Characterization of Vertical and Lateral Wheel Loads



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U.S. Department of Transportation
Federal Railroad Administration

Outline

- Method of Quantifying Loads
- Vertical Load Variation
- Lateral Load Variation
- Wheel Load Tables
- Conclusion

Overview of Mechanistic Design

- Design approach utilizing forces measured in track structure and properties of materials that will withstand or transfer them
- Uses responses (e.g. contact pressure, relative displacement) to optimize component geometry and materials requirements
- Based on measured and predicted response to load inputs that can be supplemented with practical experience
- Requires thorough understanding of load path and distribution
- Allows load factors to be used to include variability due to location and traffic composition
- Used in other engineering industries (e.g. pavement design, structural steel design, geotechnical)

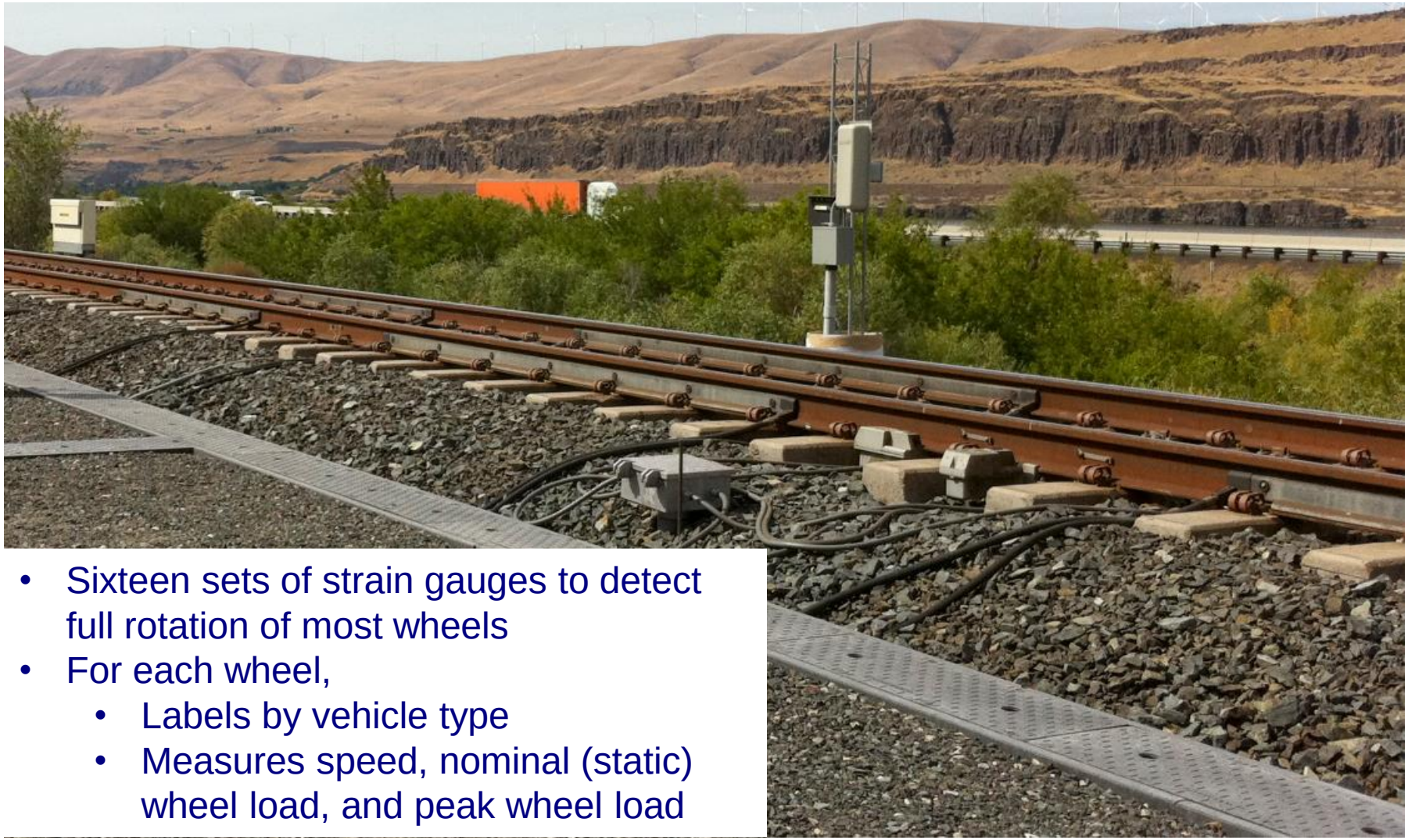
Objectives

- Measure magnitude and distribution of wheel loads to be used as an input for mechanistic design
- Quantify variation due to:
  - Car Type and Weight
  - Speed
  - Seasonal Variation
  - Cant Deficiency
- Develop wheel load tables for use in design

Measurement Technologies

Vertical Wheel Load Measurement

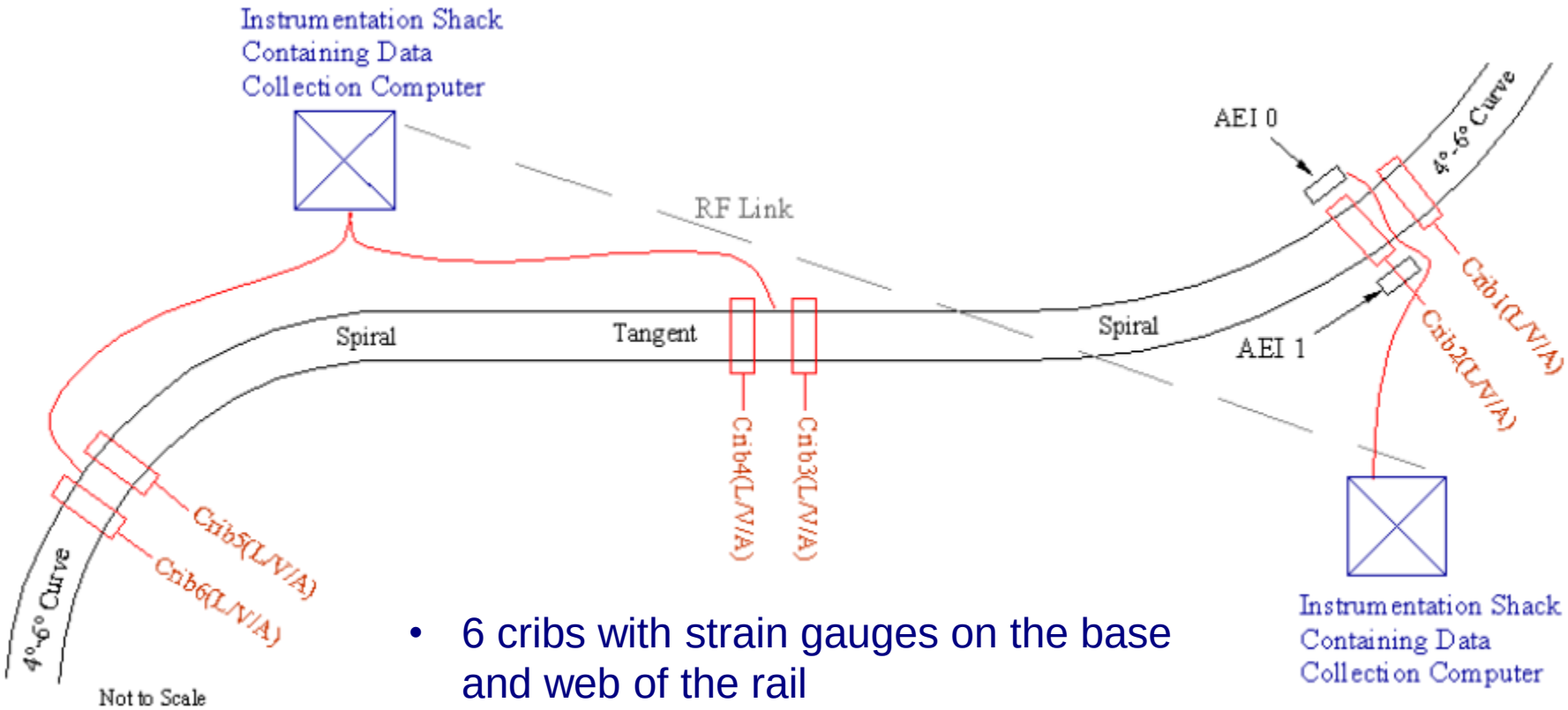
Wheel Impact Load Detectors (WILD)



- Sixteen sets of strain gauges to detect full rotation of most wheels
- For each wheel,
  - Labels by vehicle type
  - Measures speed, nominal (static) wheel load, and peak wheel load

Lateral Wheel Load Measurement

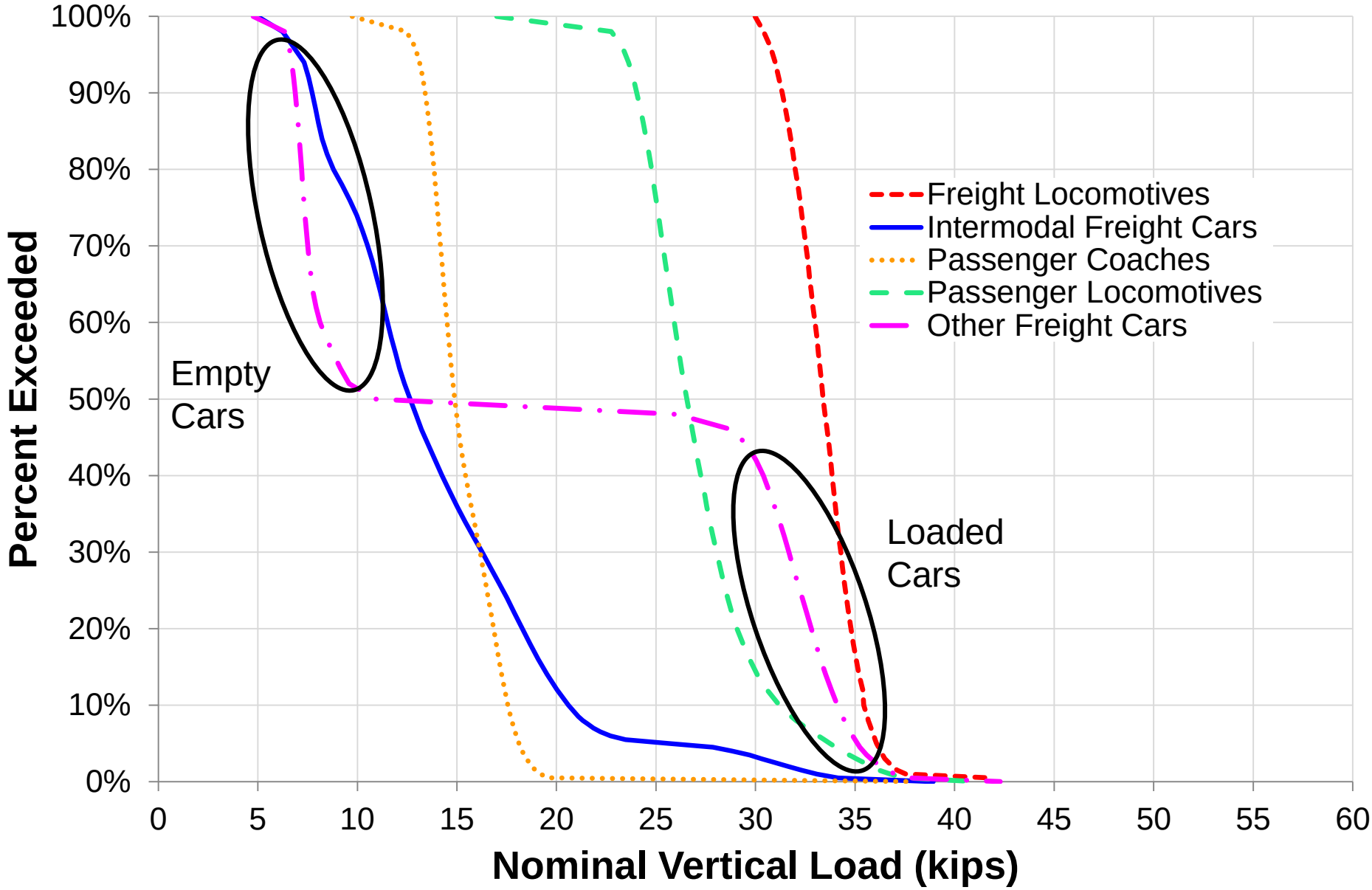
Truck Performance Detectors (TPD)



- 6 cribs with strain gauges on the base and web of the rail
- For each wheel,
  - Labels by vehicle type
  - Measures peak vertical and lateral load

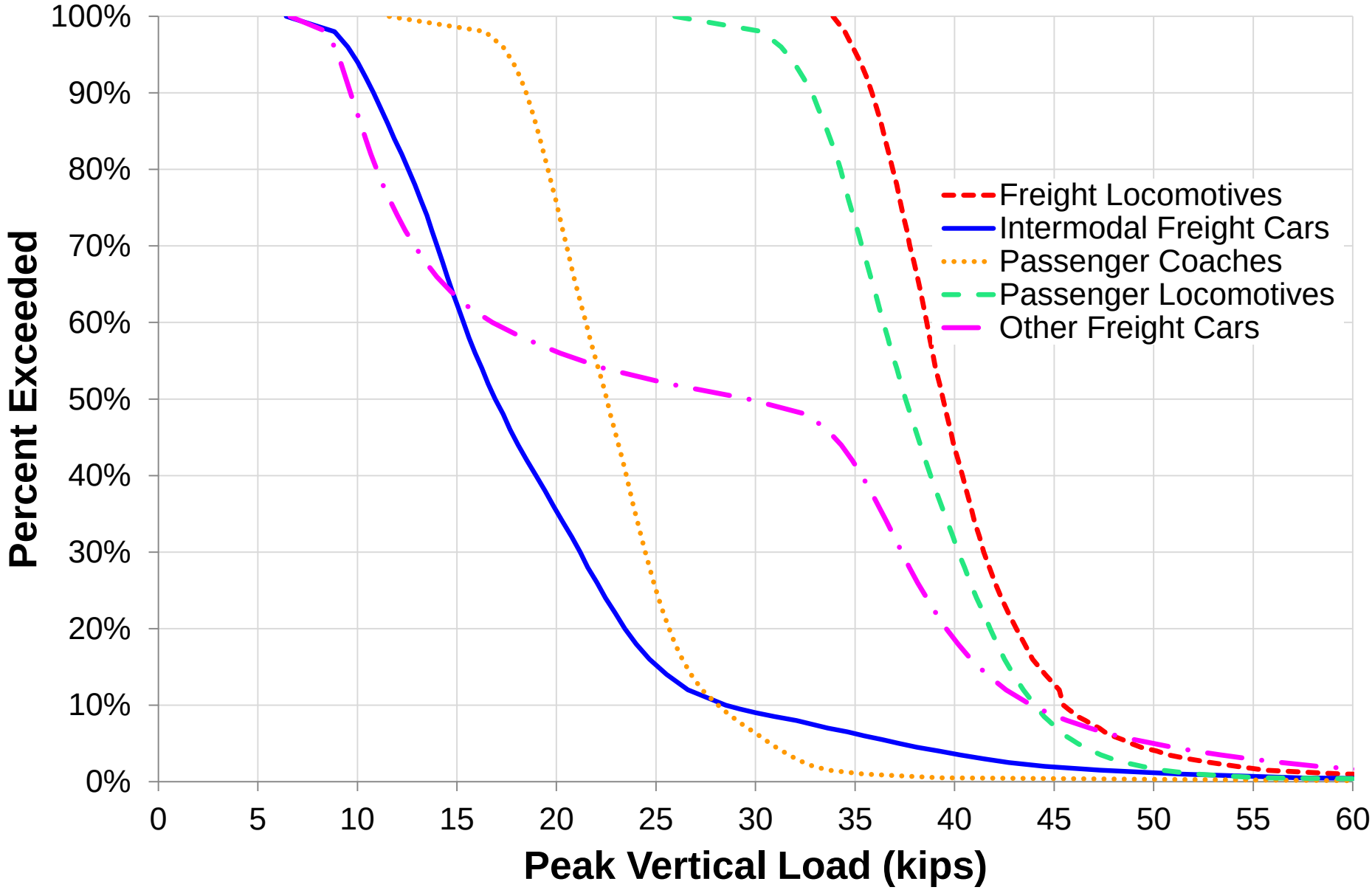
Vertical Load Variation

Traffic Distribution – Nominal Wheel Loads



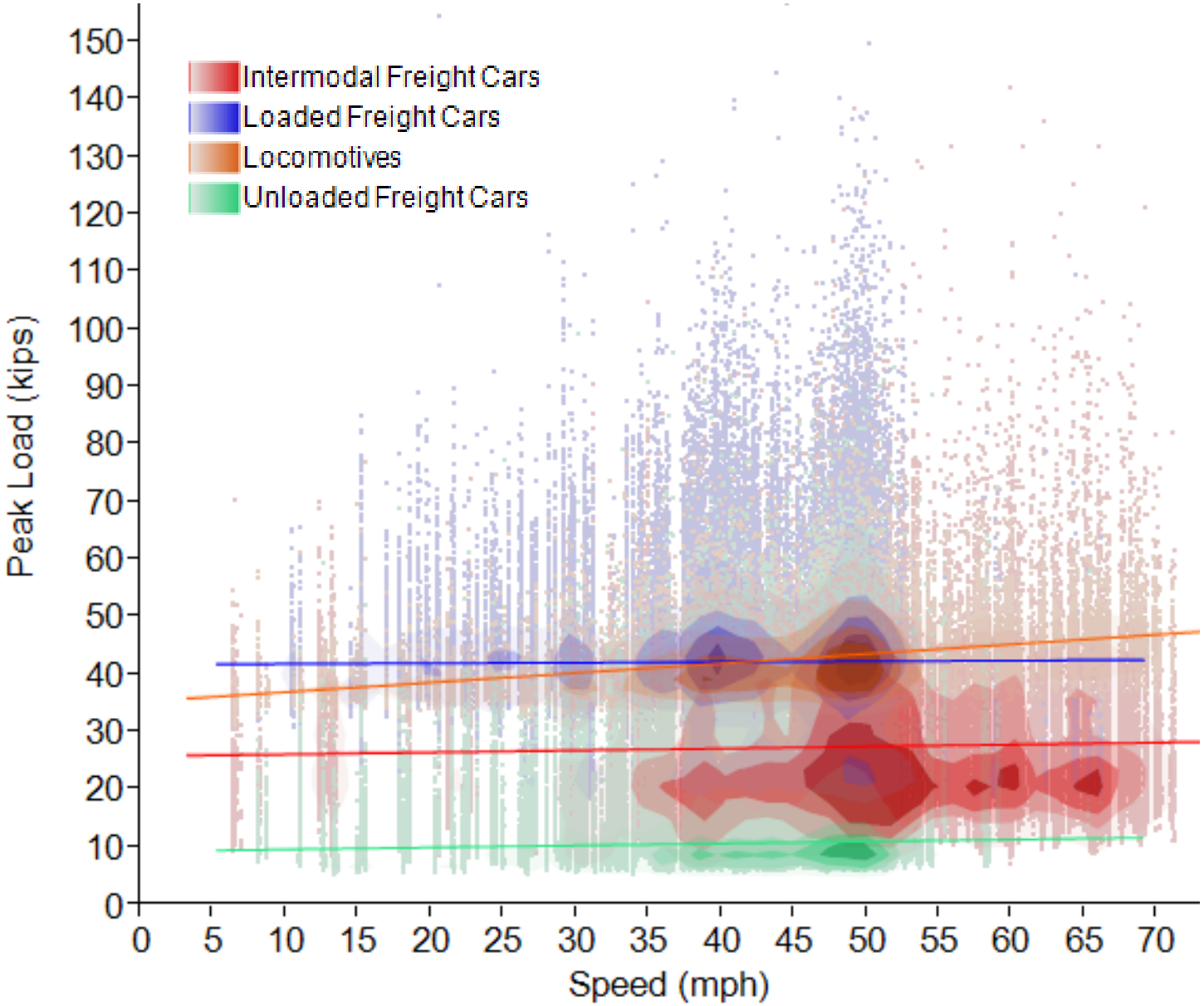
Source: Amtrak – Edgewood, MD (November 2010)

Traffic Distribution – Peak Wheel Loads

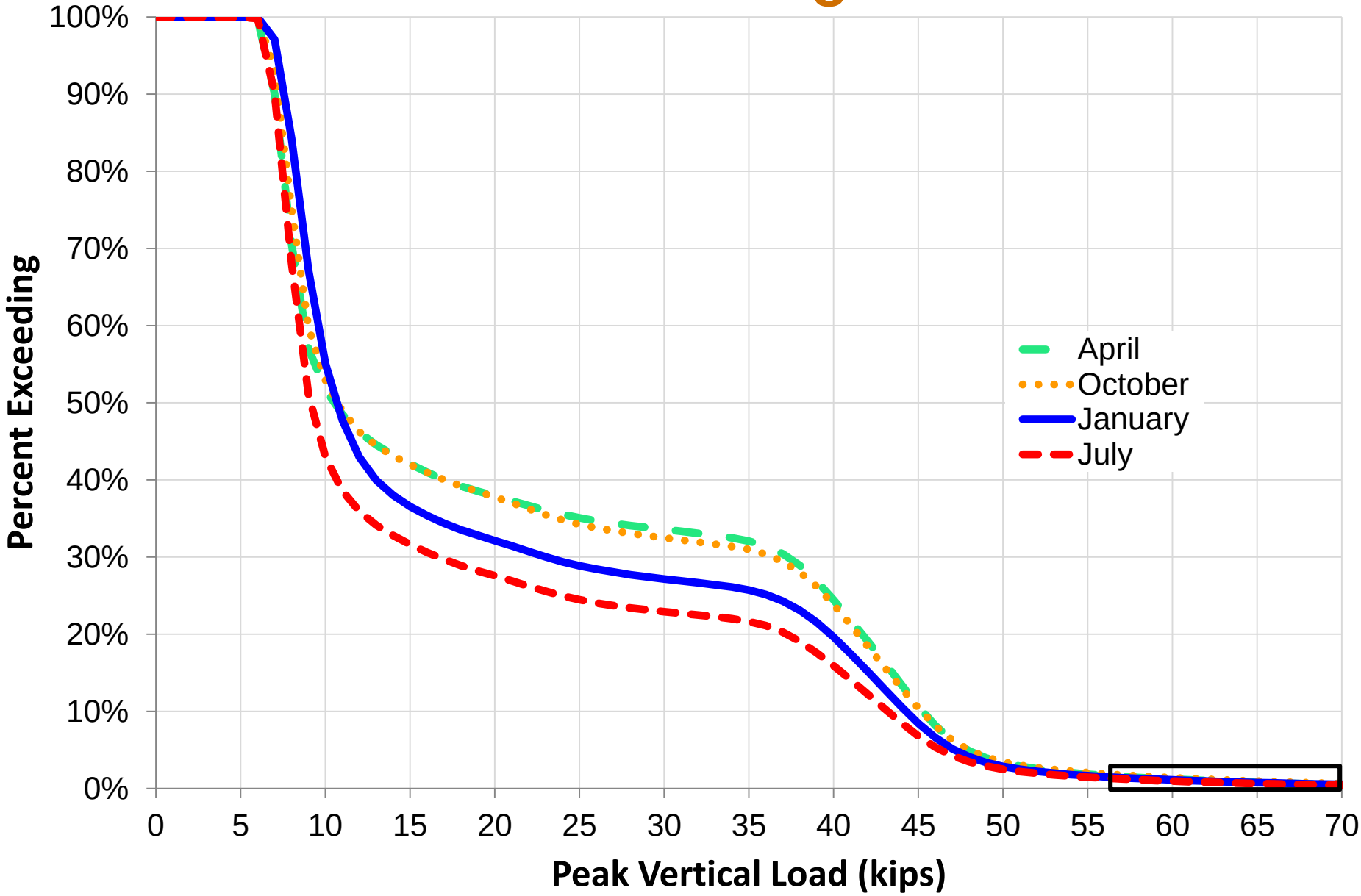


Source: Amtrak – Edgewood, MD (November 2010)

Vertical Load Variation - Speed



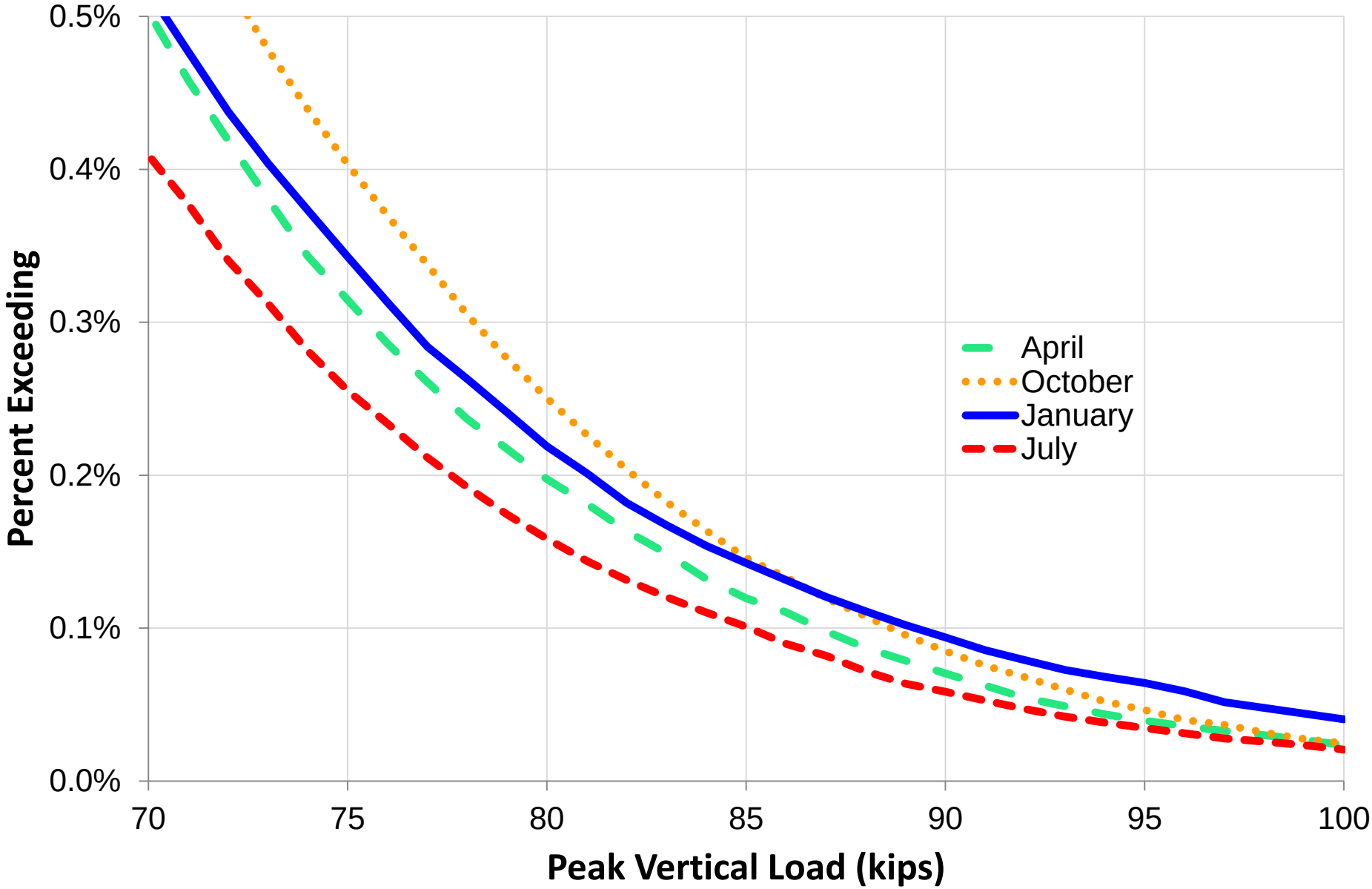
Seasonal Variation of Freight Wheel Loads



Source: Union Pacific – Gothenburg, NE (2010)

10 kips ≈ 45 kN

Seasonal Variation of Highest Freight Wheel Loads

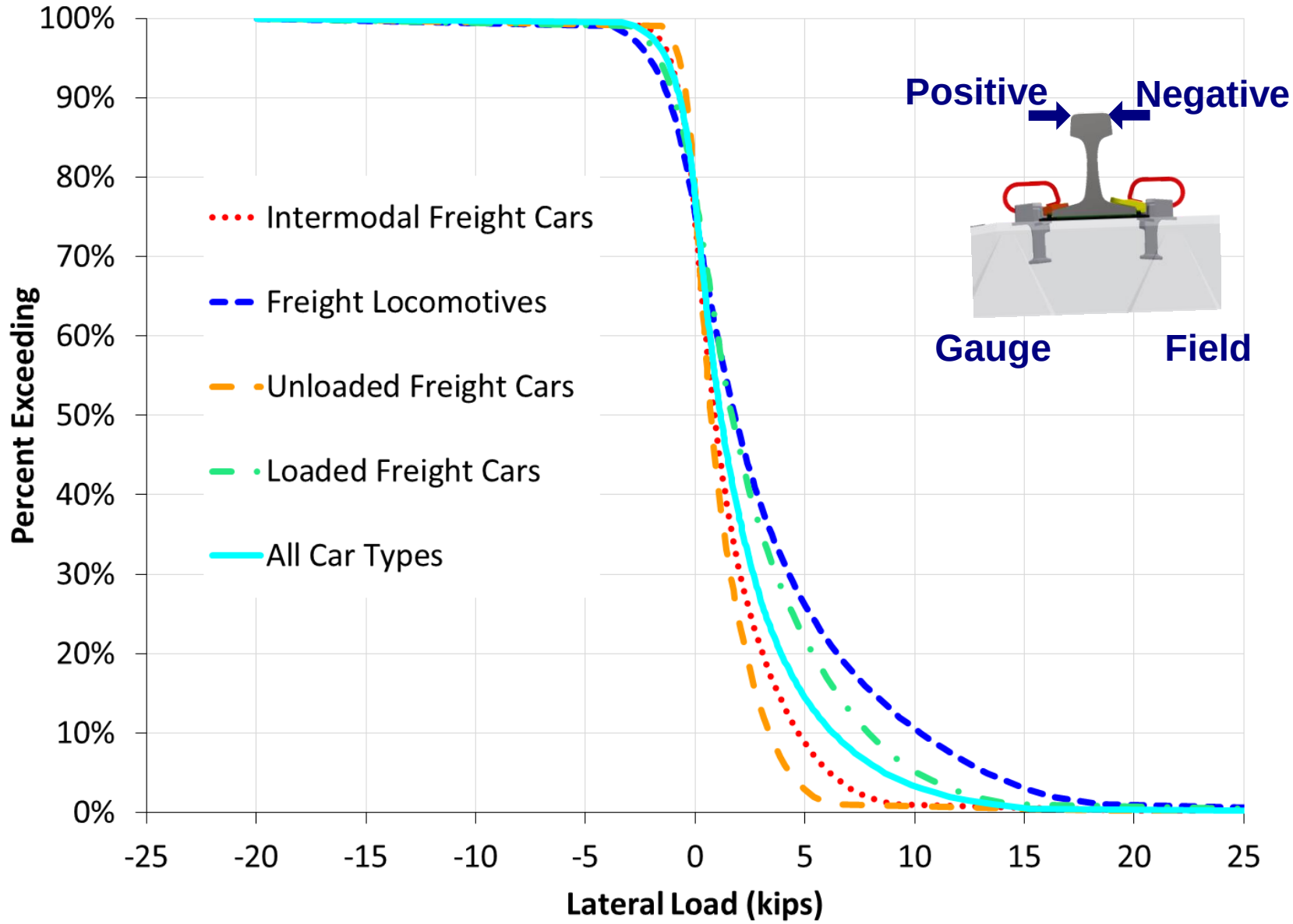


Source: Union Pacific – Gothenburg, NE (2010)

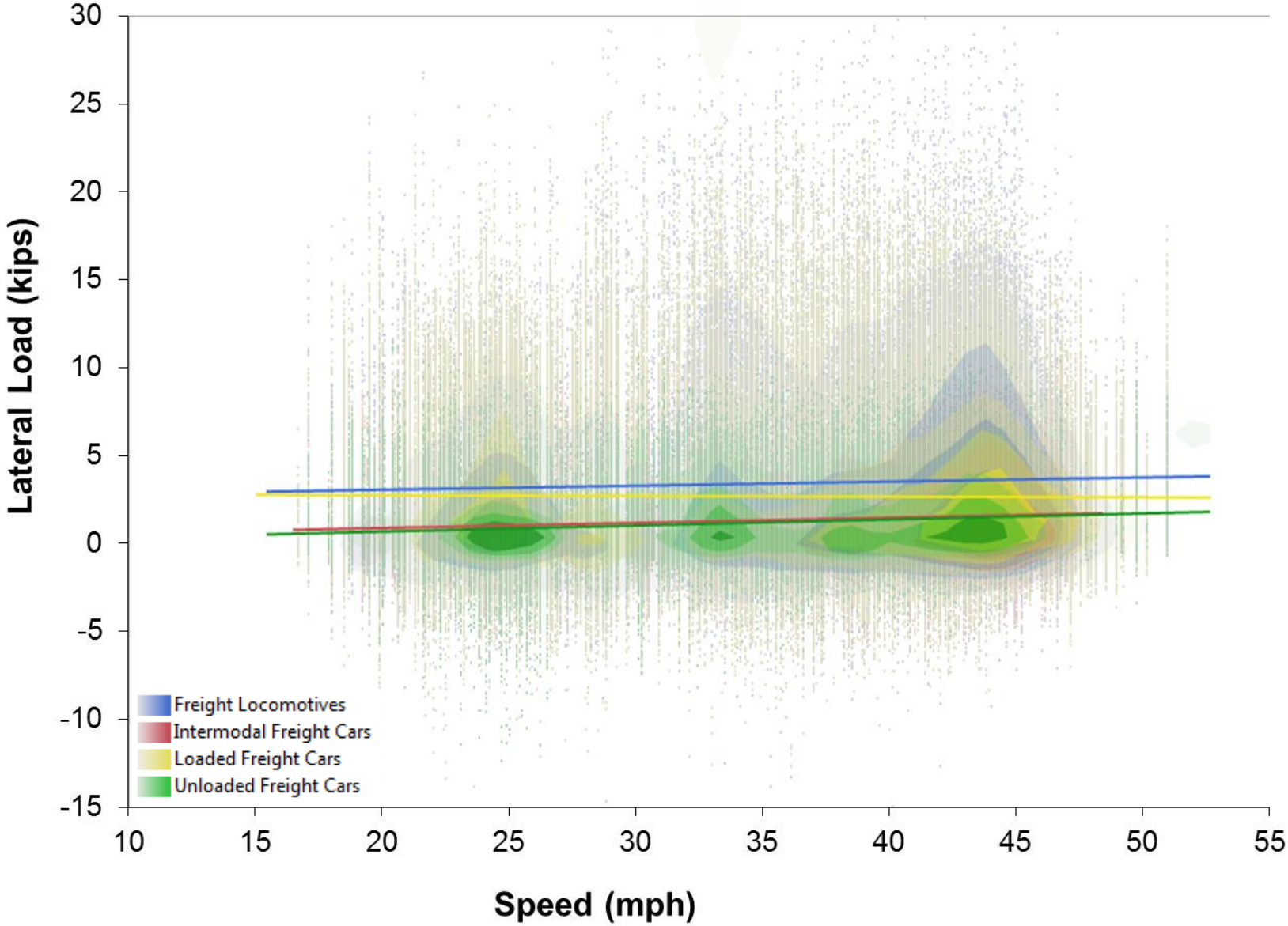
10 kips ≈ 45 kN

Lateral Load Variation

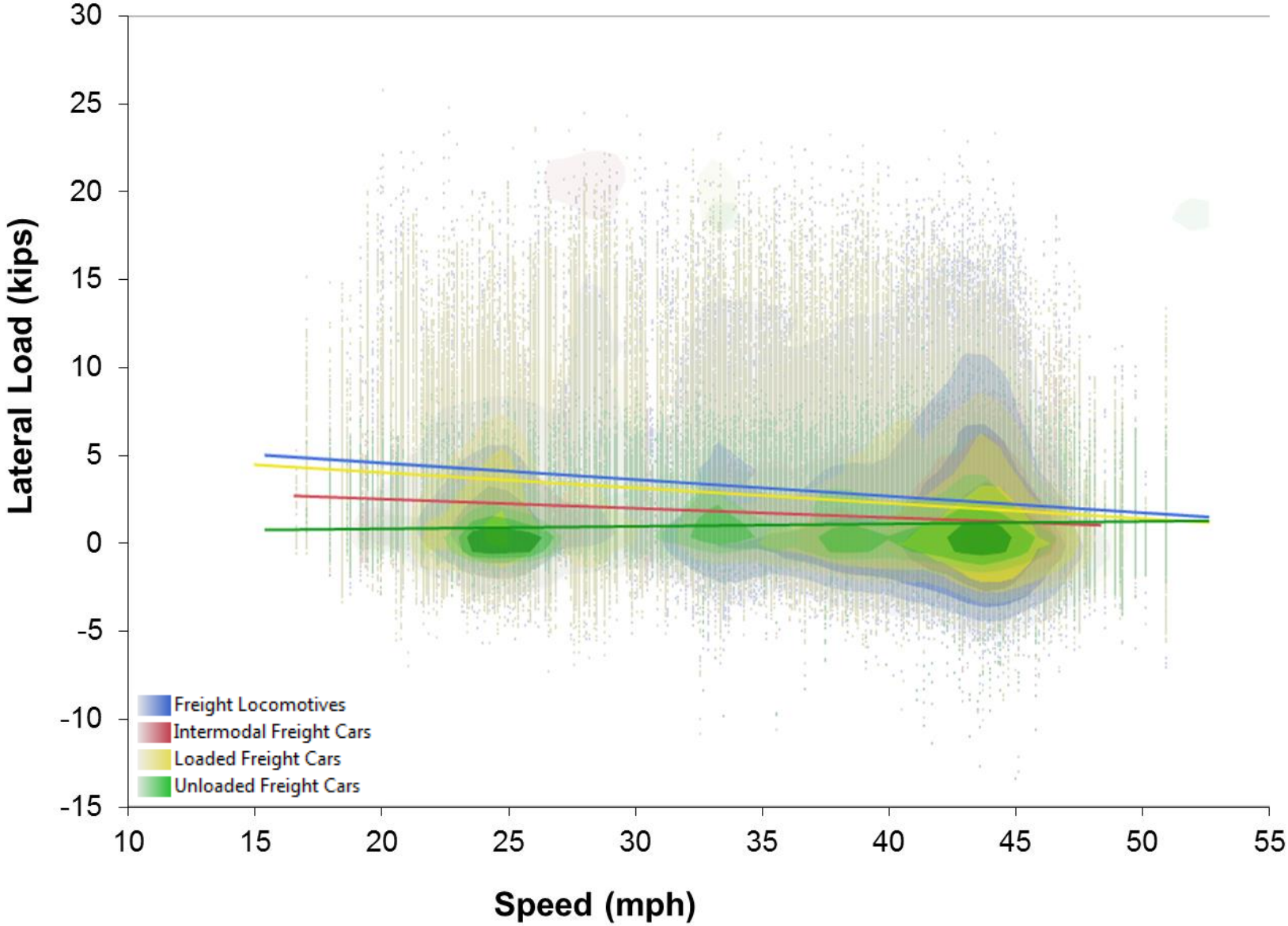
Variation According To Car Type and Weight



Speed– High Rail



Speed– Low Rail



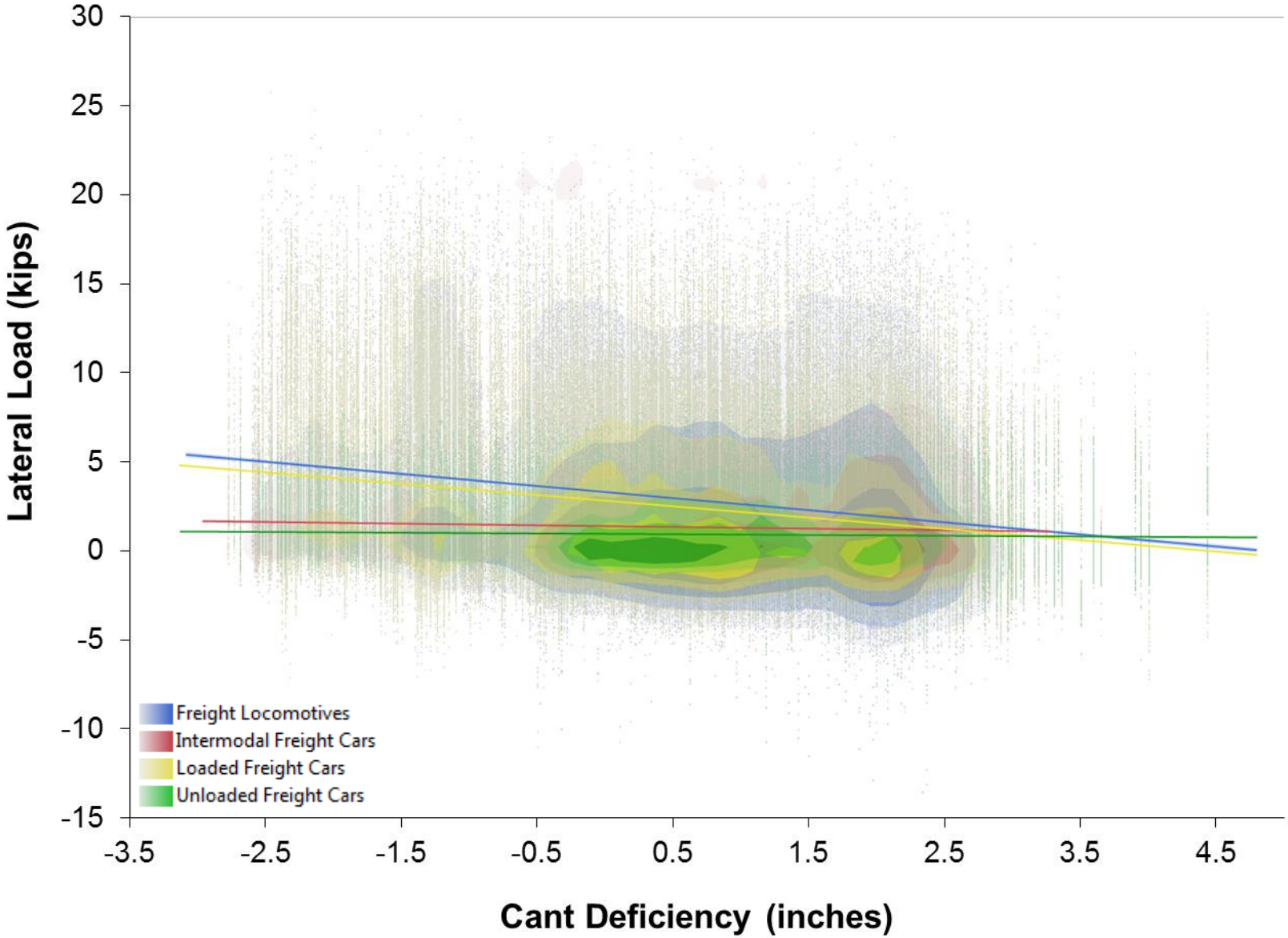
Cant Deficiency

- Measure of the difference between equilibrium superelevation and actual superelevation
- Combines the effect of degree of curvature, speed, and superelevation

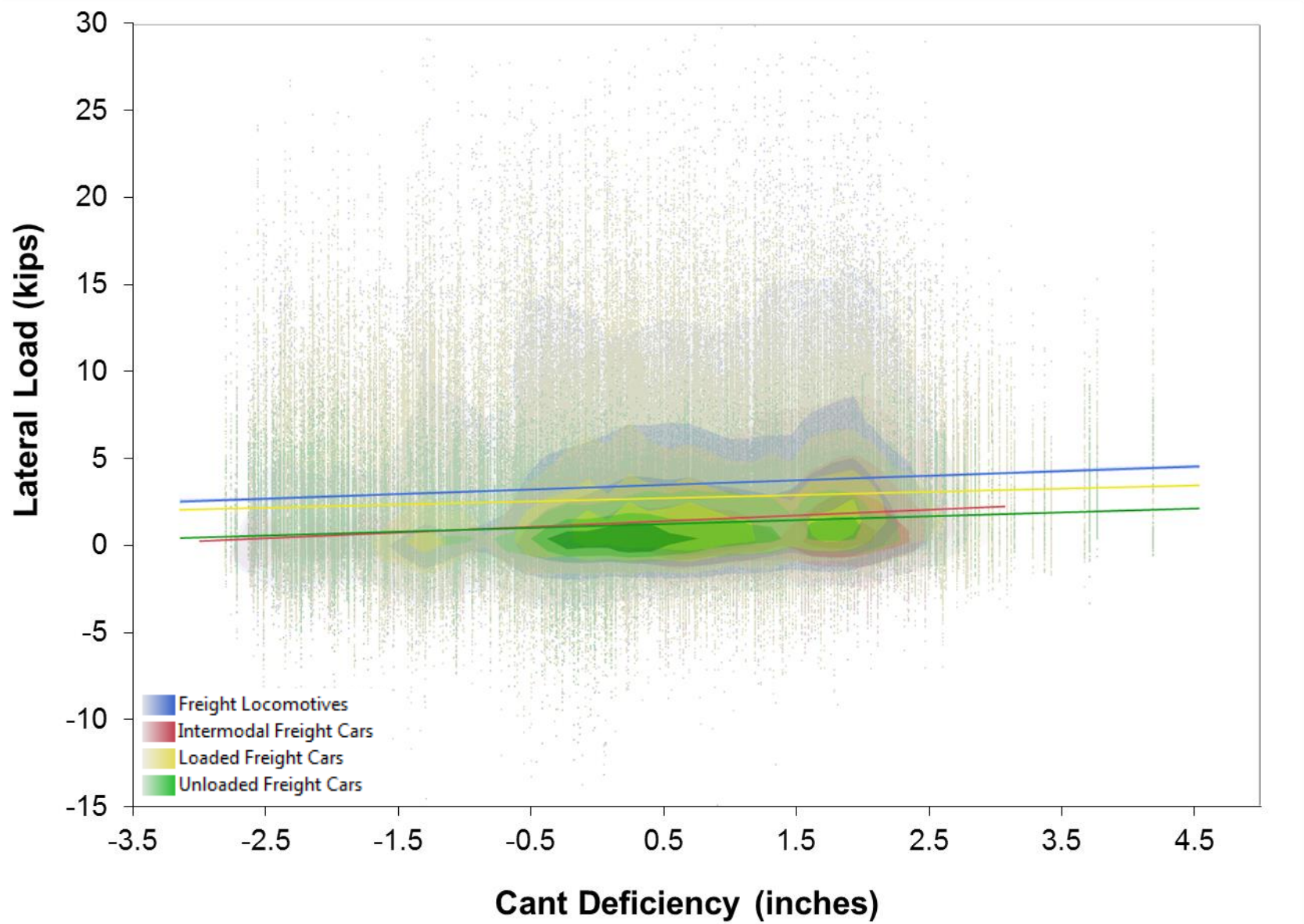
$$h_d = \frac{2b_0}{g}\left(\frac{v^2}{1746.40/D}\right) - h_t$$

- h_d = cant deficiency (mm)
- $2b_0$ = distance between contact patches on a wheel set (assumed 1500 mm)
- g = acceleration due to gravity (9.81 m/s^2)
- v = vehicle speed (m/s)
- D = degree of curvature
- h_t = actual superelevation of curve (mm)

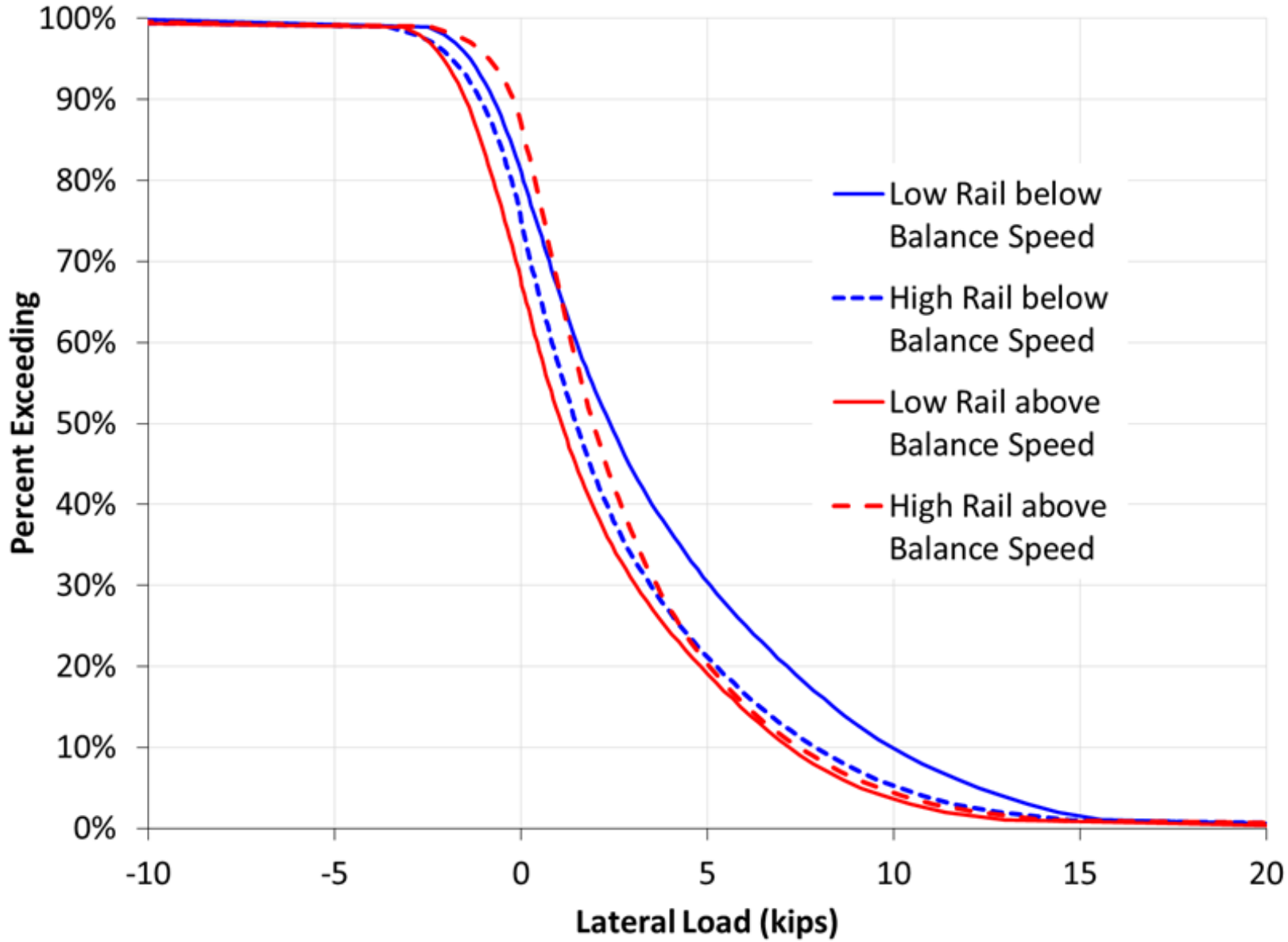
Cant Deficiency – Low Rail



Cant Deficiency – High Rail



High Rail vs. Low Rail



Design Vertical Wheel Loads (WILD)

	Nominal Load (kips)				
Car Type	Mean	95%	97.5%	99.5%	100%
Unloaded Freight Car	7	10	11	14	15
Loaded Freight Car	34	40	41	42	46
Intermodal Freight Car	21	36	37	40	51
Freight Locomotive	34	37	38	39	44
Passenger Locomotive	27	36	38	40	43
Passenger Coach	15	19	19	21	46

	Peak Load (kips)				
Car Type	Mean	95%	97.5%	99.5%	100%
Unloaded Freight Car	11	21	27	40	101
Loaded Freight Car	43	57	66	85	157
Intermodal Freight Car	28	47	55	75	142
Freight Locomotive	43	54	58	69	110
Passenger Locomotive	39	50	54	64	94
Passenger Coach	24	36	43	59	109

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Design Lateral Wheel Loads (TPD)

Car Type	Lateral Load (kips)				
	Mean	95%	97.5%	99.5%	100% (Max)
Unloaded Freight Car	1.1	4.4	5.2	6.9	22.4
Loaded Freight Car	2.7	10.1	12.1	15.9	33.5
Intermodal Freight Car	1.9	6.2	7.4	10.1	22.8
Freight Locomotive	3.9	13.3	15.6	20.5	34.4

Car Type	L/V				
	Mean	95%	97.5%	99.5%	100% (Max)
Unloaded Freight Car	0.15	0.44	0.50	0.64	4.00
Loaded Freight Car	0.11	0.35	0.41	0.52	1.46
Intermodal Freight Car	0.12	0.39	0.46	0.59	1.61
Freight Locomotive	0.11	0.38	0.44	0.56	0.81

- Locomotives have higher lateral load than loaded freight cars due to poor curving characteristics
- L/V ratio is most critical for unloaded freight cars
  - Near the danger threshold of 0.68 at 99.5% level

Conclusion

- Most significant predictor of vertical and lateral load is car type and weight
- Speed does not have a significant effect on the magnitude of vertical or lateral load
- Wayside technologies provide an accurate measure of wheel loads that can be used for design

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Questions?

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