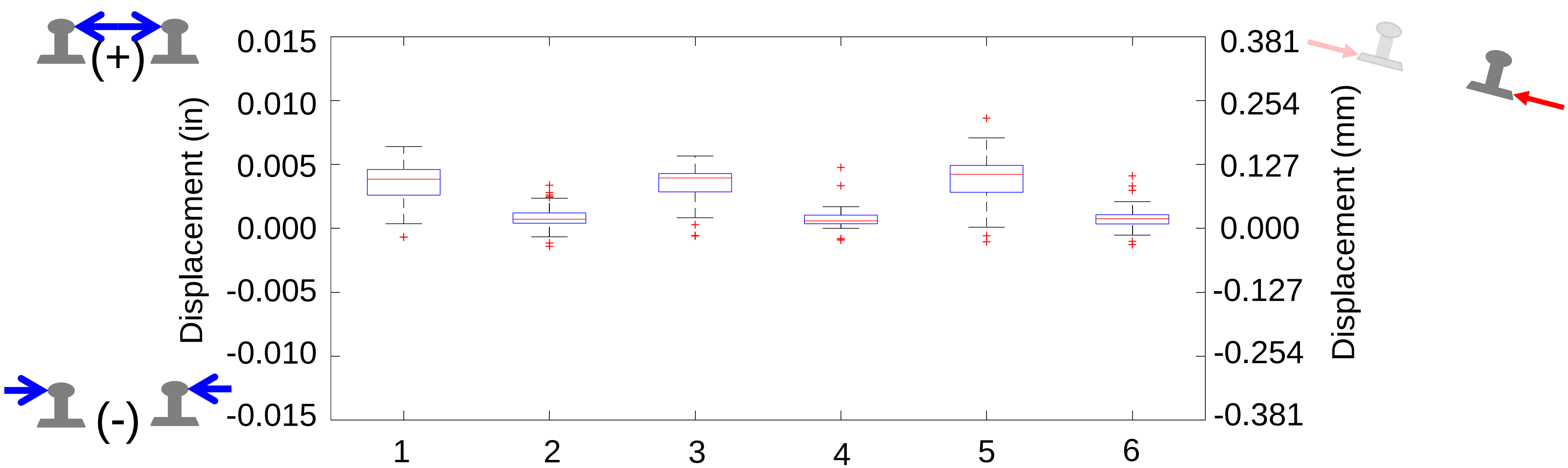
- Each MetroLink train consists of a two-car set, so each 6 axles is a 'repeat' of the equipment (order aside)
- The following graphs can be compressed by stacking 'repeat' axles



Rail Displacements by Axle

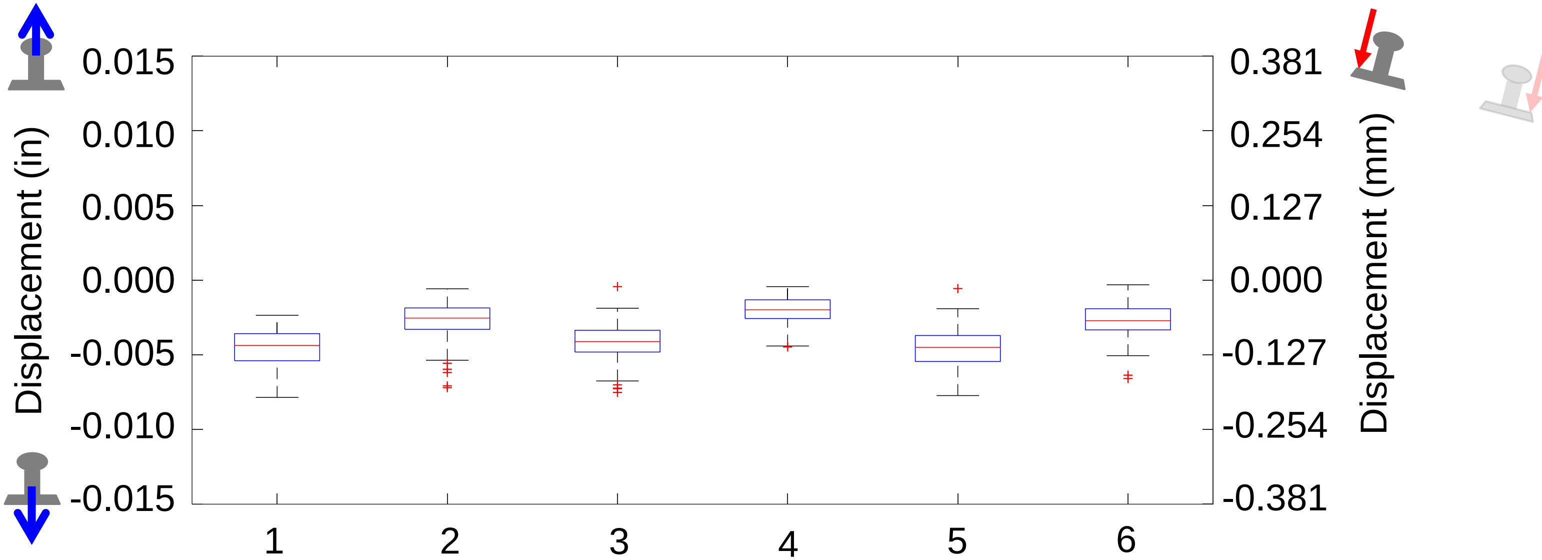
St. Louis MetroLink Curve Site

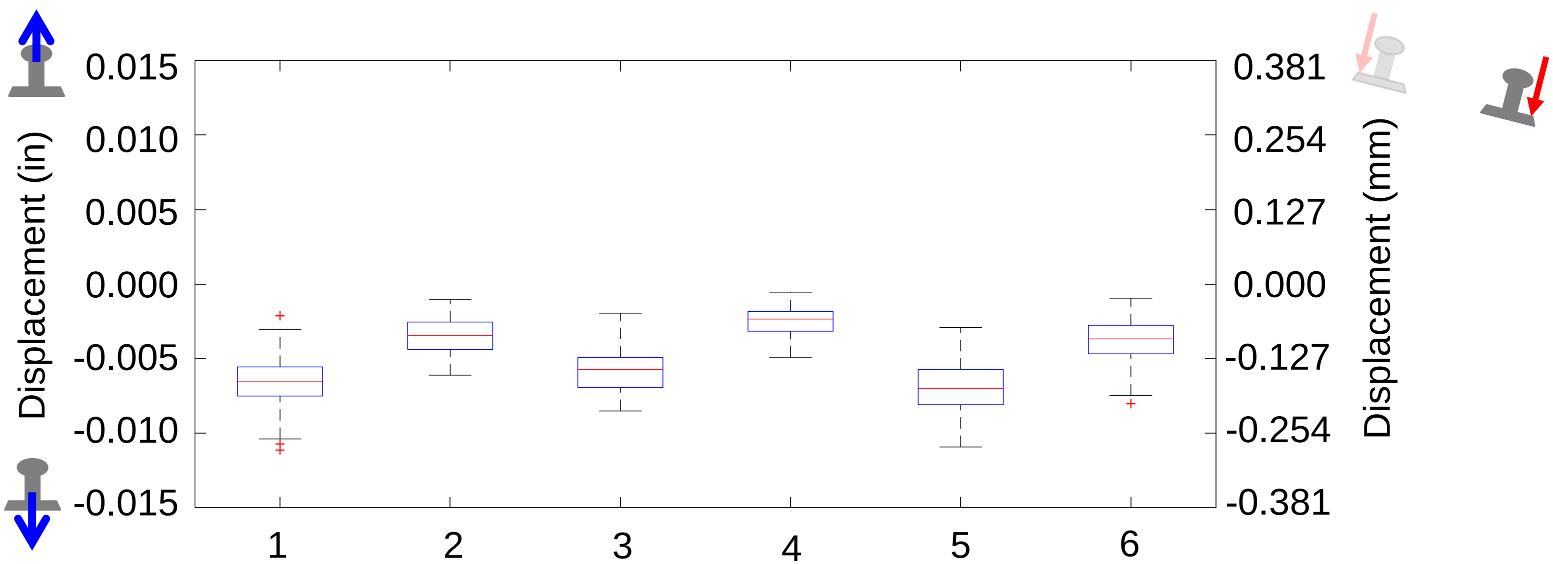




Rail Displacements by Axle

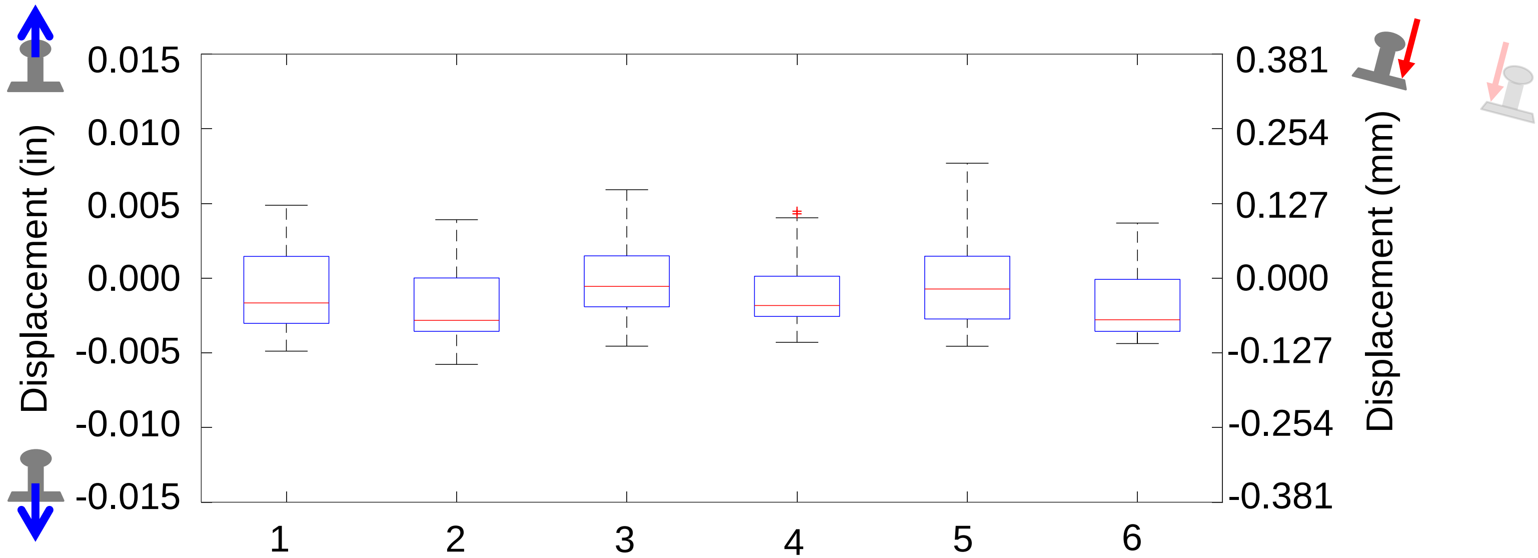
St. Louis MetroLink Curve Site

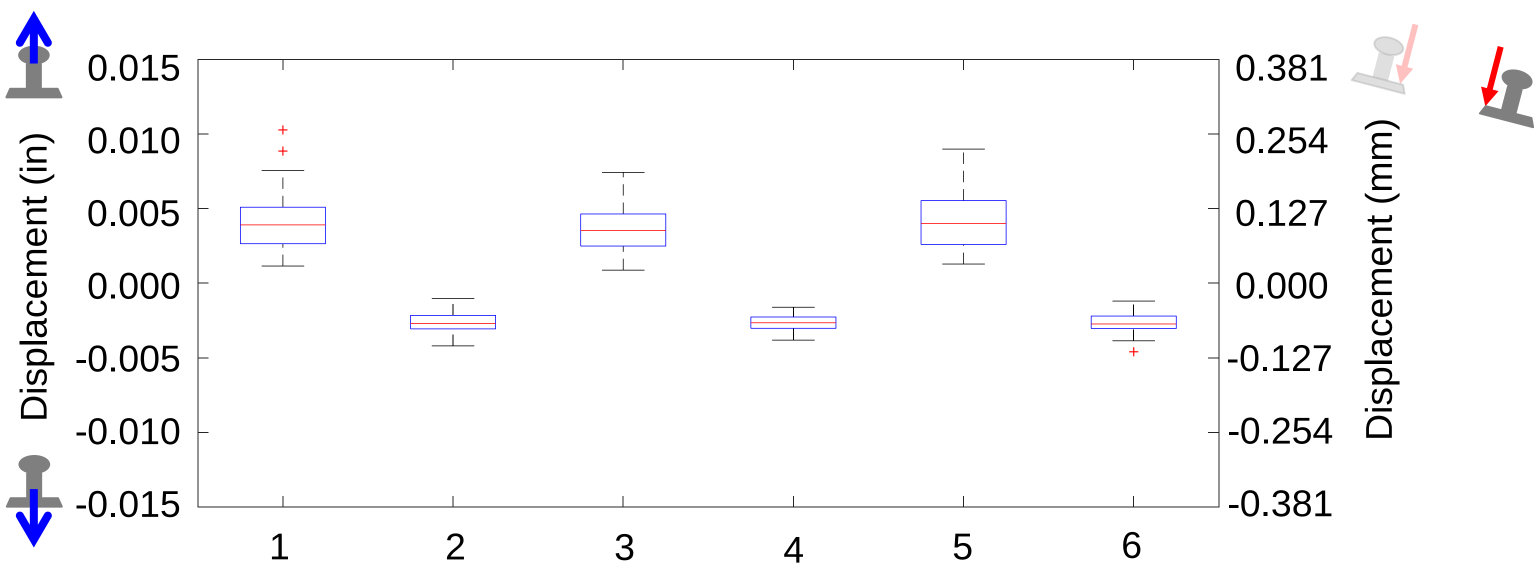




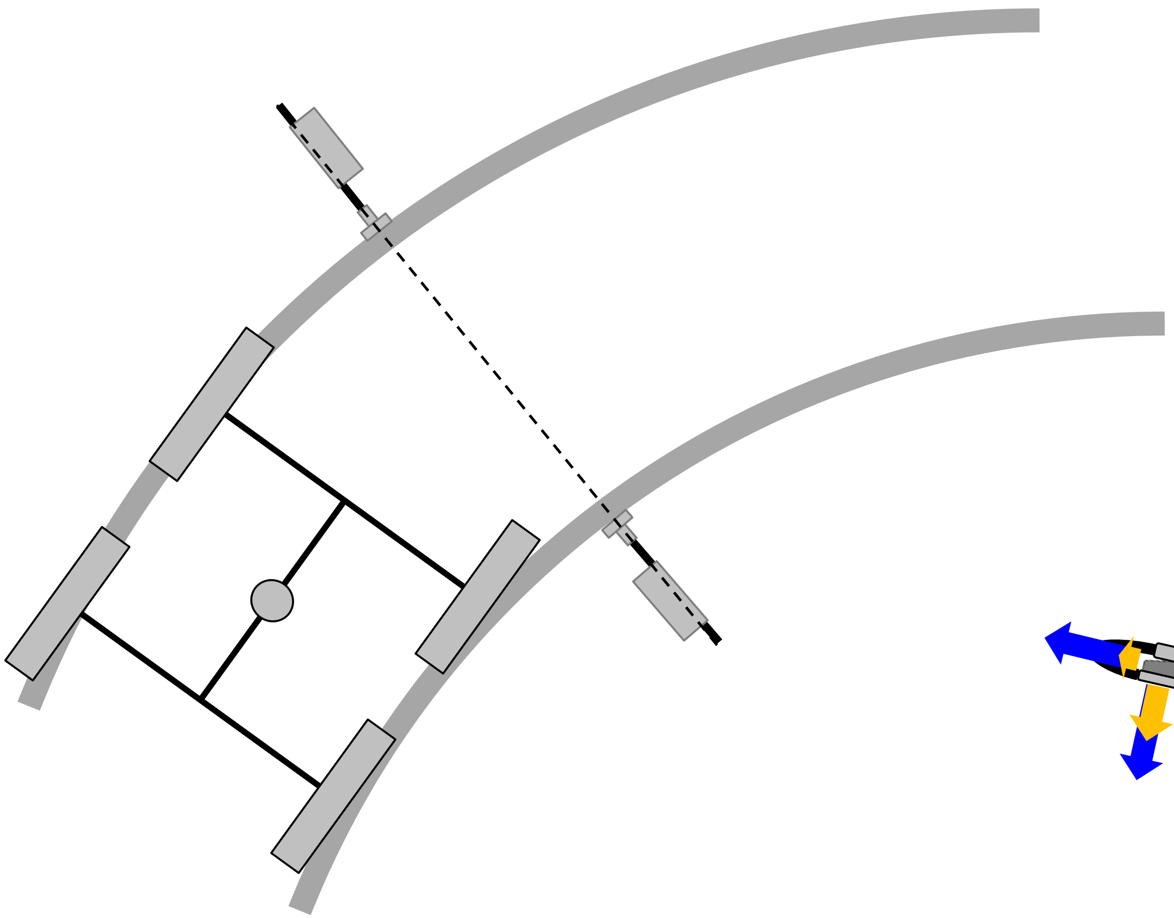
Rail Displacements by Axle

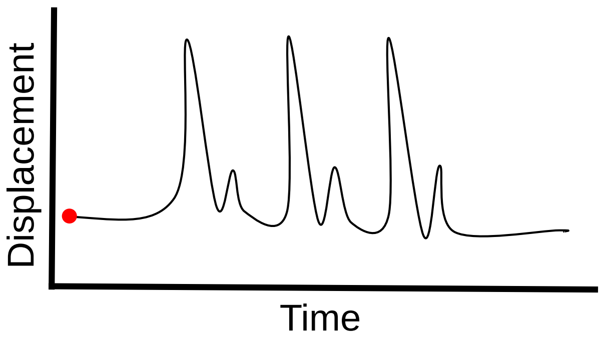
St. Louis MetroLink Curve Site

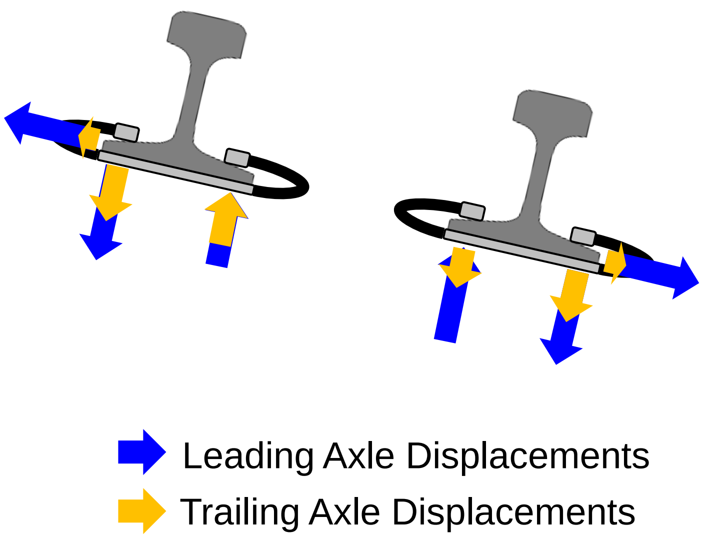




Representation of Curve Results







Light Rail Tangent Data

(Tangent Site)

Trains in Dataset: 6
8 March 2016

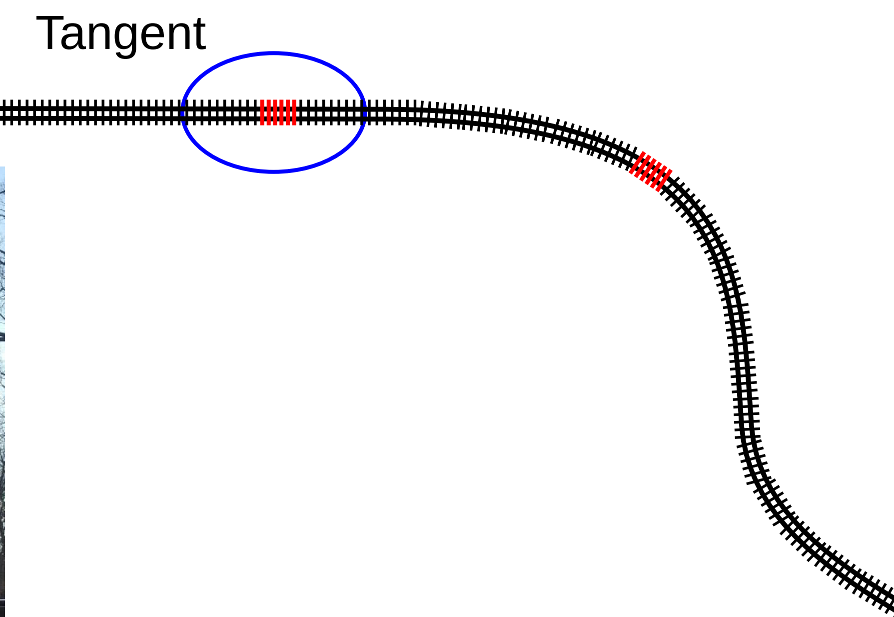
MetroLink Tangent Location

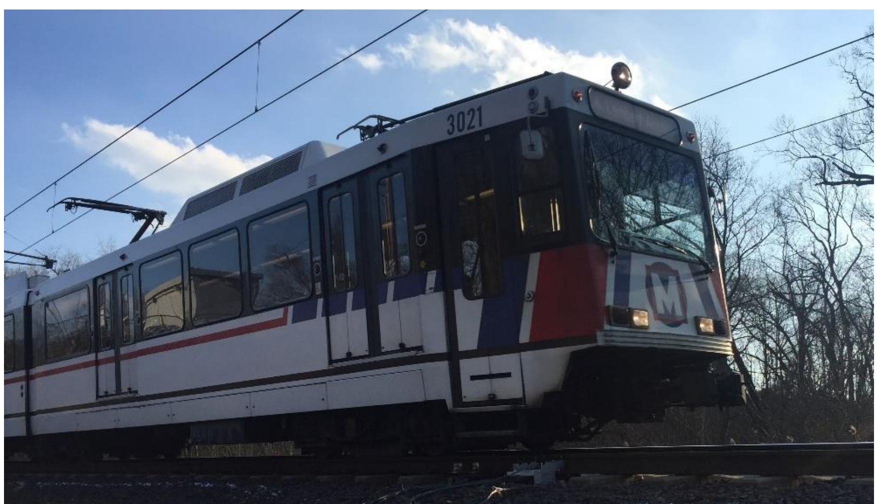
- East St. Louis, IL
- Track speed: 55 MPH
- ~154 trains/day (Red & Blue lines)
- 0.86 miles west of Fairview Heights Station

Track Geometry

St. Louis MetroLink Tangent Site

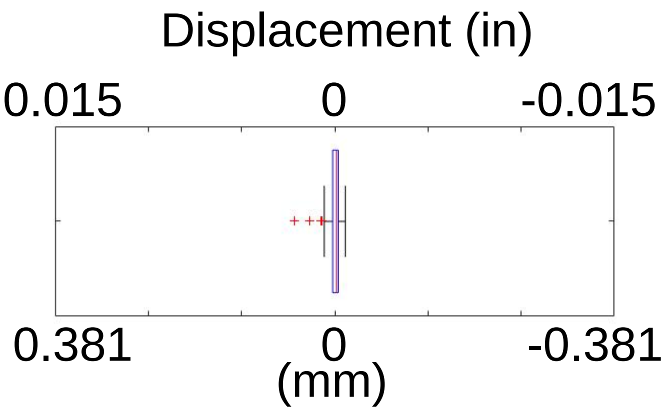
- Tangent site
- Fastening System: Pandrol Fastclip FC
- Measured speeds
  - From 26 mph (42 km/h) to 52 mph (84 km/h)
- One rail instrumented

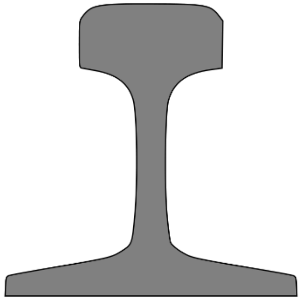


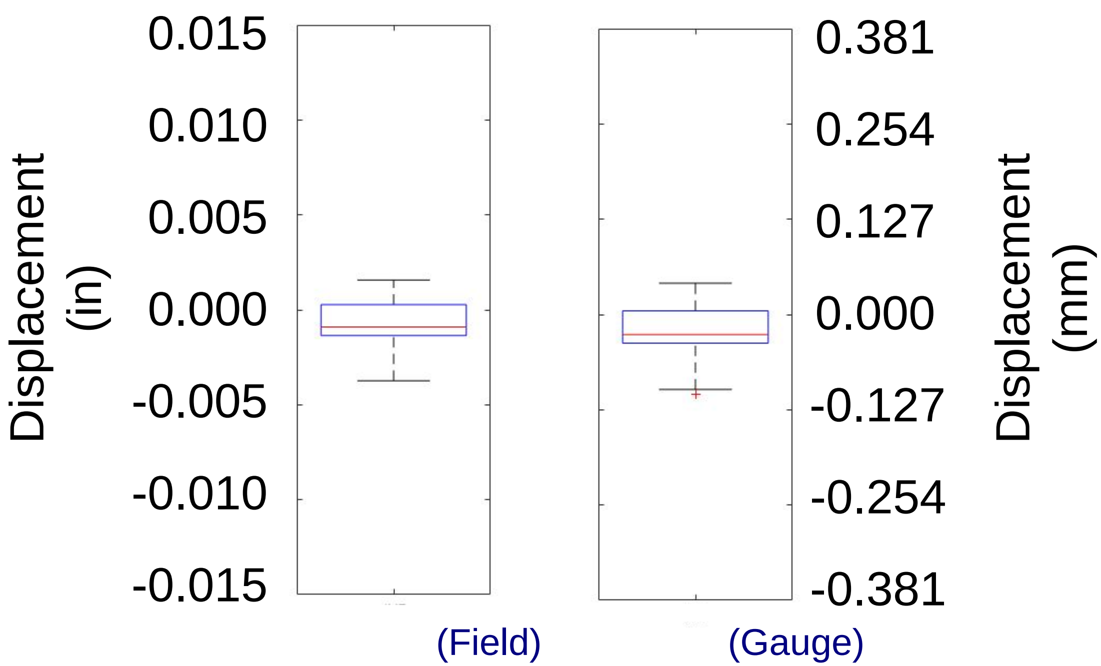


Rail Displacement

St. Louis MetroLink Tangent Site







Results Summary

Maximum Displacement ($in*10^{-3}$)		Curve Site							
		Light Rail		Heavy Rail		Commuter		Freight	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Low Rail	Horizontal	8.6	-1.7	30.4	-3.5	---	---	38.0	---
	Vertical Gauge	10.3	-4.6	27.6	-24.6	---	---	---	---
	Vertical Field	4.2	-11.1	-3.5	-51.2	---	---	---	---
High Rail	Horizontal	11.3	-3.0	22.2	-0.2	---	---	29.0	---
	Vertical Gauge	7.7	-5.8	29.5	-20.1	---	---	---	---
	Vertical Field	3.9	-7.8	-0.4	-30.7	---	---	---	---

Maximum Displacement ($in*10^{-3}$)		Tangent Site							
		Light Rail		Heavy Rail		Commuter		Freight	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Rail A	Horizontal	2.2	-0.5	---	---	---	---	21.5	---
	Vertical Gauge	1.6	-4.2	---	---	---	---	---	---
	Vertical Field	1.6	-3.7	---	---	---	---	---	---

- Minor displacements under light rail transit revenue service (track equipment not accounted)
- Other rail transit systems to be analyzed to fill in the table

Conclusions

- Horizontal displacement consistently to the field side, resulting in gauge opening
- Larger displacements were found at the curve site
- For curve site:
  - Gauge side alternates positive and negative values
  - Leading axles caused the largest displacements in the system
  - Rotation of the rail found to be towards field side
- For tangent site:
  - Rotation of rail almost negligible
  - Minor lateral displacements due to rocking of LRV

Future Work

- Compare obtained results with working range of fastening system to assess performance
- Expand understanding of speed and load effect on displacements
- Repeat work for different rail transit loading conditions
- Compare with analytical models, Finite Element models, and laboratory experimentation
- Study the effect and contribution of each element of the fastening system to the overall behavior

Acknowledgements

U.S. Department of Transportation
Federal Transit Administration

NURail Center

FTA Industry Partners:

- **Funding for this research has been provided by:**
  - **Federal Transit Administration (FTA)**
  - **National University Rail Center (NURail Center)**
- Industry partnership and support has been provided by:
  - American Public Transportation Association (APTA)
  - New York City Transit (NYCTA)
  - Metra (Chicago, Ill.)
  - MetroLink (St. Louis, Mo.)
  - TriMet (Portland, Ore.)
  - Pandrol USA
  - Progress Rail Services
  - LBFoster, CXT Concrete Ties
  - GIC USA
  - Hanson Professional Services, Inc.
  - Amtrak

Contact Information

Alvaro E. Canga Ruiz
Graduate Research Assistant
cangaru2@illinois.edu

Matthew V. Csenge
Manager of Experimentation
csenge2@illinois.edu

J. Riley Edwards
Senior Lecturer and Research Scientist
jedward2@illinois.edu

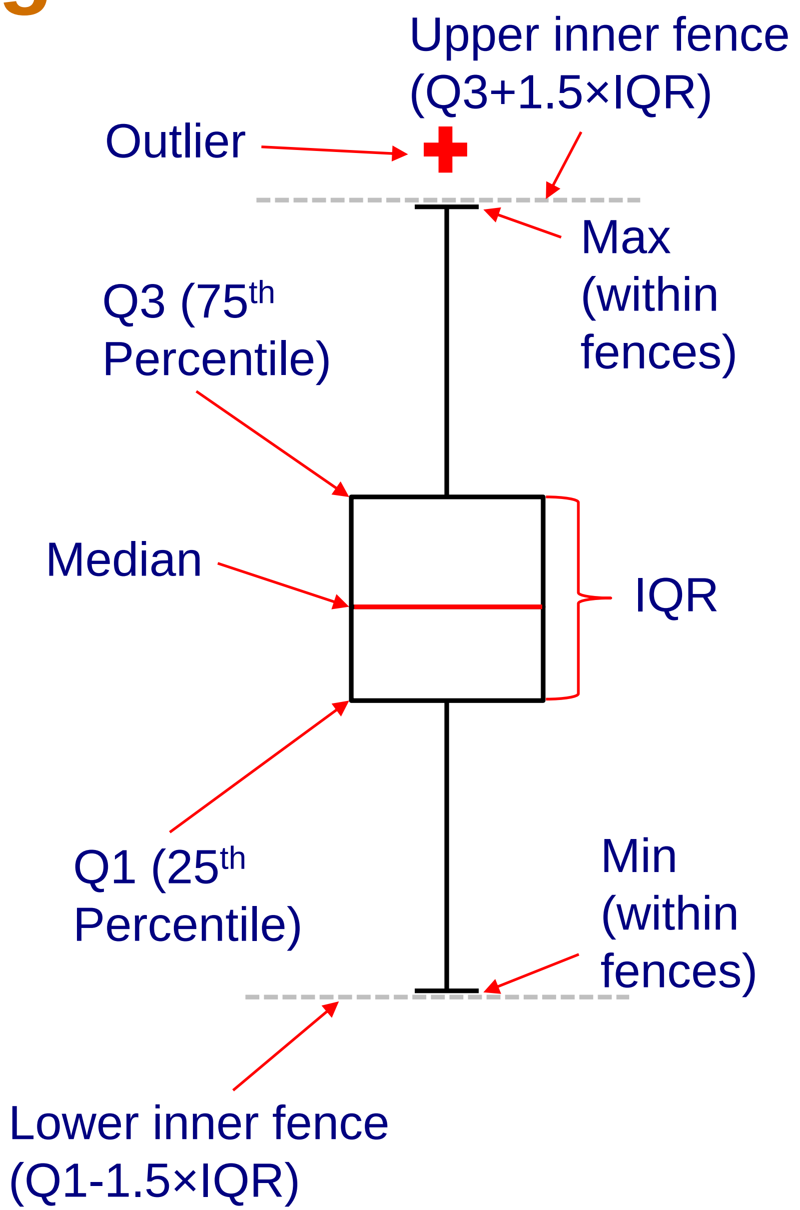
Yu Qian
Research Engineer
yuqian1@illinois.edu

Marcus S. Dersch
Senior Research Engineer
mdersch2@illinois.edu

Appendix

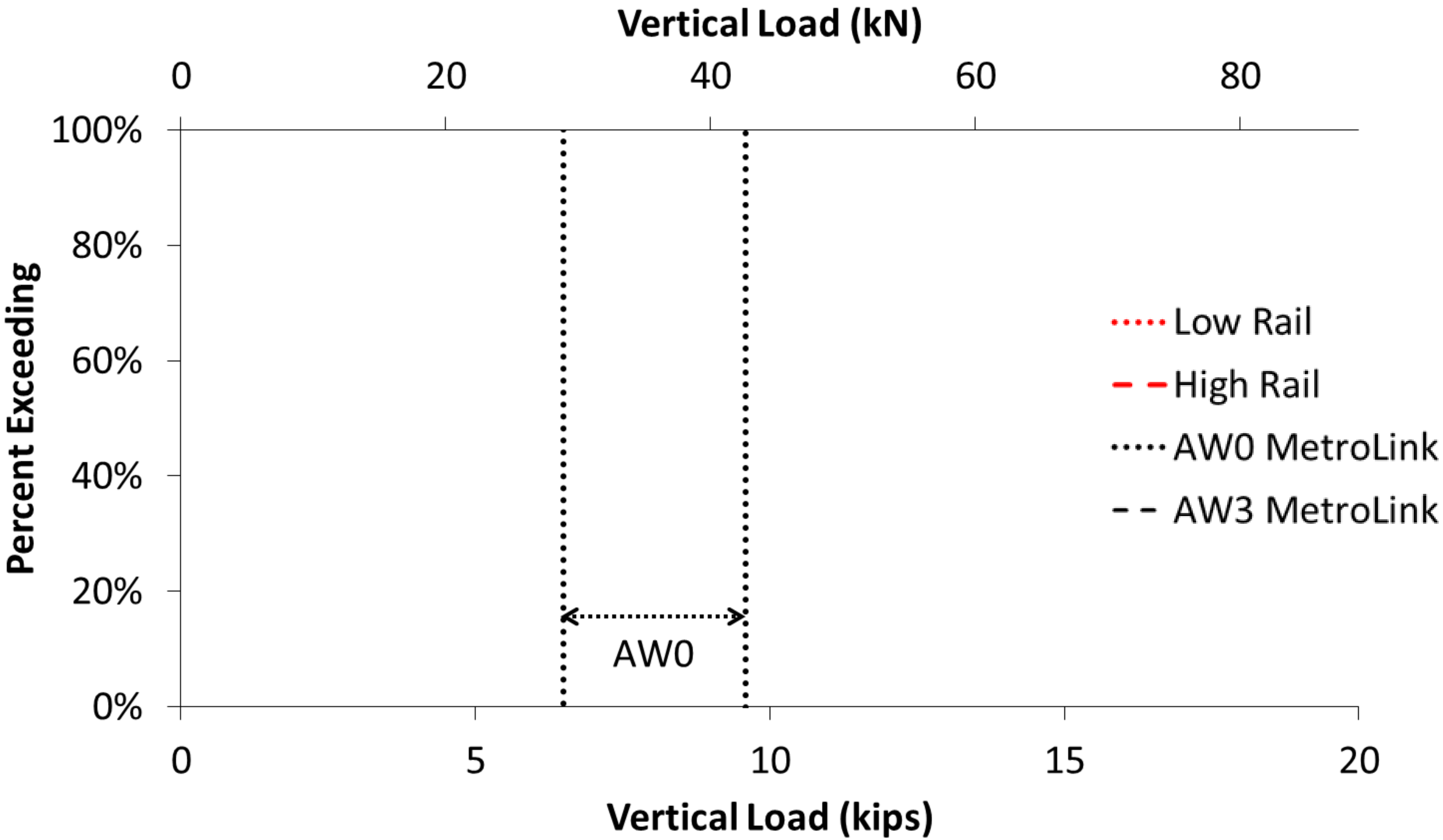
Box Plot Background

- Box plots are great to:
  - Visualize outliers
  - Compare variability of different cases
  - Check for symmetry
  - Check for normality



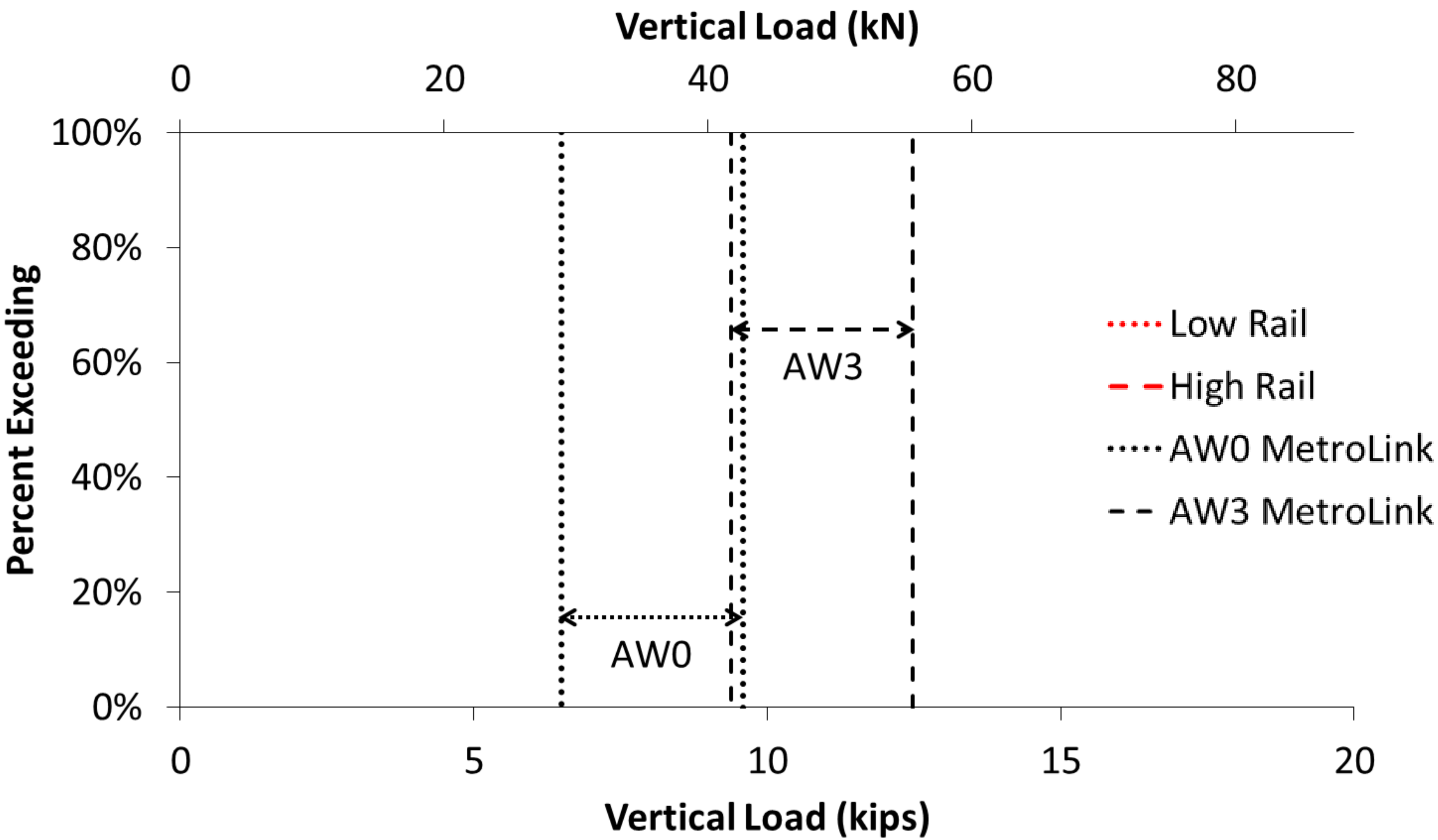
Vertical Rail Loads

St. Louis MetroLink – Curve Location



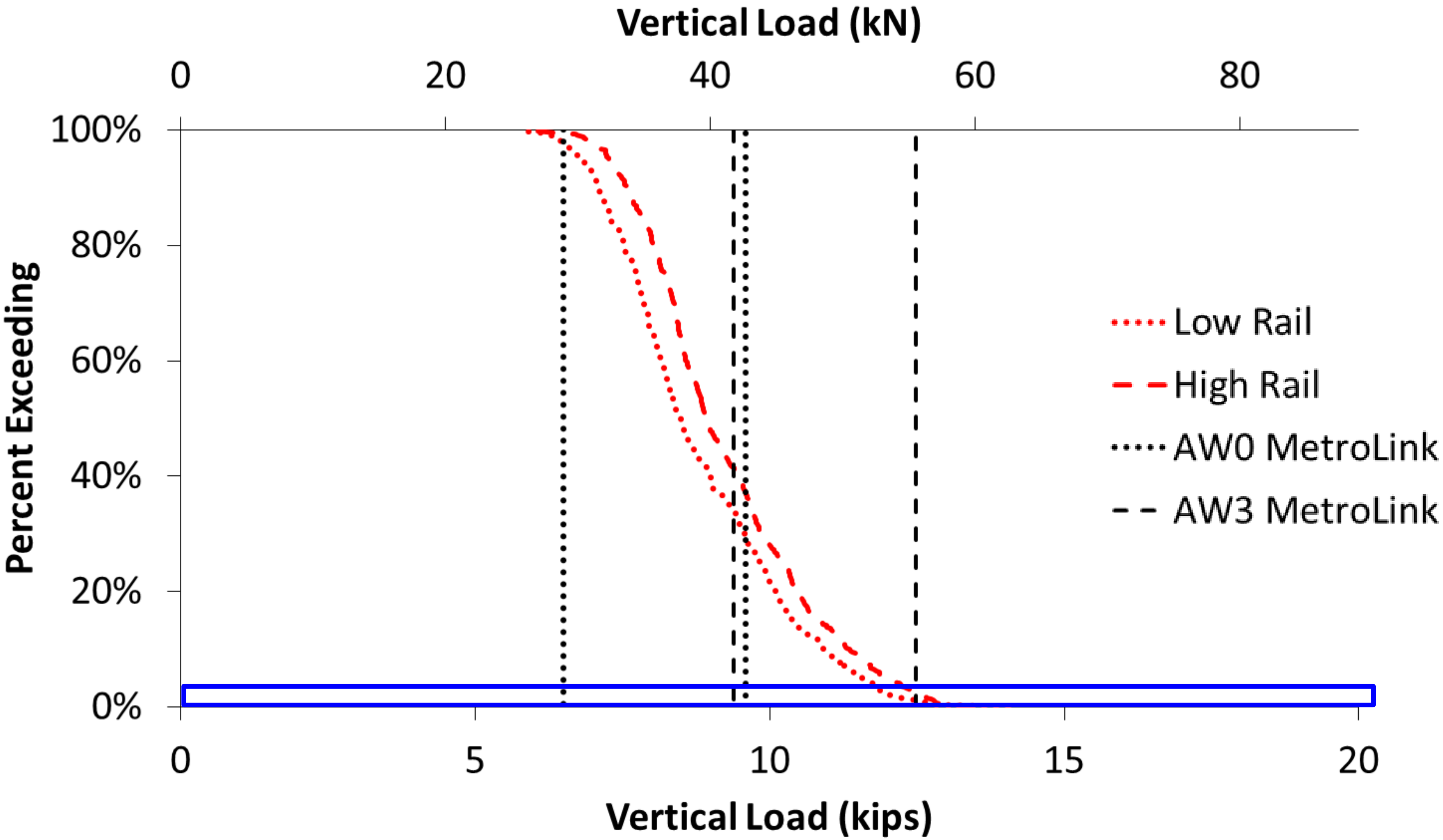
Vertical Rail Loads

St. Louis MetroLink – Curve Location



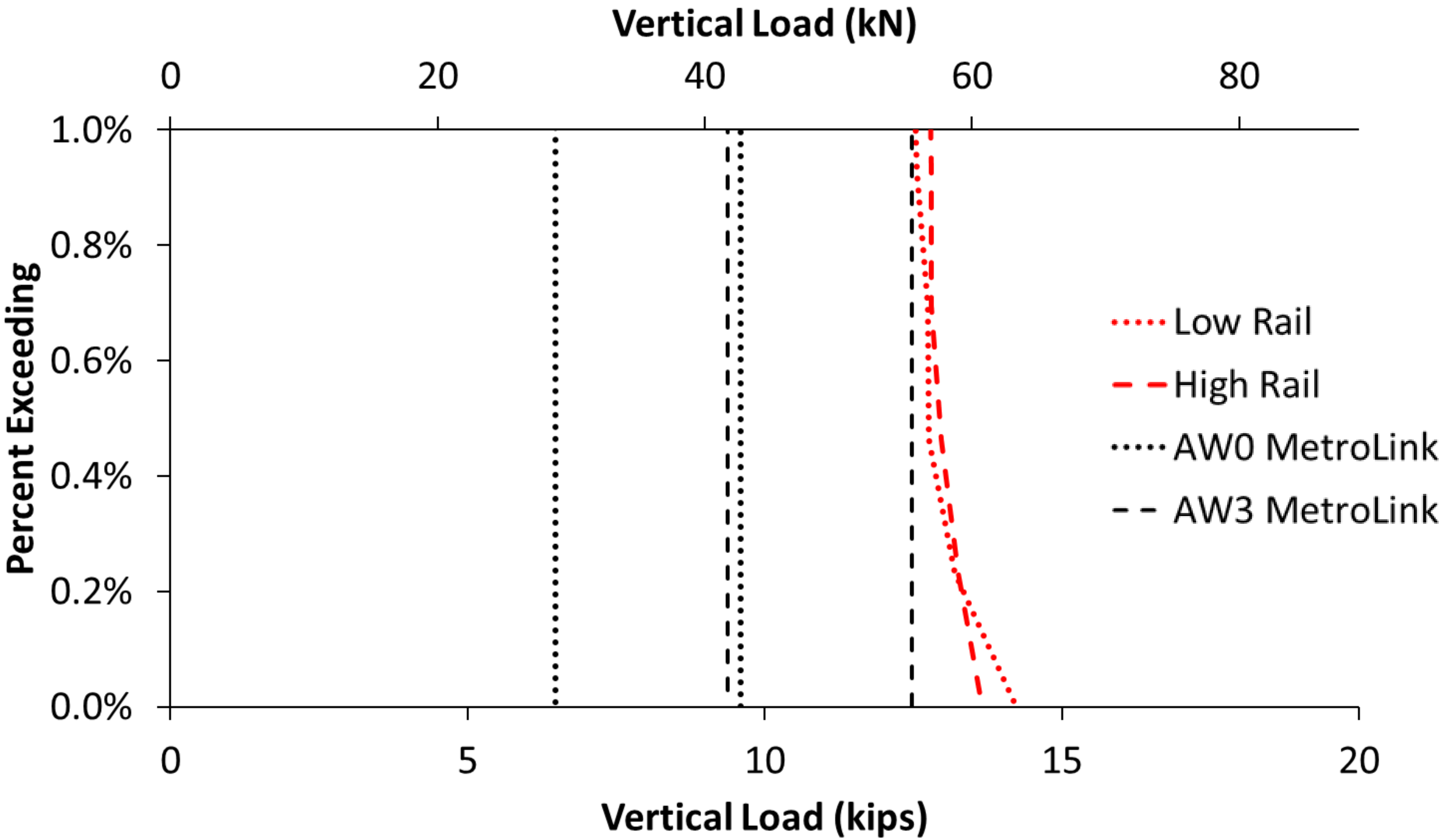
Vertical Rail Loads

St. Louis MetroLink – Curve Location



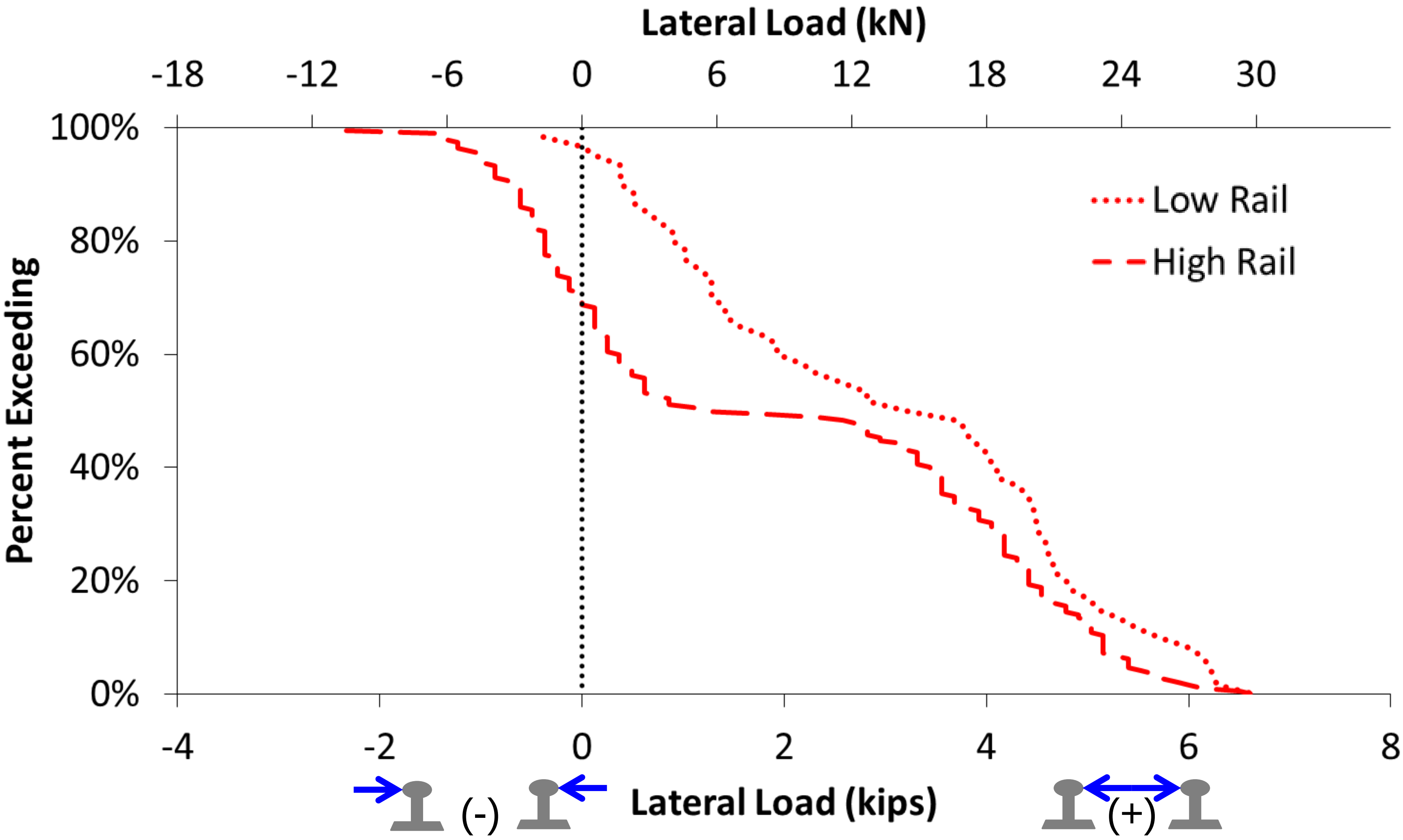
Vertical Rail Loads

St. Louis MetroLink – Curve Location



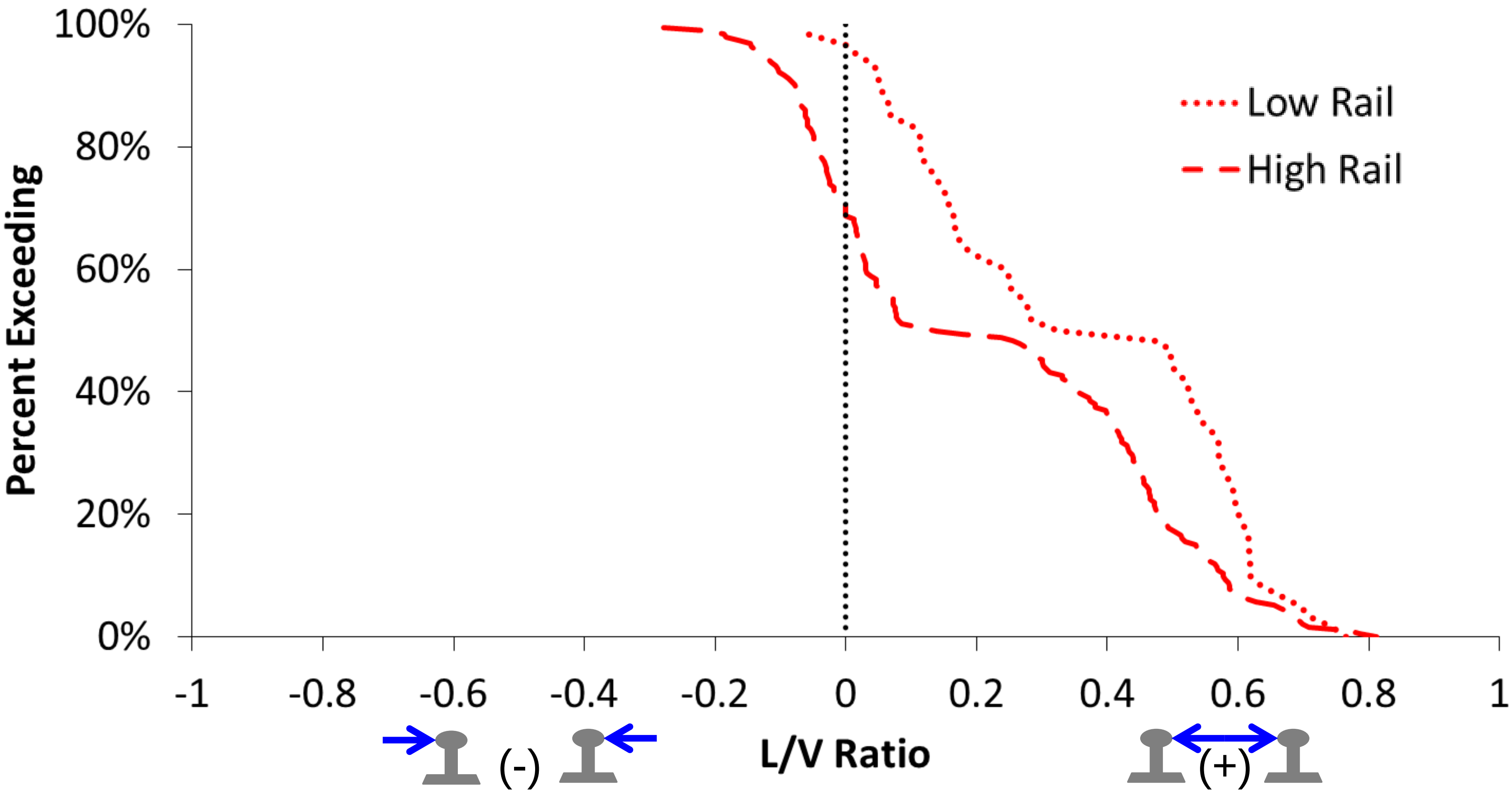
Lateral Rail Loads

St. Louis MetroLink – Curve Location



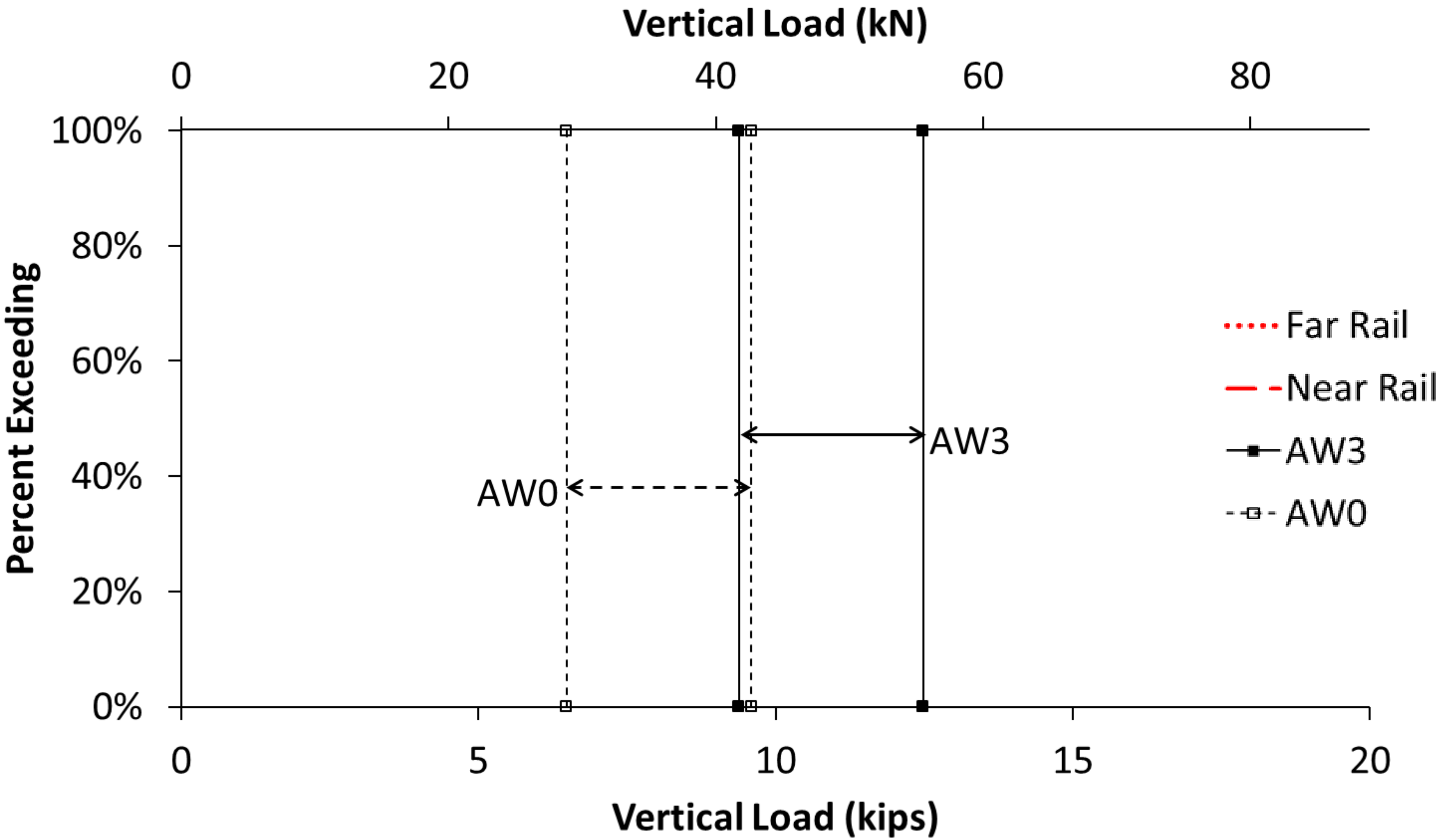
Lateral/Vertical (L/V) Ratios

St. Louis MetroLink – Curve Location



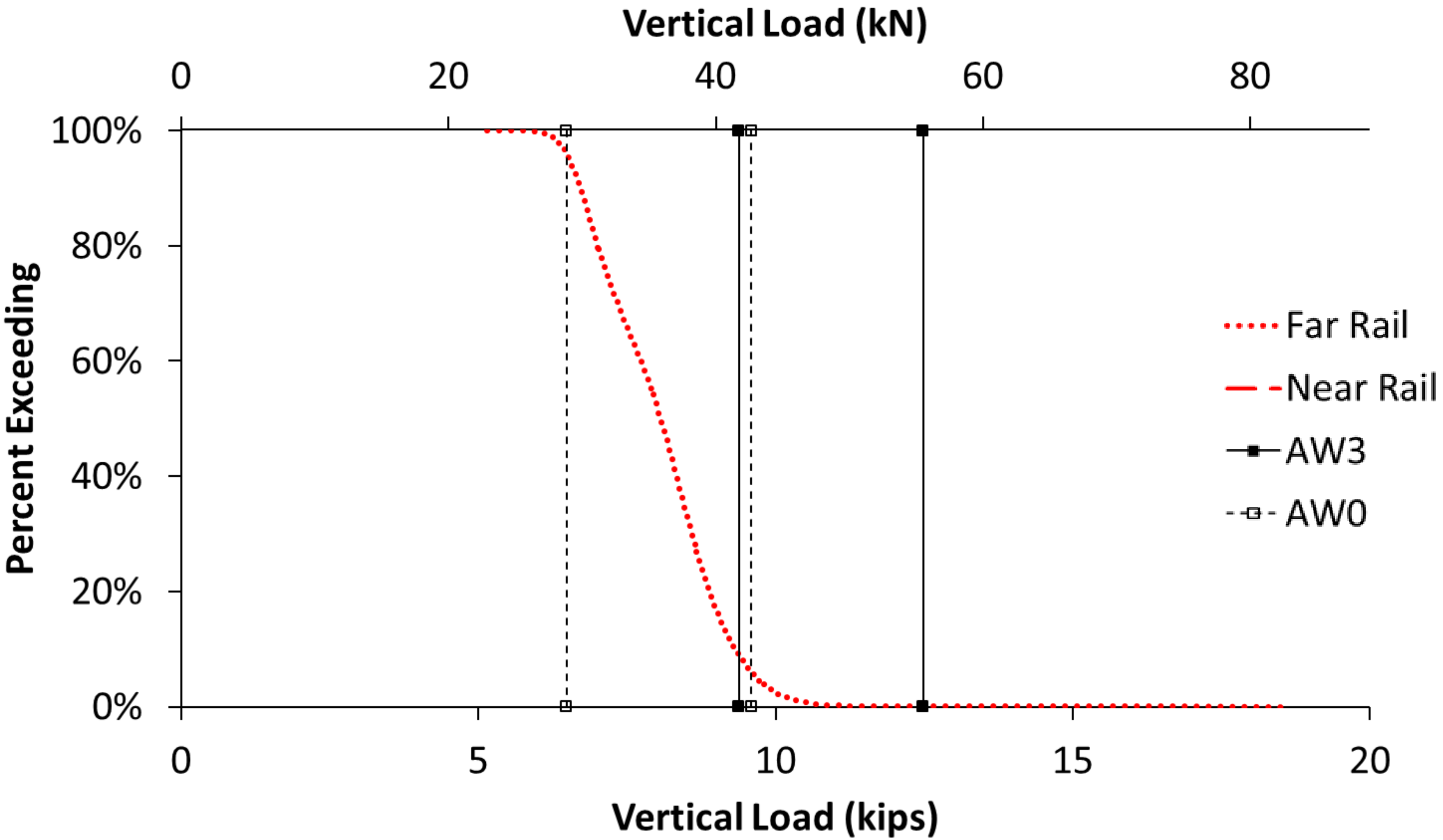
Vertical Rail Loads

St. Louis MetroLink – Tangent Location



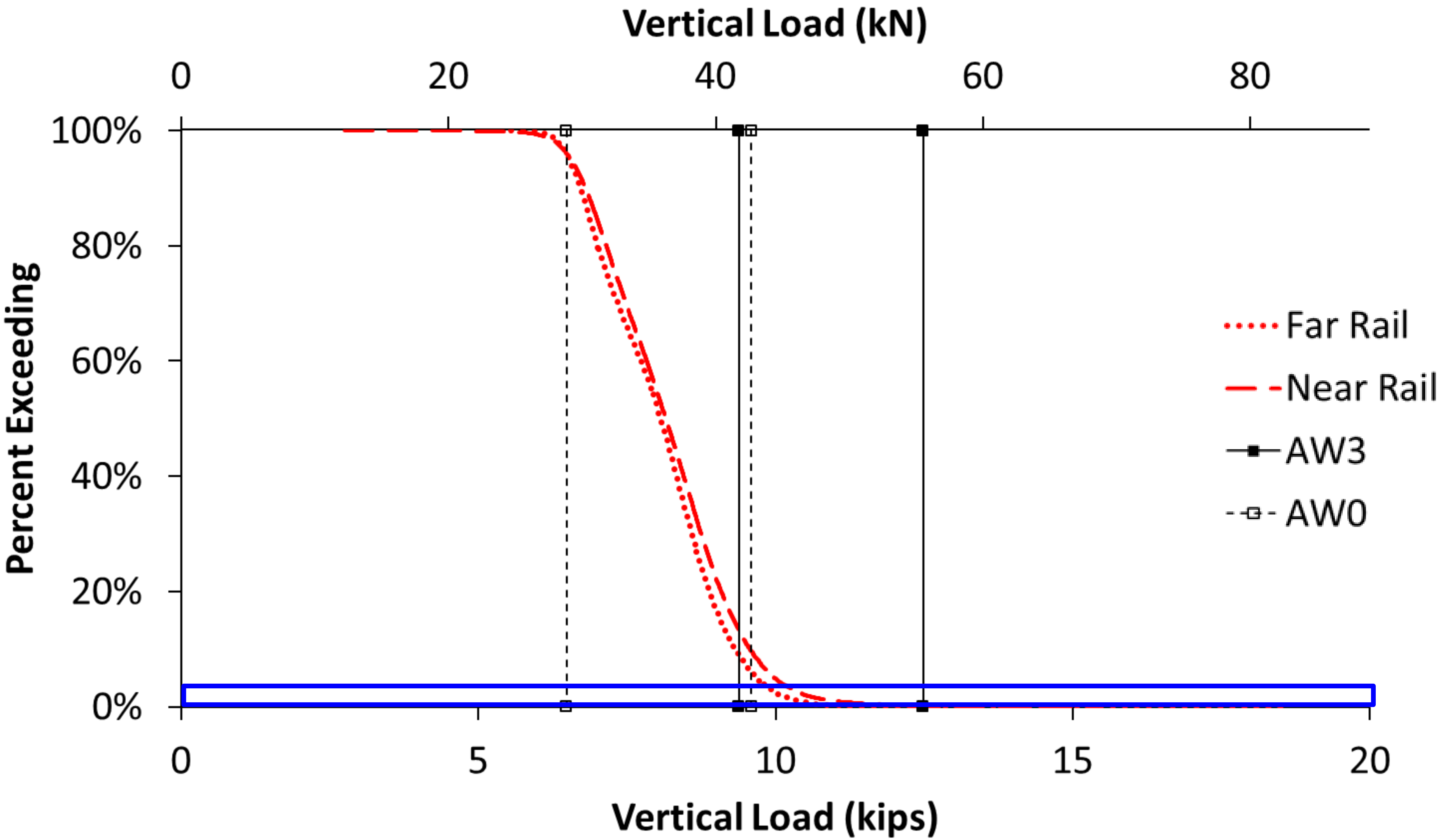
Vertical Rail Loads

St. Louis MetroLink – Tangent Location



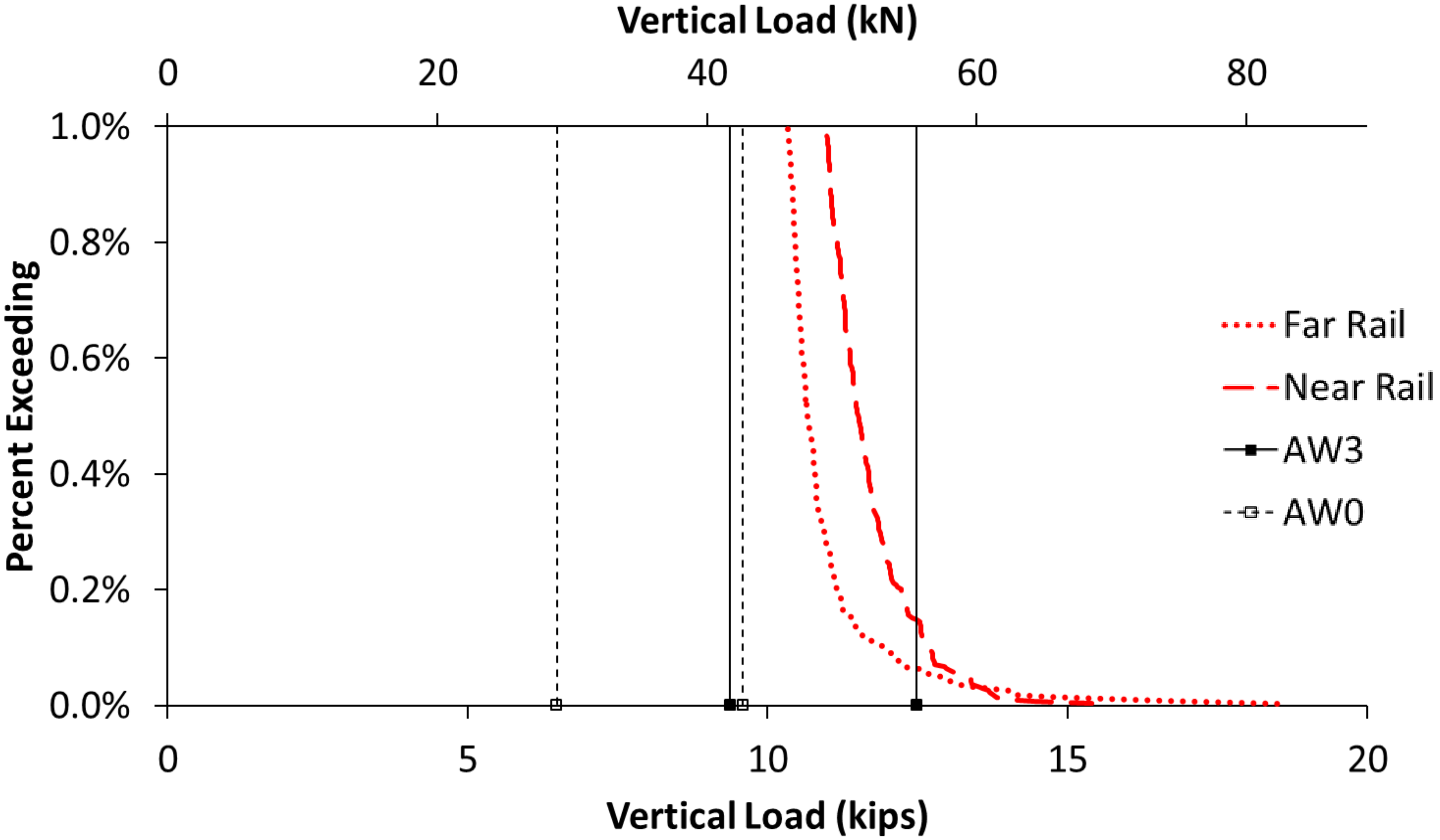
Vertical Rail Loads

St. Louis MetroLink – Tangent Location



Vertical Rail Loads

St. Louis MetroLink – Tangent Location



Lateral Rail Loads

St. Louis MetroLink – Tangent Location