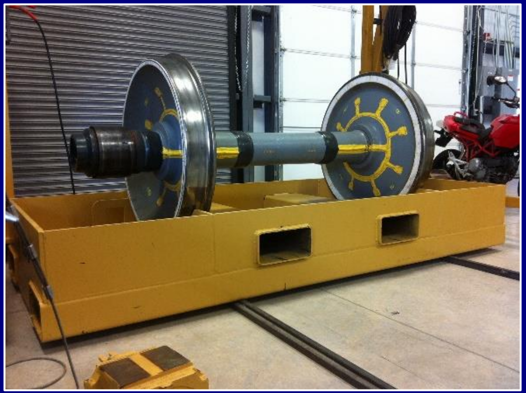
Statistical Analysis of Lateral Wheel Loads Using Truck Performance Detectors (TPD)





San Jose State University, San Jose, CA

Joint Rail Conference

24 March 2015

Andrew Scheppe, Riley Edwards, Marcus Dersch

NURail Center

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

U.S. Department of Transportation
Federal Railroad Administration

Outline

- Motivation
- Summary of Truck Performance Detectors
- Effect Size Statistical Analysis
- Leading Versus Trailing Axles
  - Car Type
  - Curvature
- Conclusions
- Future Work

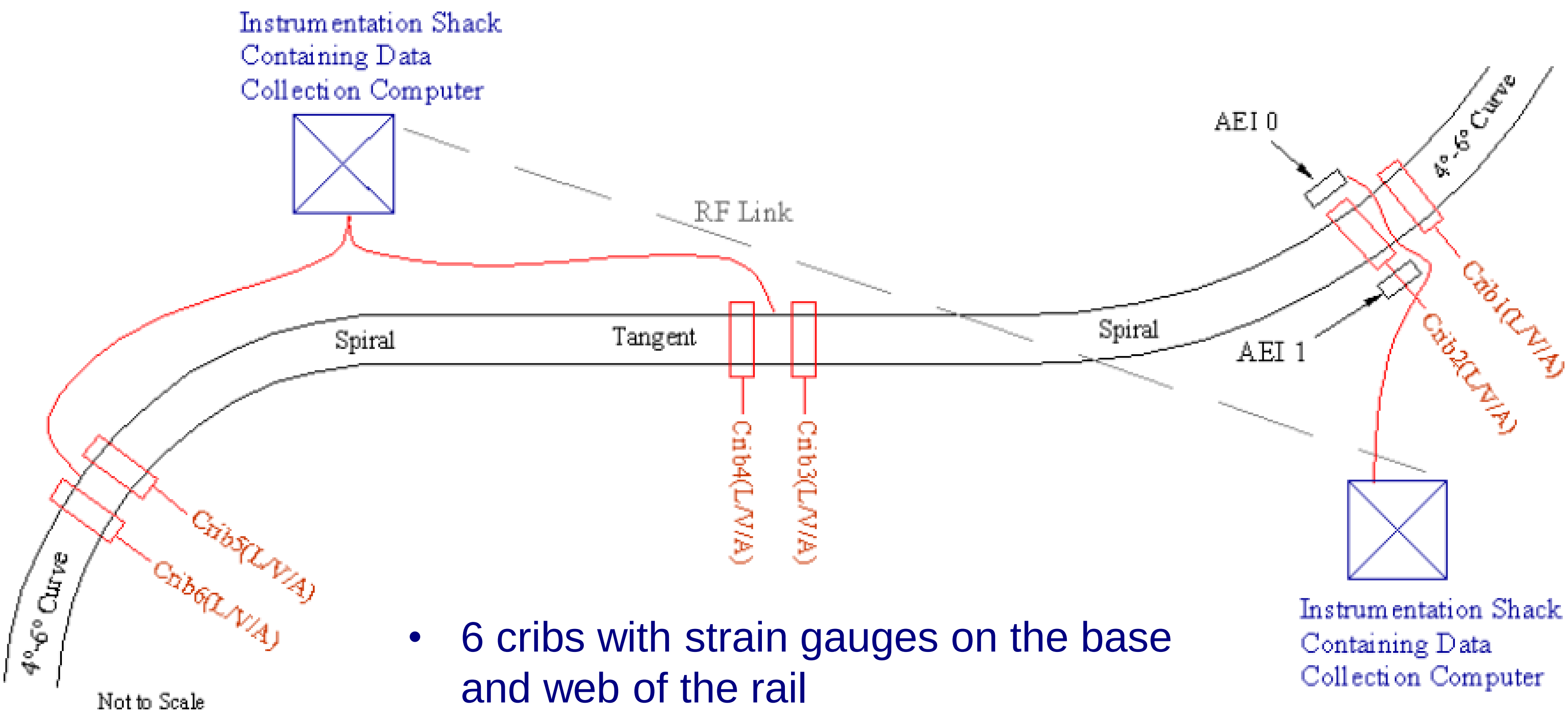
Motivation

- Current components have been designed empirically through trial over time
- Accelerated rate of component wear in certain areas
- Wear can be minimized by understanding the loading conditions
- Drive towards mechanistic design of components

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)

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

TPD Site Information

- Eight TPD locations located in six states across the US
- All TPDs located on concrete crosstie track
- Degree of Curvature: Range from 3 to 6 degrees
- Superelevation: Range from 1 to 4 inches

Location	Curvature		Superelevation (in)*		Balance Speed (mph)	
	Curve 1	Curve 2	Curve 1	Curve 2	Curve 1	Curve 2
Argyle_1, IA	4° 5’	3° 4’	3.63	3.39	35.61	39.73
Argyle_2, IA	4° 5’	3° 4’	3.63	3.39	35.61	39.73
Elmira, ID	4° 23’	4° 9’	3.63	3.63	35.61	35.61
Joppa, MT	4° 30’	3° 36’	2.06	1.25	25.57	22.25
Ludlow_1, CA	4° 5’	4° 6’	3.63	3.63	35.61	35.61
Ludlow_2, CA	4° 7’	4° 19’	3.63	3.63	35.61	35.61
Ludlow, CO	5° 0’	6° 0’	2.77	3.72	28.11	29.76
Pomona, MO	3° 55’	4° 10’	3.48	3.12	35.62	32.71

Summary of Current Findings

- Based on previous analysis, it was found that car weight was the most significant predictor of vertical and lateral wheel load
  - Degree of curvature, speed, and cant deficiency were found to have a relatively small impact

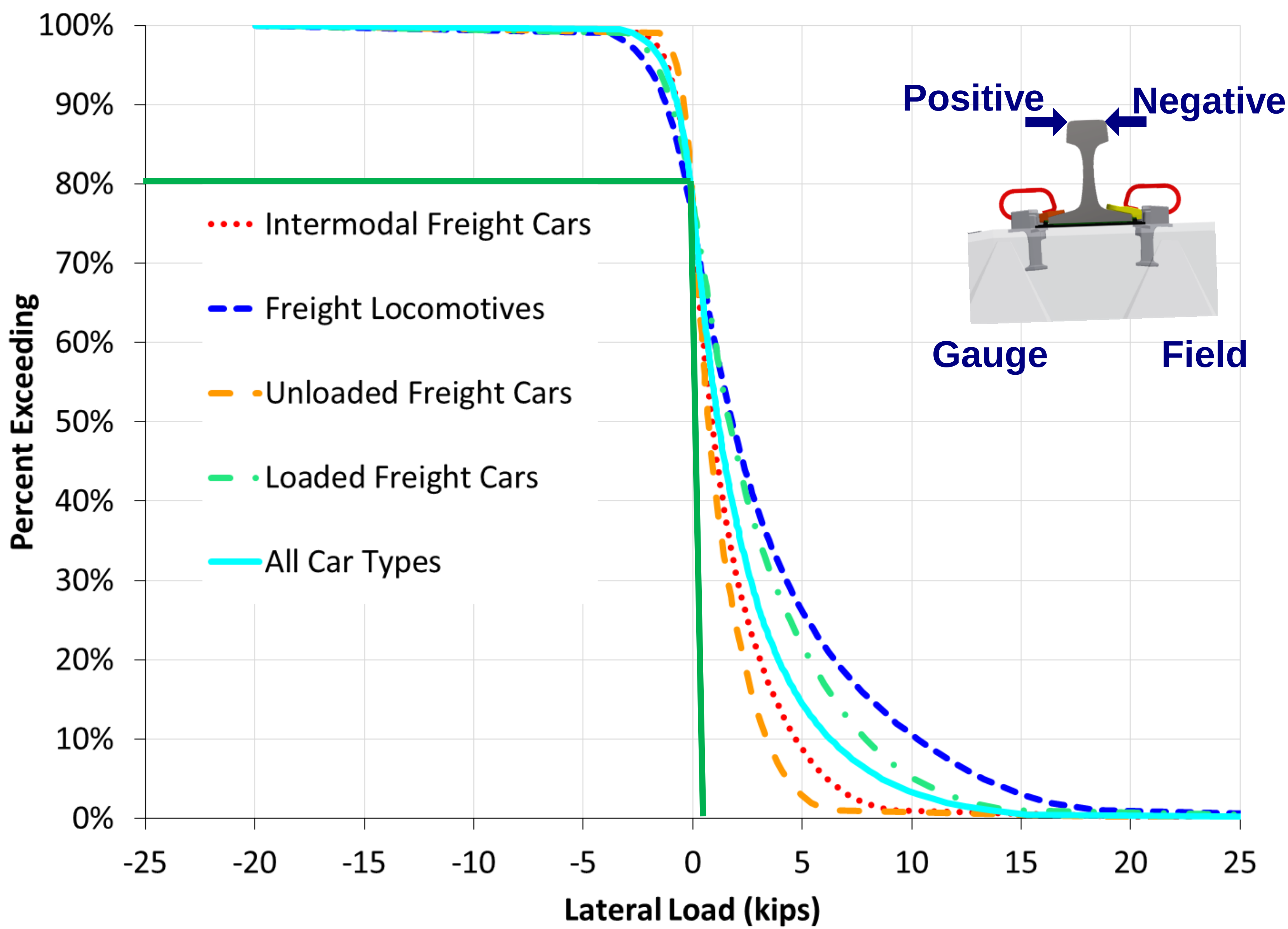
Questions to be Answered

- How do the leading axles of cars differ from the overall distribution?
  - Car weight
  - Degree of curvature

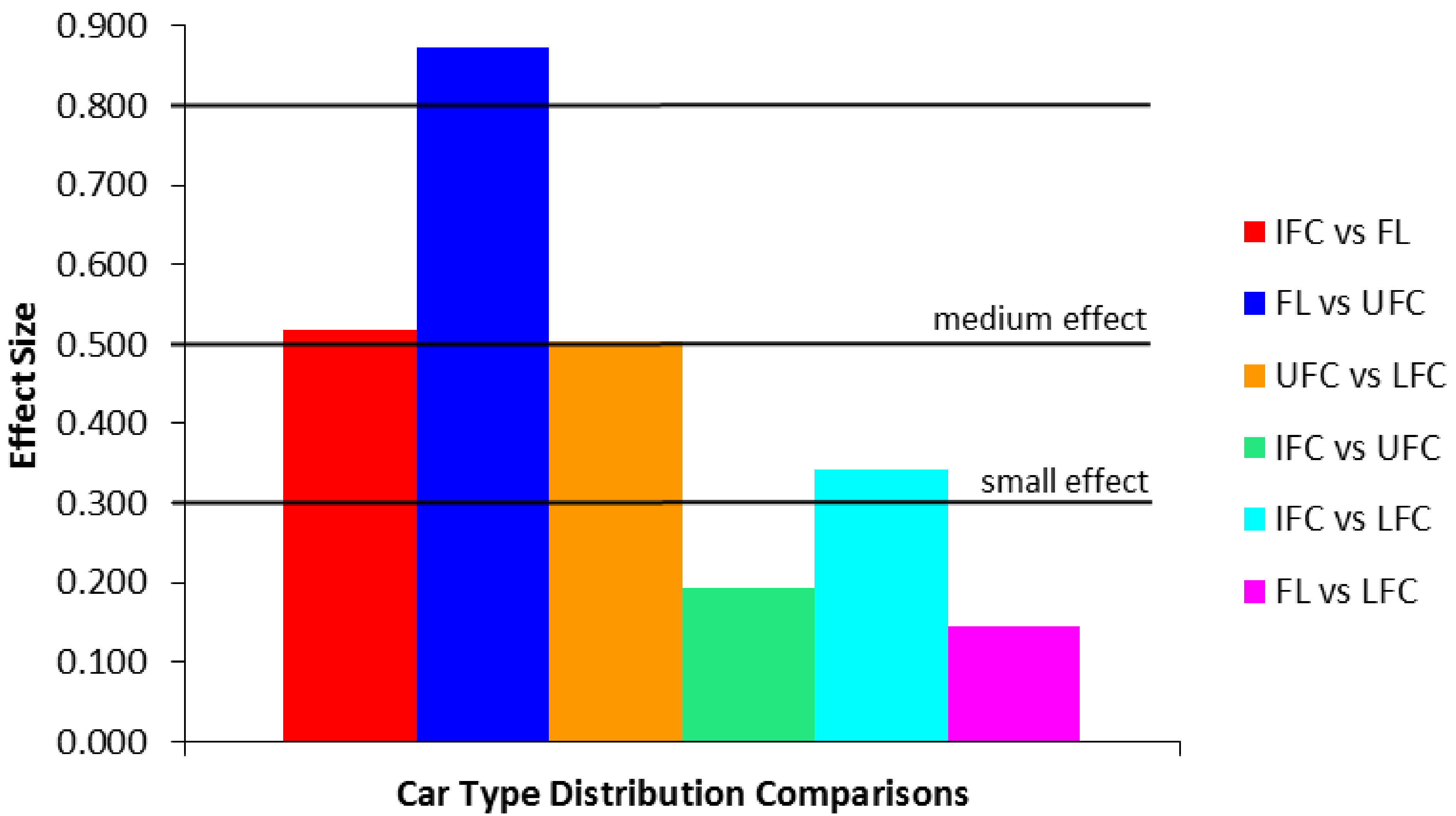
Effect Size Summary

- For large samples, even very similar distributions will have statistically significant difference when using T-test
- T-test effect size can determine whether difference between average of two groups is meaningful
- Effect size is a quantitative measure of the strength of a phenomenon
- Three levels of effect size
  - 0.3 = Small Hardly visible
  - 0.5 = Medium Observable
  - 0.8 = Large Plainly evident
- Compare populations with each other and calculate effect size
  - Car type, degree of curvature

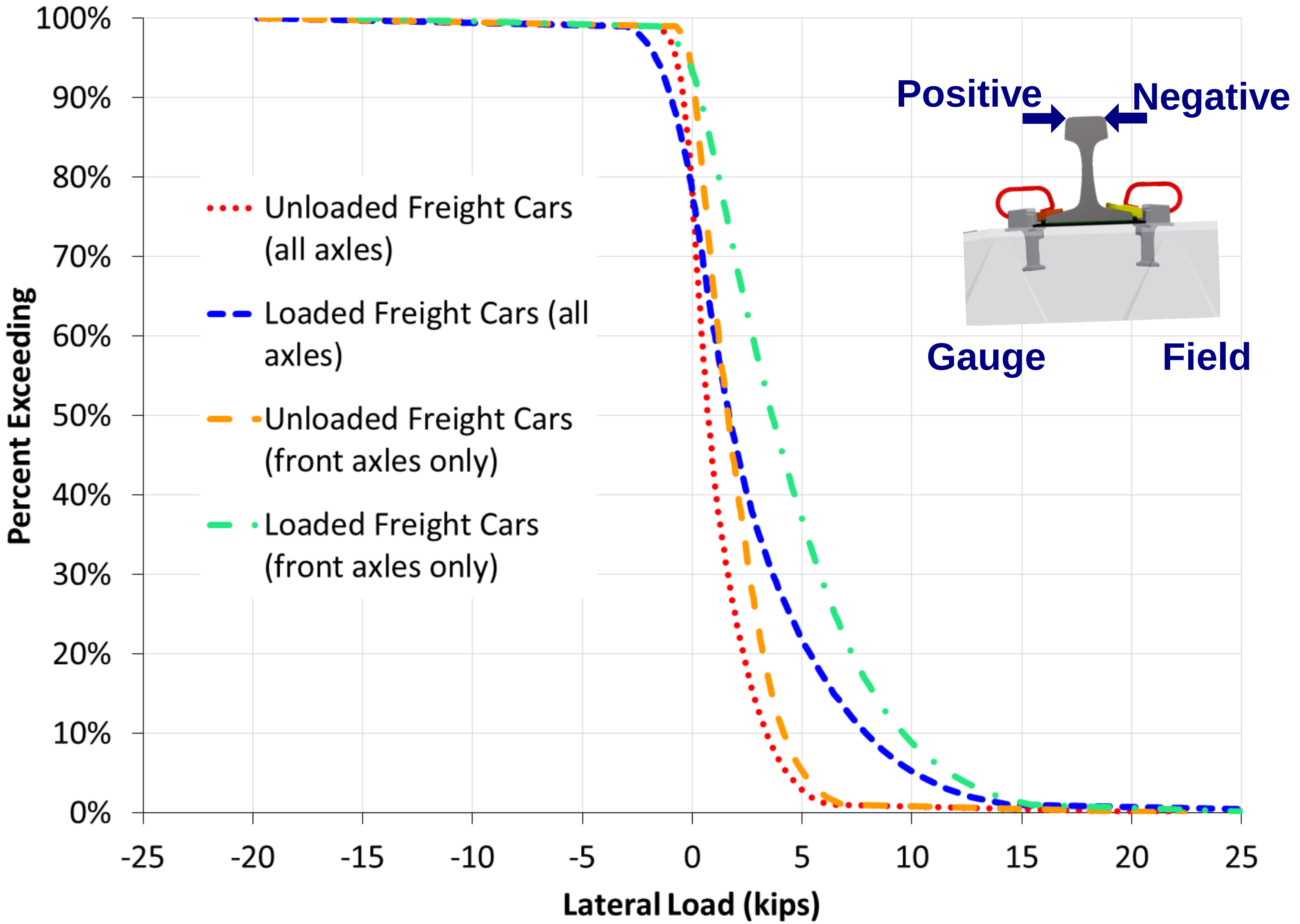
Variation According To Car Type



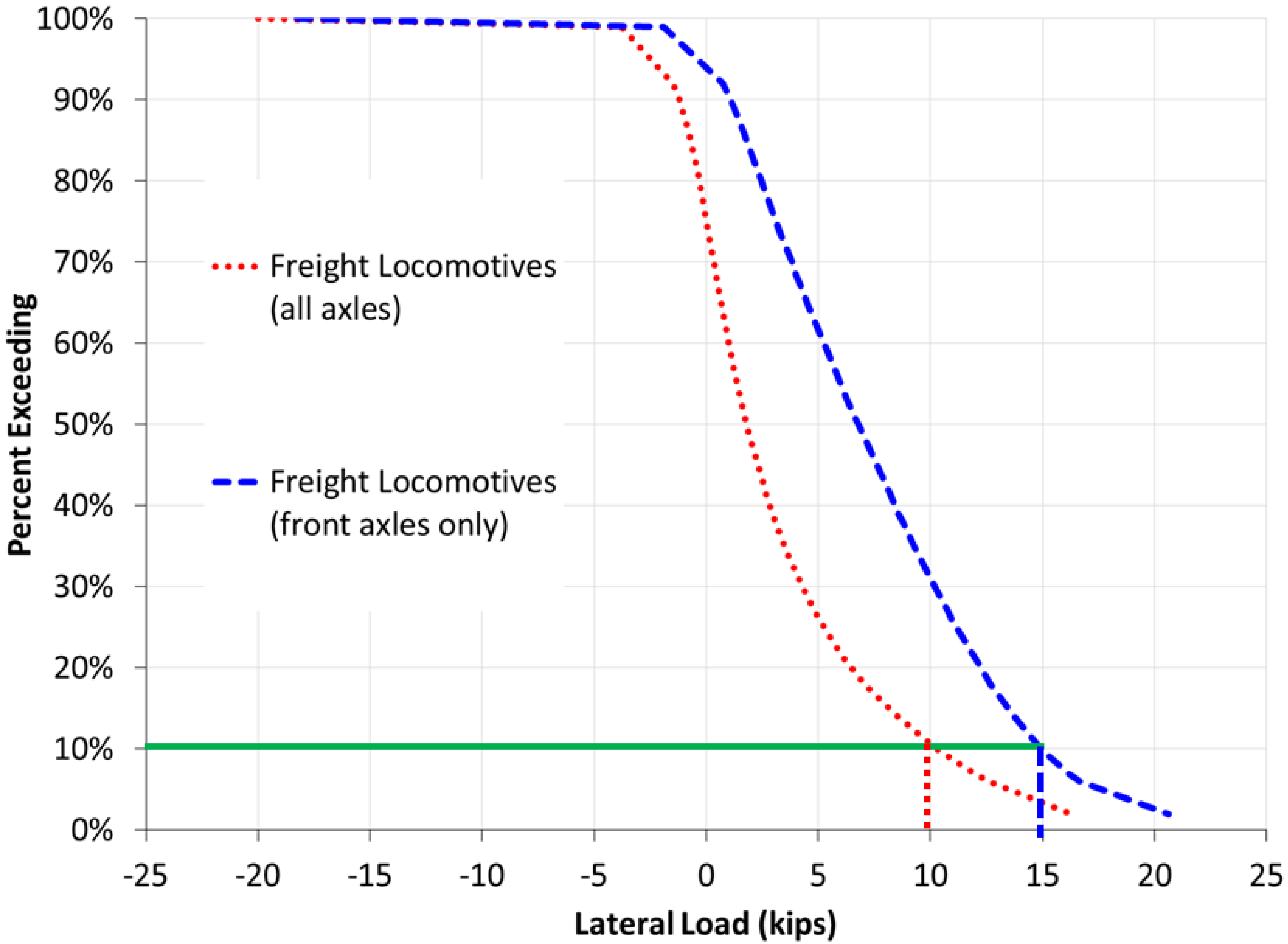
Car Type Effect Size



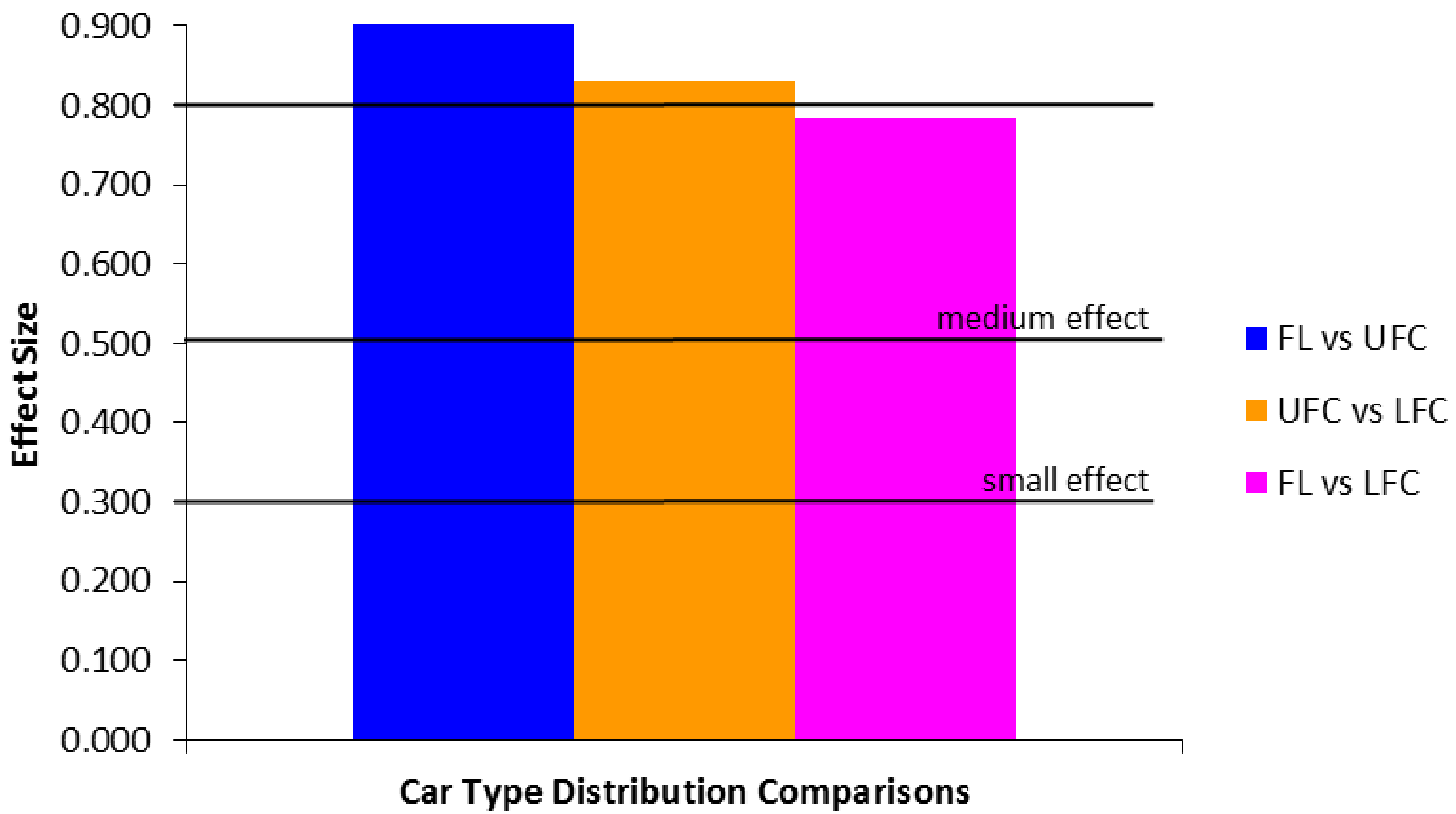
Car Type – Leading and All Axles



Locomotive – Leading and All Axles

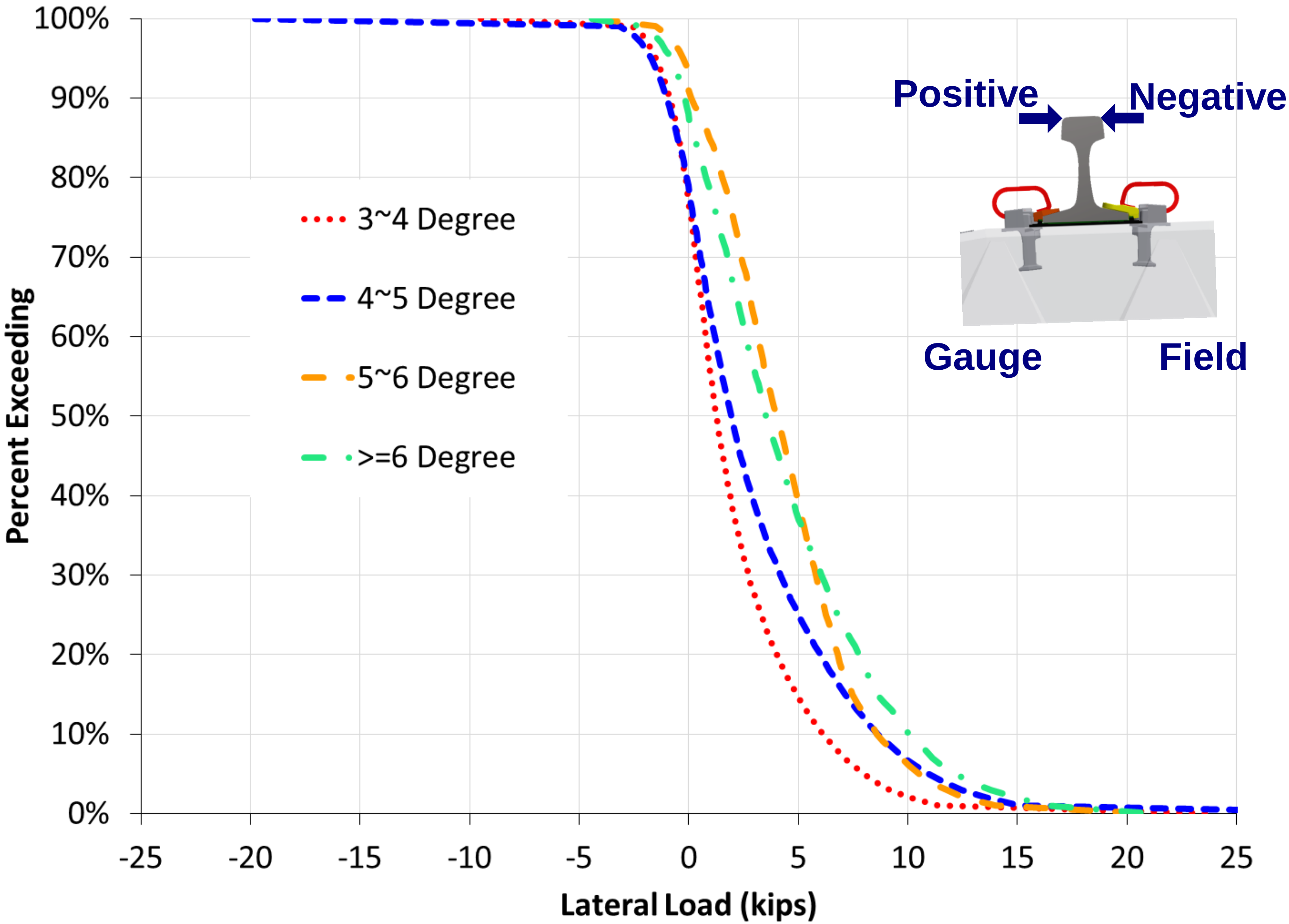


Car Type Effect Size – Leading Axles

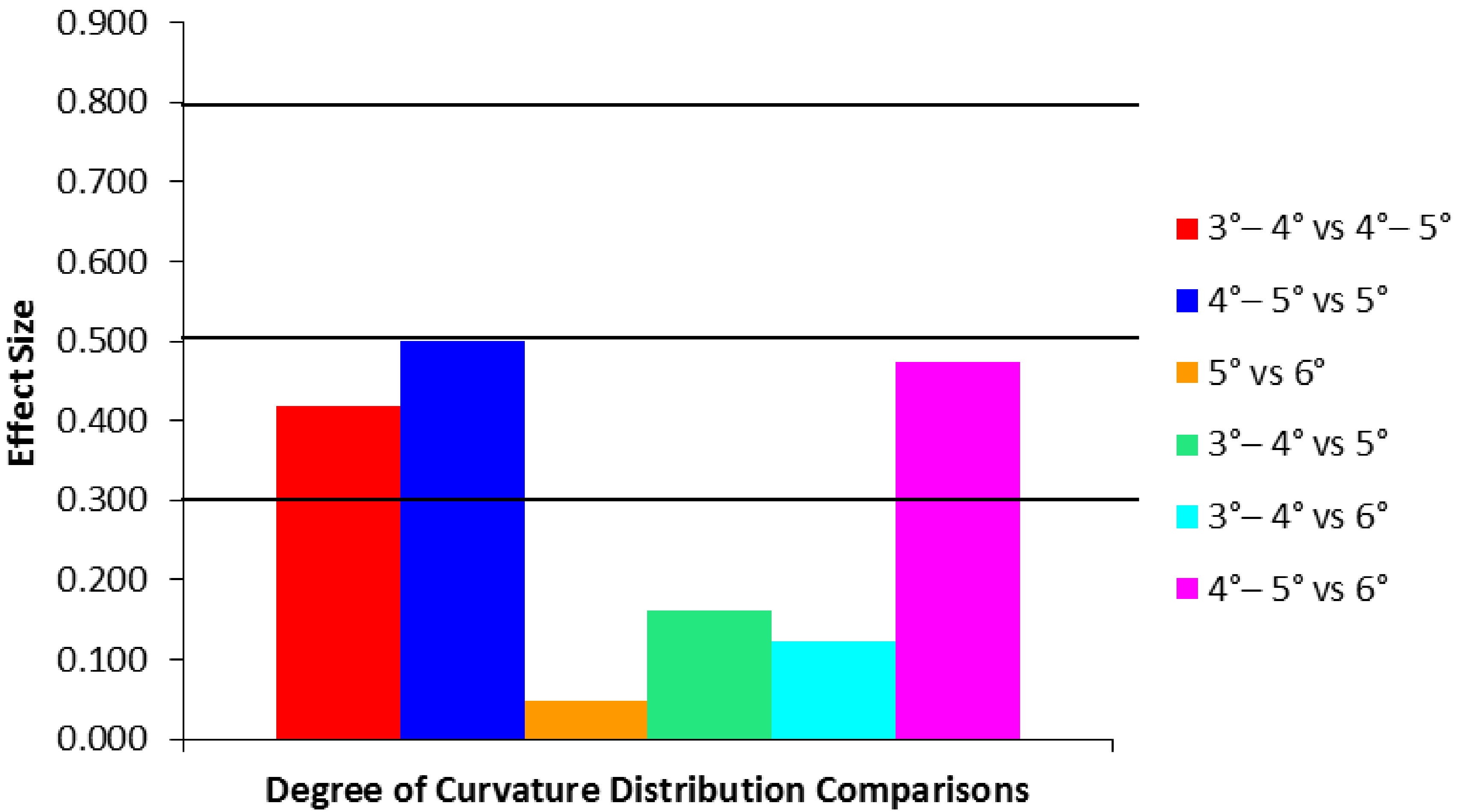


Degree of Curvature

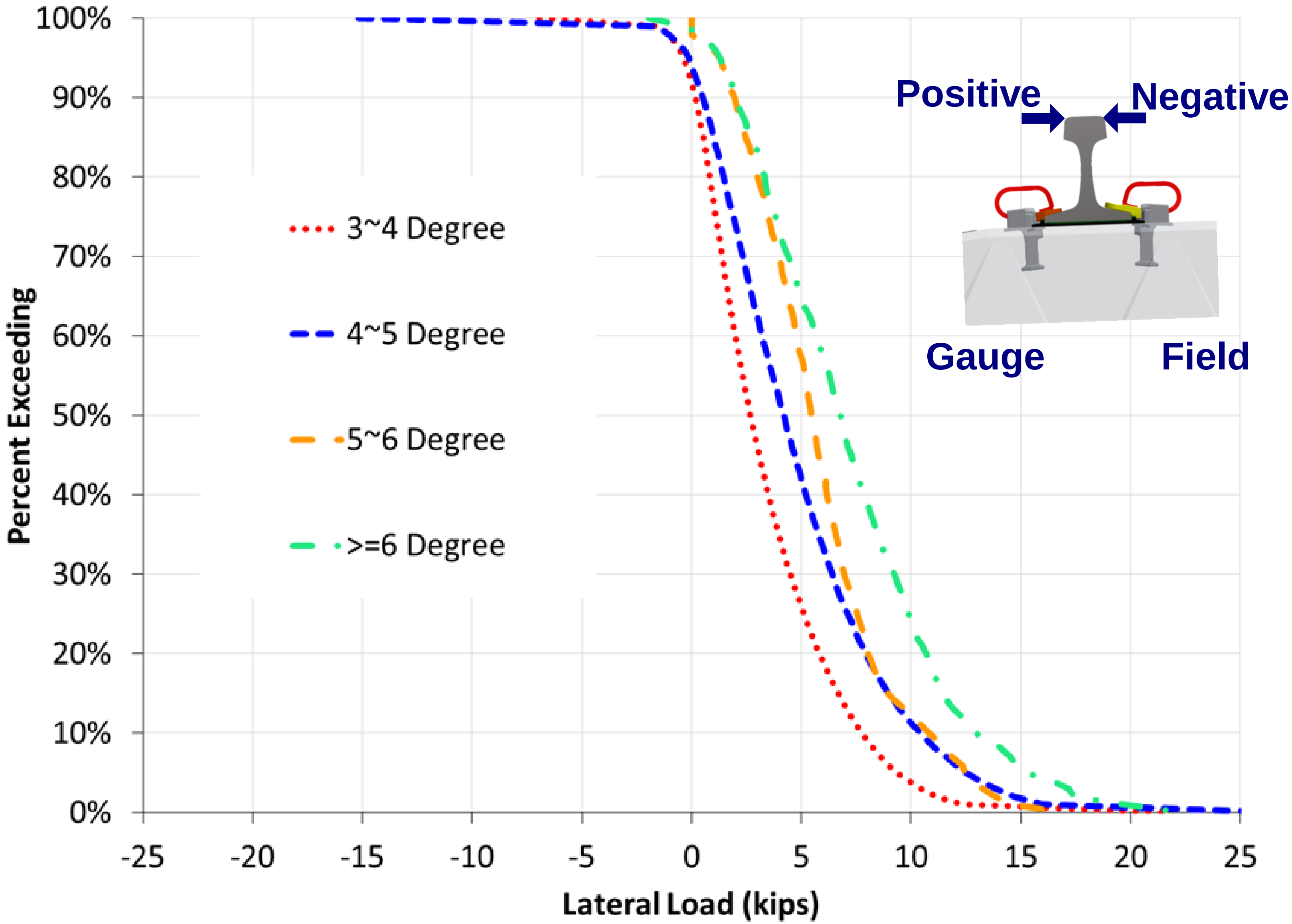
Loaded - Degree of Curvature – All Axles



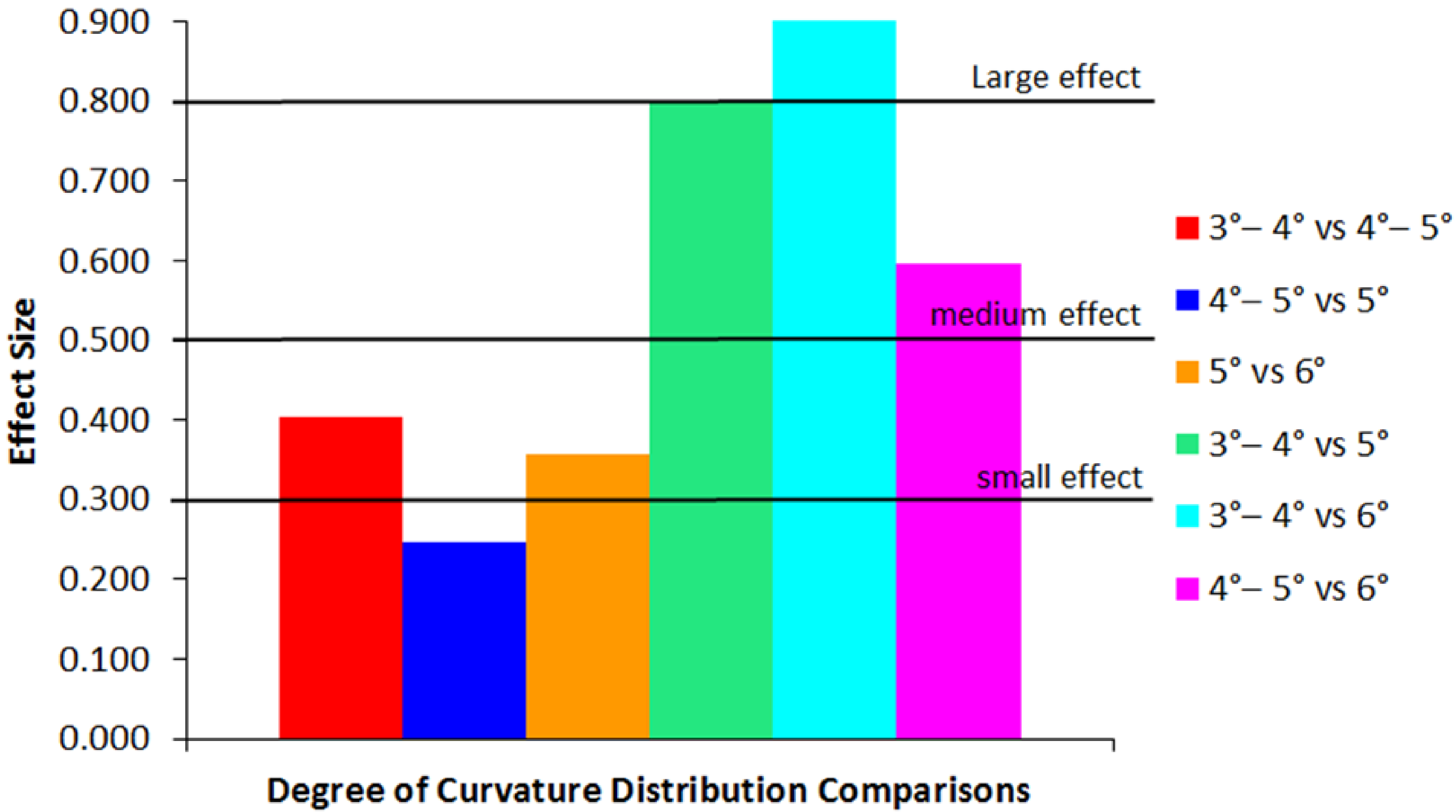
Degree of Curvature Effect Size



Loaded - Degree of Curvature – Leading Axles



Degree of Curvature Effect Size – Leading Axles



Conclusion

- Truck performance detectors can be used to quantify and predict the lateral wheel load of rail cars
- Car type is the most significant predictor of lateral wheel loads when considering all wheels
- Leading axles impart statistically significantly higher lateral loads than trailing axles
- Degree of curvature has a significant effect when solely considering leading axles, in particular for loaded cars

Future Questions to Answer

- Do higher degree of curvature (6+ degrees) curves change the lateral load distribution?
- Do 4 axle locomotives impart different lateral loads than 6 axle locomotives?
- Does truck type affect lateral load?
  - Articulated vs. standard
- Can the factors that affect lateral load be combined using a regression analysis to provide a prediction of lateral load?

Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

NURail Center

FRA Tie and Fastener BAA Industry Partners:

- **Funding for this research has been provided by:**
  - **Federal Railroad Administration (FRA)**
  - **National University Rail Center (NURail)**
- Industry partnership and support has been provided by:
  - Union Pacific Railroad
  - BNSF Railway
  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS / Amsted Rail, Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
  - TTX Company
- For assistance with research and analysis:
  - Zhengboyang Gao

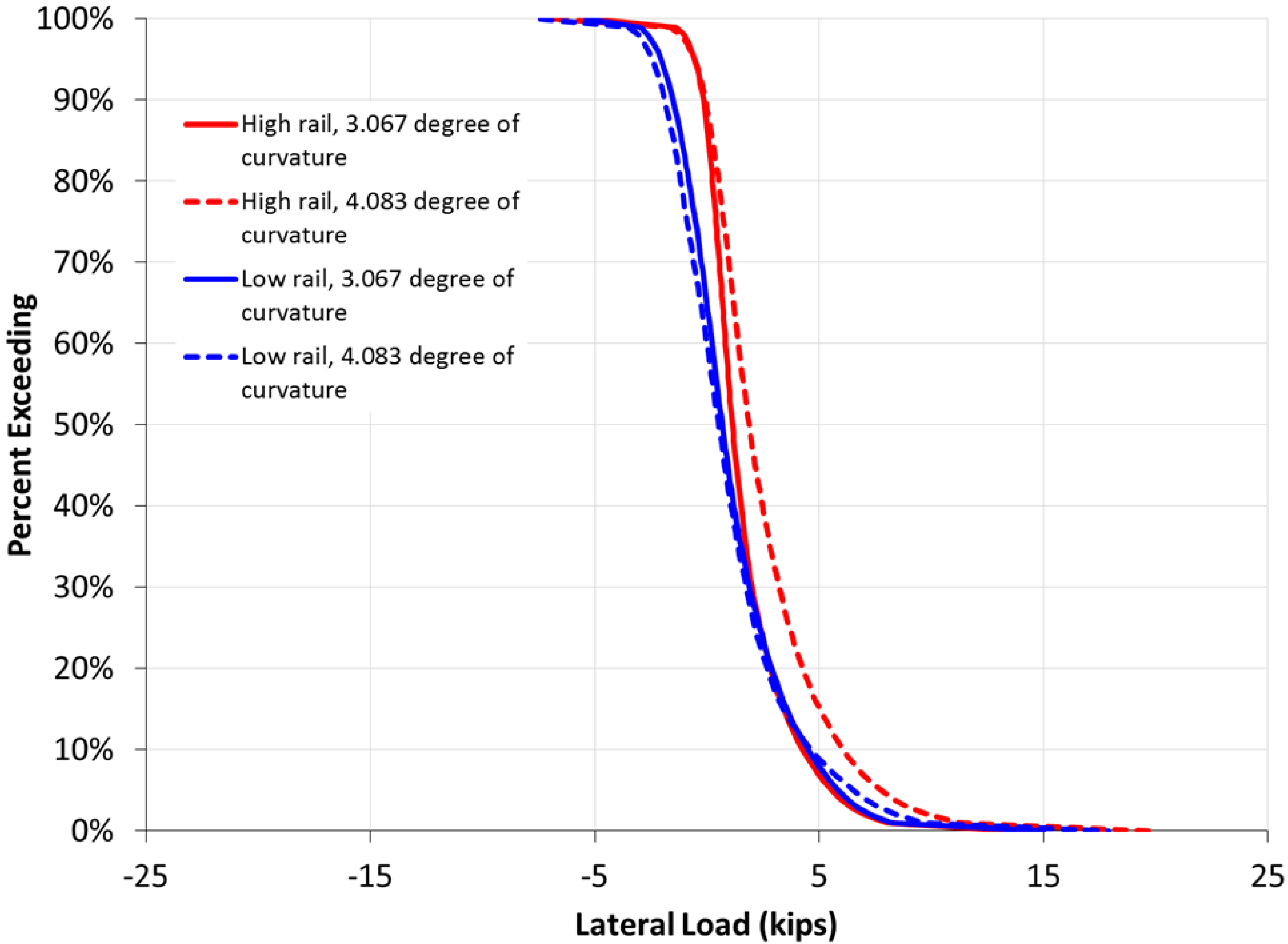
Questions?

Marcus Dersch, P.E.
Senior Research Engineer
RailTEC
Email: mdersch2@Illinois.edu

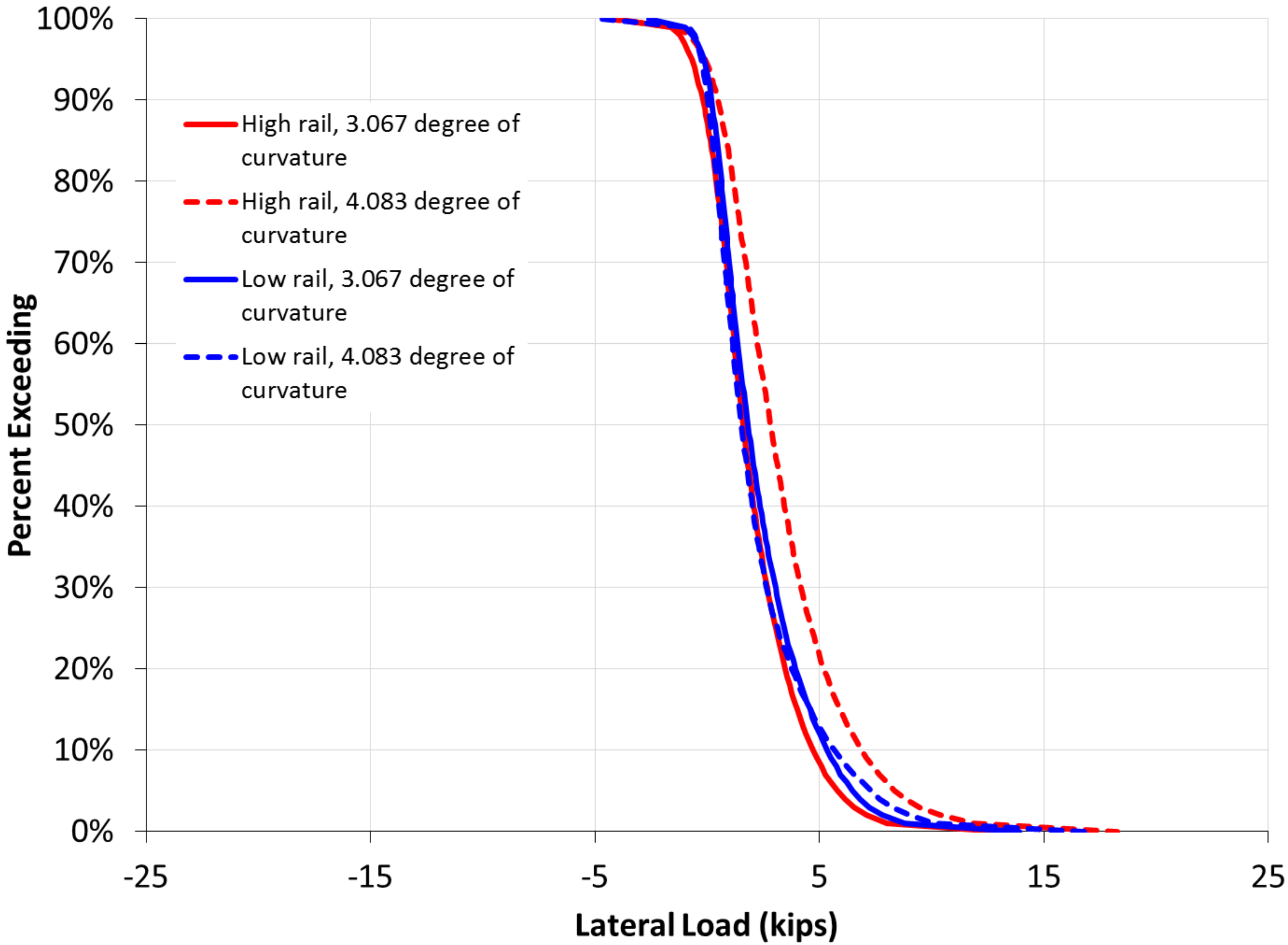
Andrew Scheppe
Graduate Research Assistant
RailTEC
Email: scheppe1@illinois.edu

Individual TPD Site Degree of Curvature Analysis

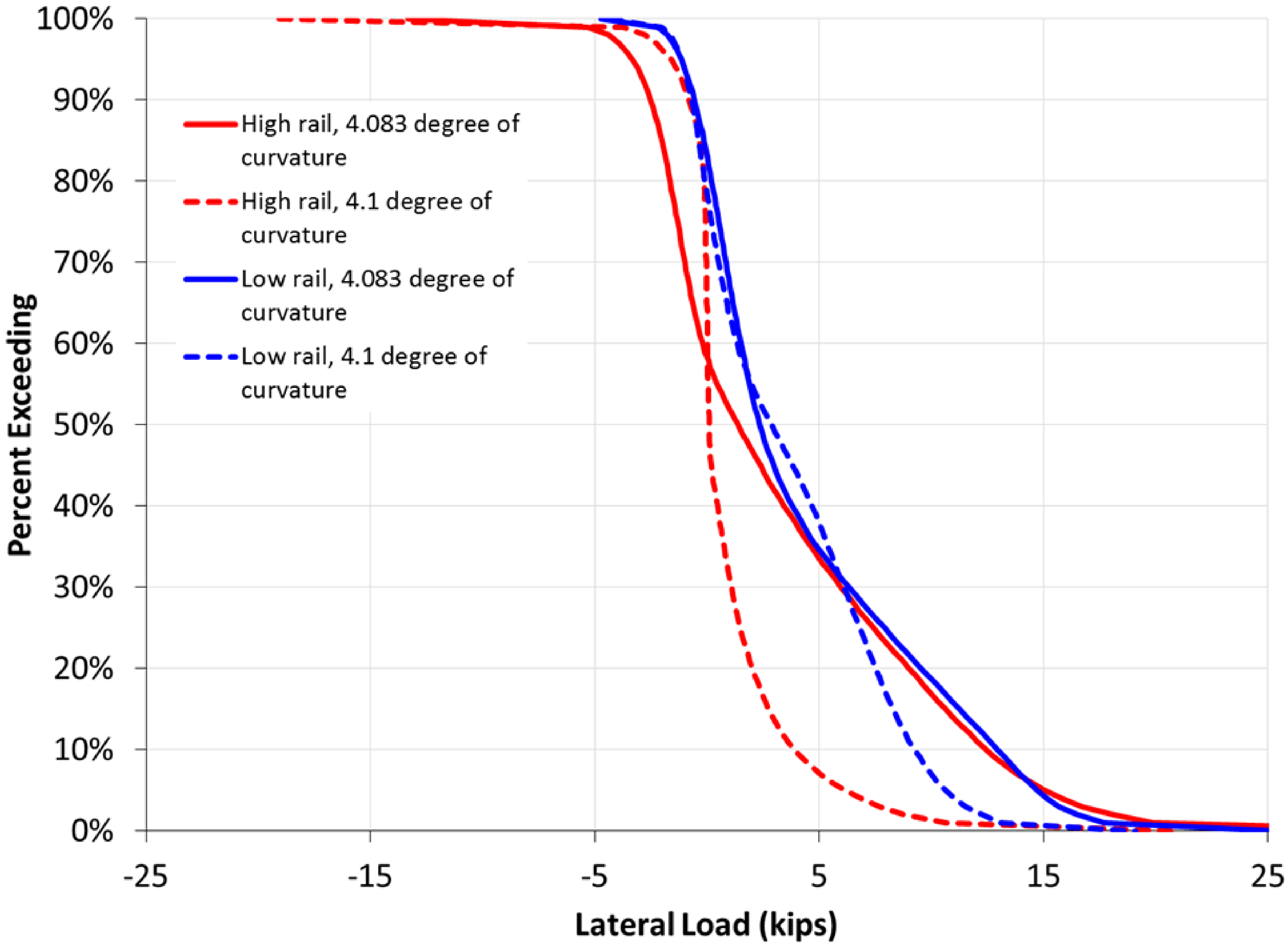
Argyle_1 All Axles



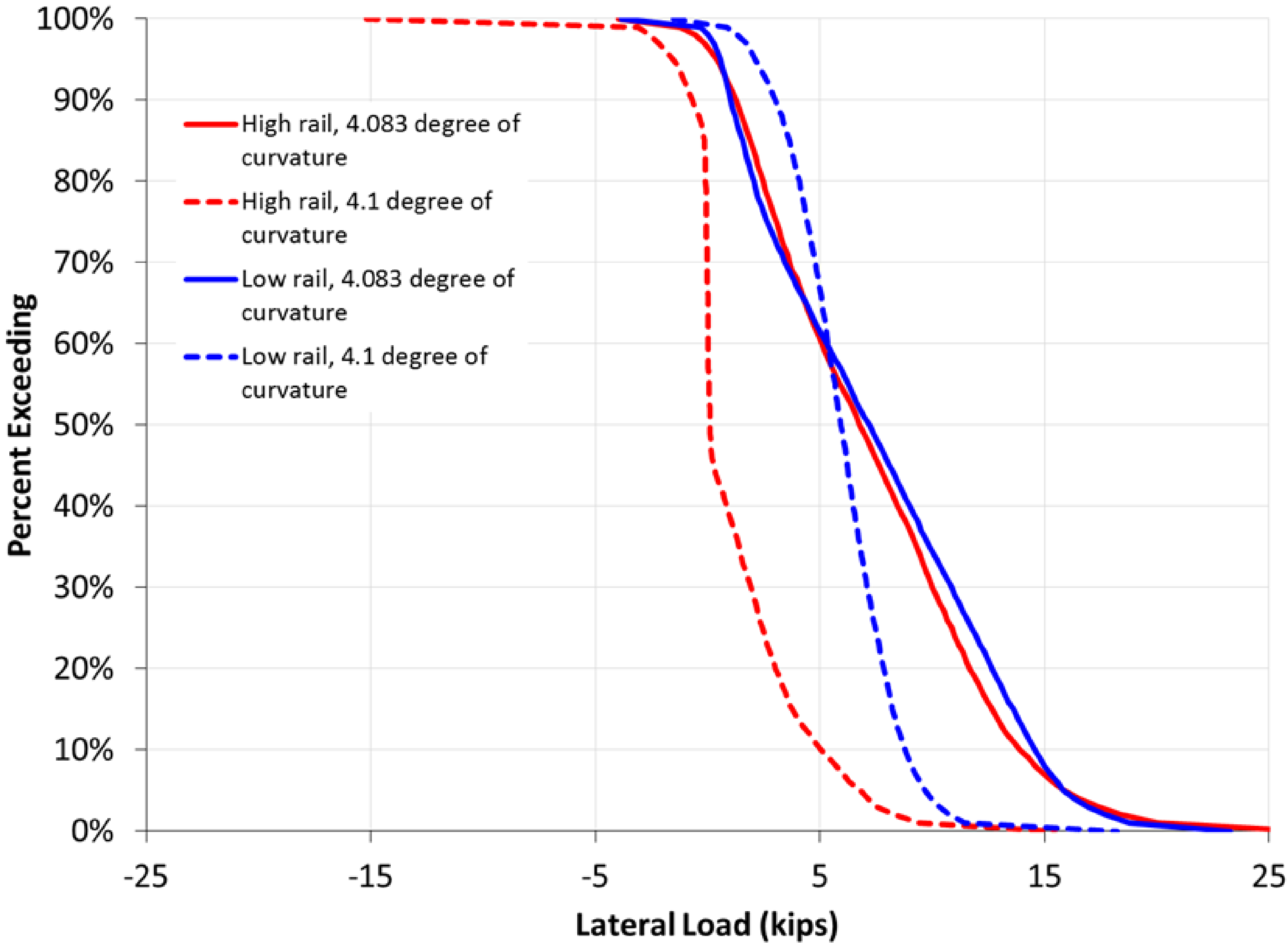
Argyle_1 Leading Axles Only



Ludlow_CA_1 All Axles



Ludlow_CA_1 Leading Axles Only



- The curve specific variability of measured lateral wheel loads is high
  – Even within one curve, two curves with similar degree of curvature can behave very differently