Concrete Crossties and Fastening Systems – Characterizing the Loading Environment

FRA Tie and Fastener BAA Industry Partners Meeting

Tampa, FL

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Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Outline

- Motivation for load environment characterization
- Methodologies and measurement technologies
- Analysis of loads on shared infrastructure
  - Causes of load variation
  - Impact factor evaluation
- Conclusions and Acknowledgements

Objectives

- Use multiple load quantification methods to better understand loading environment
- Determine which operating and geometric parameters affect load magnitude
- Characterize relationship between speed and load
- Clarify designation and magnitude of impact loading and how it is affected by speed
- Use quantitative understanding of loading conditions to improve design of concrete crossties and fastening systems (mechanistic design)

Principles of Mechanistic Design

1. Quantify track system input loads (wheel loads)
2. Qualitatively establish load path (free body diagrams, basic modeling, etc.)
   - Establish the locations for load transfer
3. Quantify loading conditions at each interface / components (including displacements)
   a. Laboratory experimentation
   b. Field experimentation
   c. Analytical modeling (basic → complex/system)
4. Link quantitative data to component geometry and materials properties (materials decision)

Principles of Mechanistic Design (cont.)

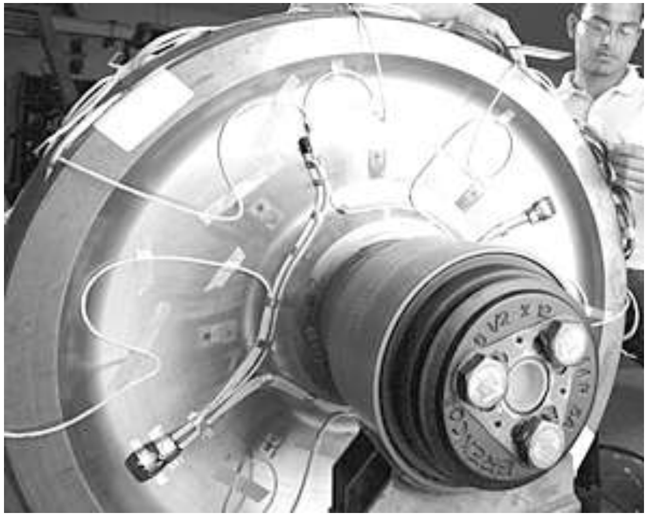
5. Relate loading to failure modes (e.g., how does lateral loading relate to post insulator wear?)
6. Investigate interdependencies through modeling
7. Run parametric analyses
   – Materials, geometry, load location
8. *Development and testing of innovative designs*
   – *Novel rail pad, crosstie, insulator designs*
   – *Geometry and materials improvements*
9. Establish mechanistic design practices
10. Adoption into AREMA Recommended Practices

Quantifying System Input Loads

- Methods of data collection:
  - Wheel Impact Load Detectors (WILD)
  - Instrumented Wheel Sets (IWS)
  - Truck Performance Detectors (TPD)
  - UIUC Instrumentation Plan (FRA Tie BAA)
- Most methods are used to monitor rolling stock performance and assess vehicle health
- Can provide insight into the magnitude and distribution of loads entering track structure

Instrumented Wheel Sets (IWS)

- Continuous loading data, with variable:
  - Speed
  - Track quality
  - Curvature and grades
  - Special trackwork
  - Environment



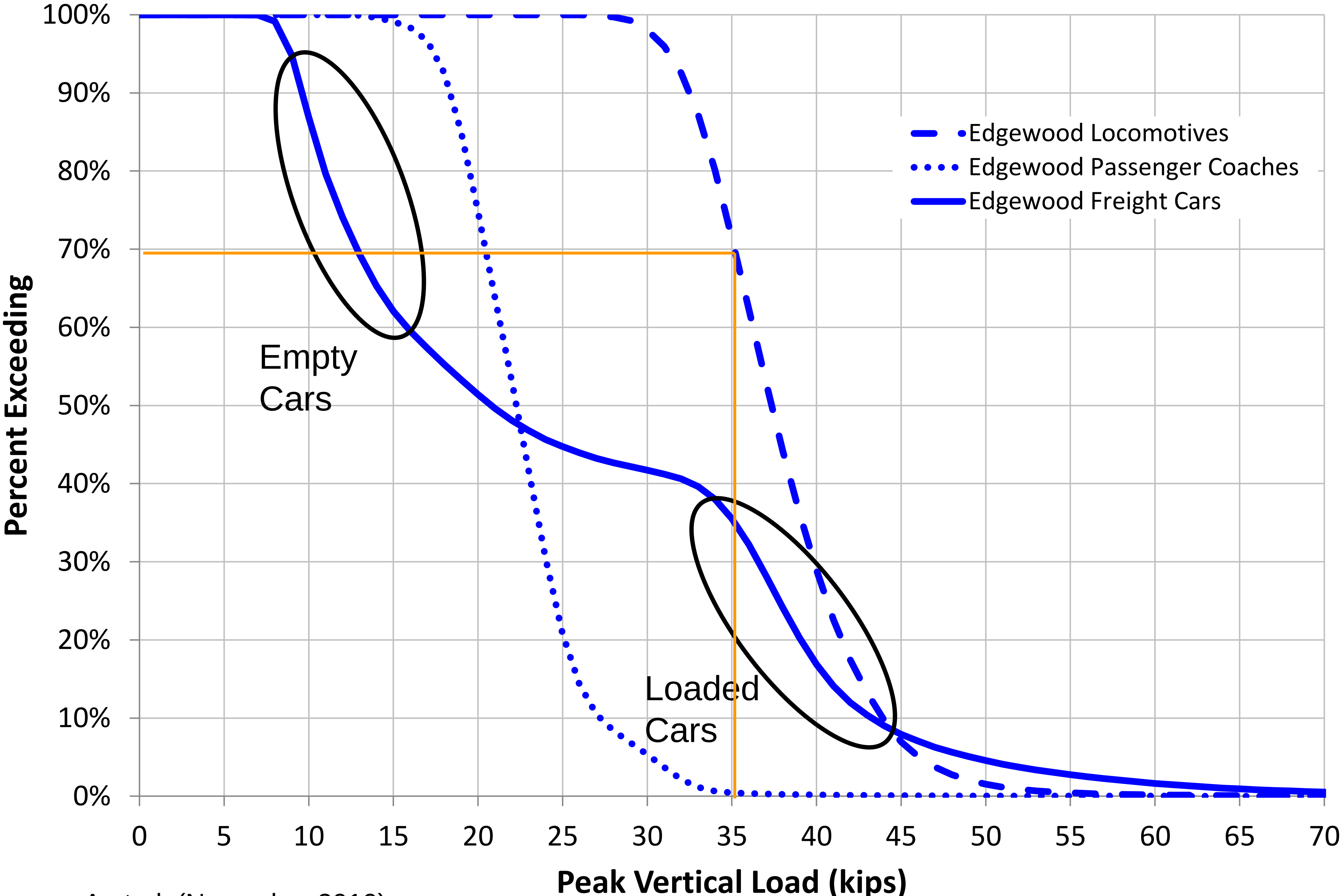
- Seasonal effects on track stiffness
- Can be deployed on any type of vehicle
- Currently analyzing data from unit coal train (courtesy AAR)

Wheel Impact Load Detectors (WILD)

Wheel Impact Load Detectors (WILD)

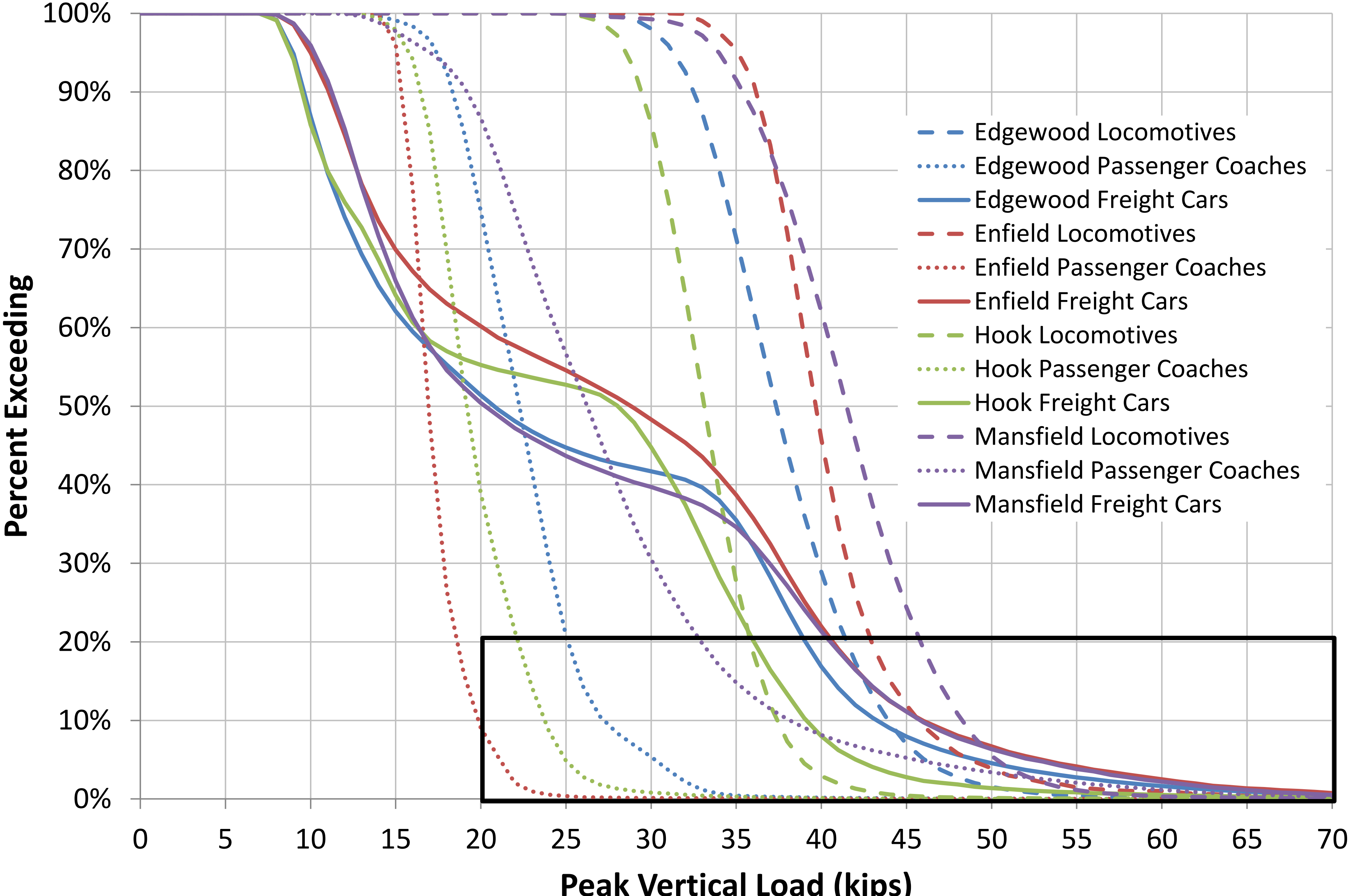
- Discrete loading data, with variable:
  - Traffic type
    - Static car weight
    - Wheel condition
  - Environment
  - Speed
- Seasonal traffic variations and temperatures
- Pristine track conditions
  - Concrete ties and premium ballast
  - Well-compacted subgrade (possibly hot mix asphalt underlayment)
  - Tangent track

Variation of Loads on Amtrak's Northeast Corridor



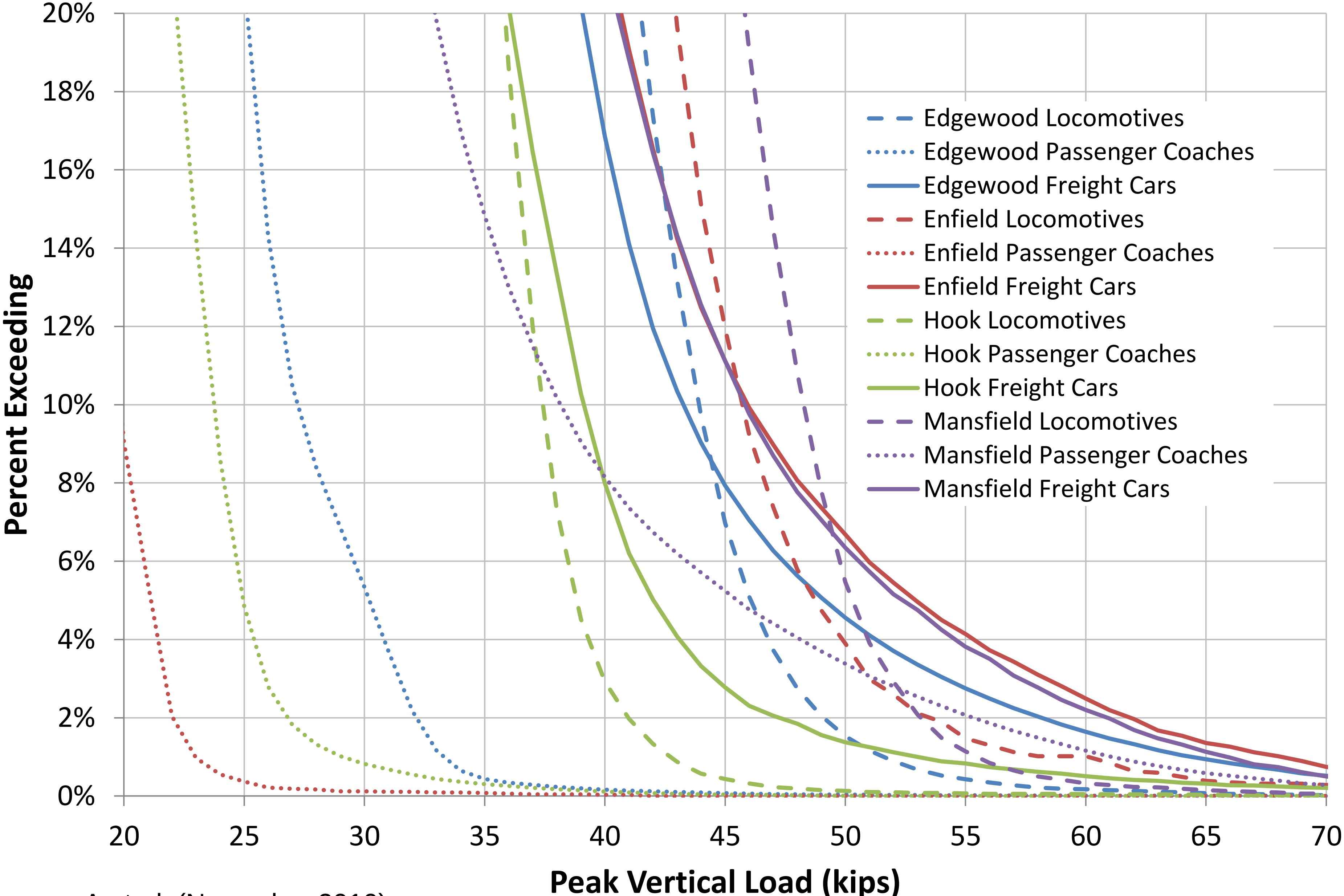
Source: Amtrak (November 2010)

Variation of Loads on Amtrak's Northeast Corridor



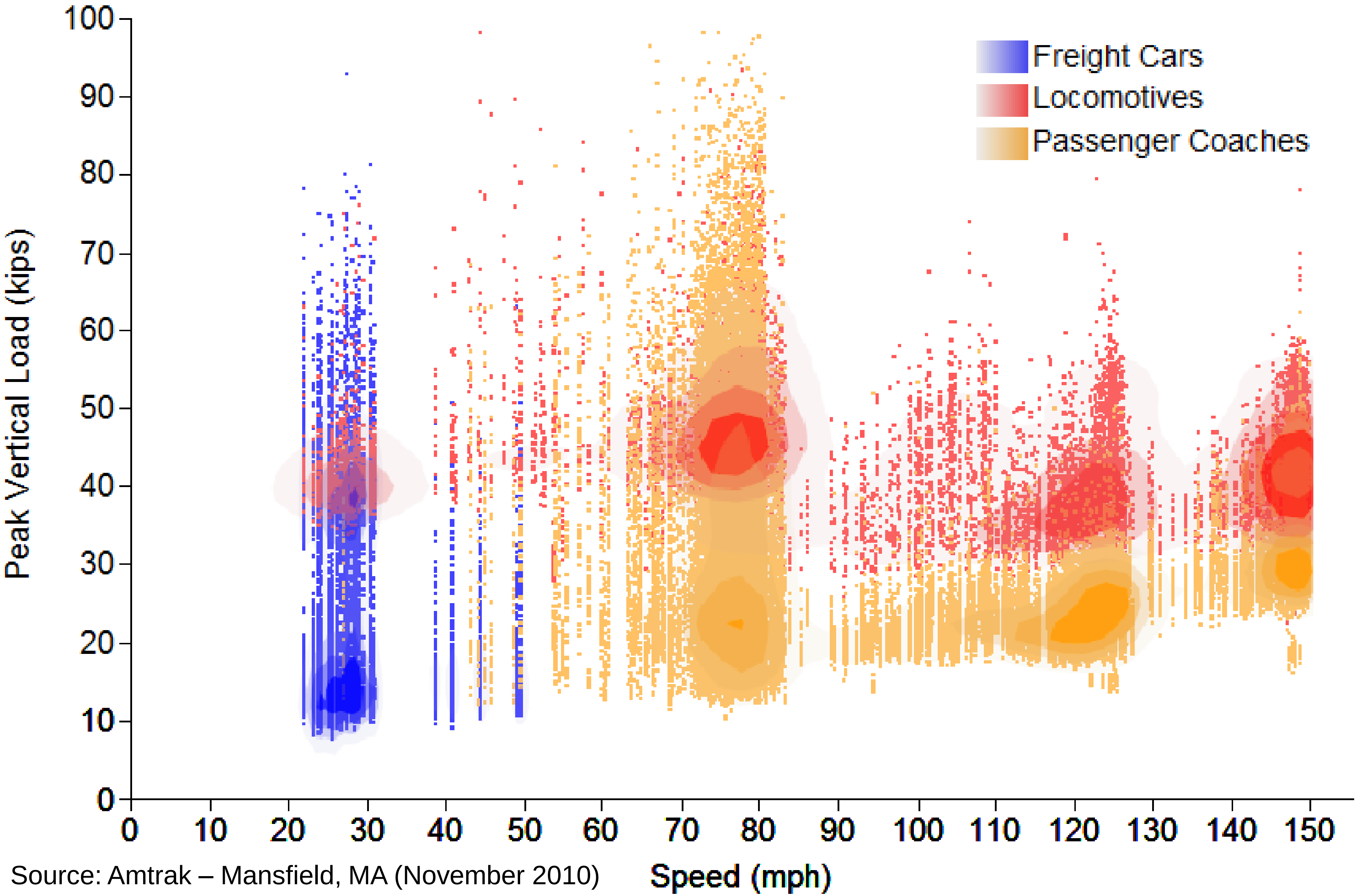
Source: Amtrak (November 2010)

Variation of Loads on Amtrak's Northeast Corridor



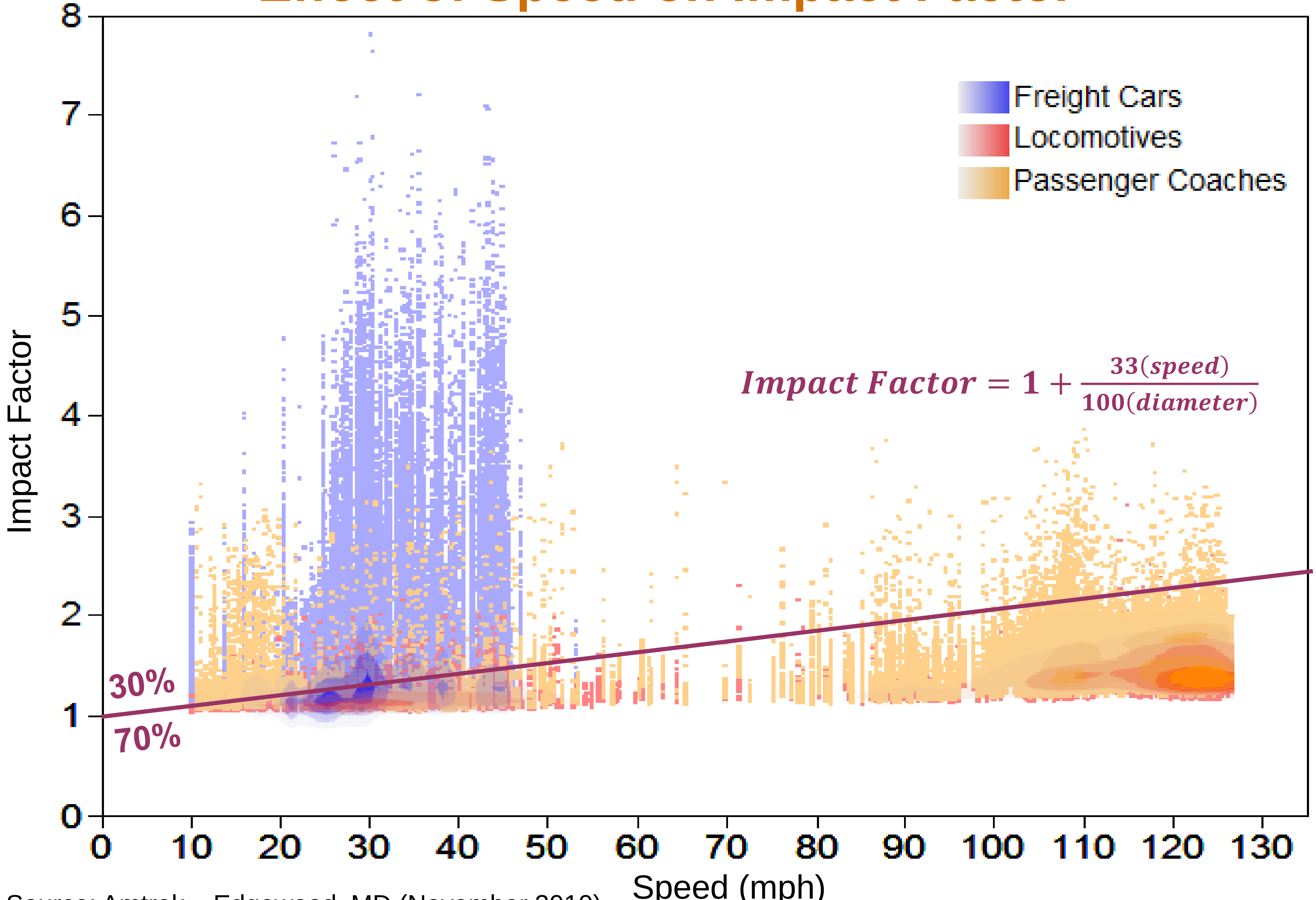
Source: Amtrak (November 2010)

Effect of Traffic Type on Wheel Load



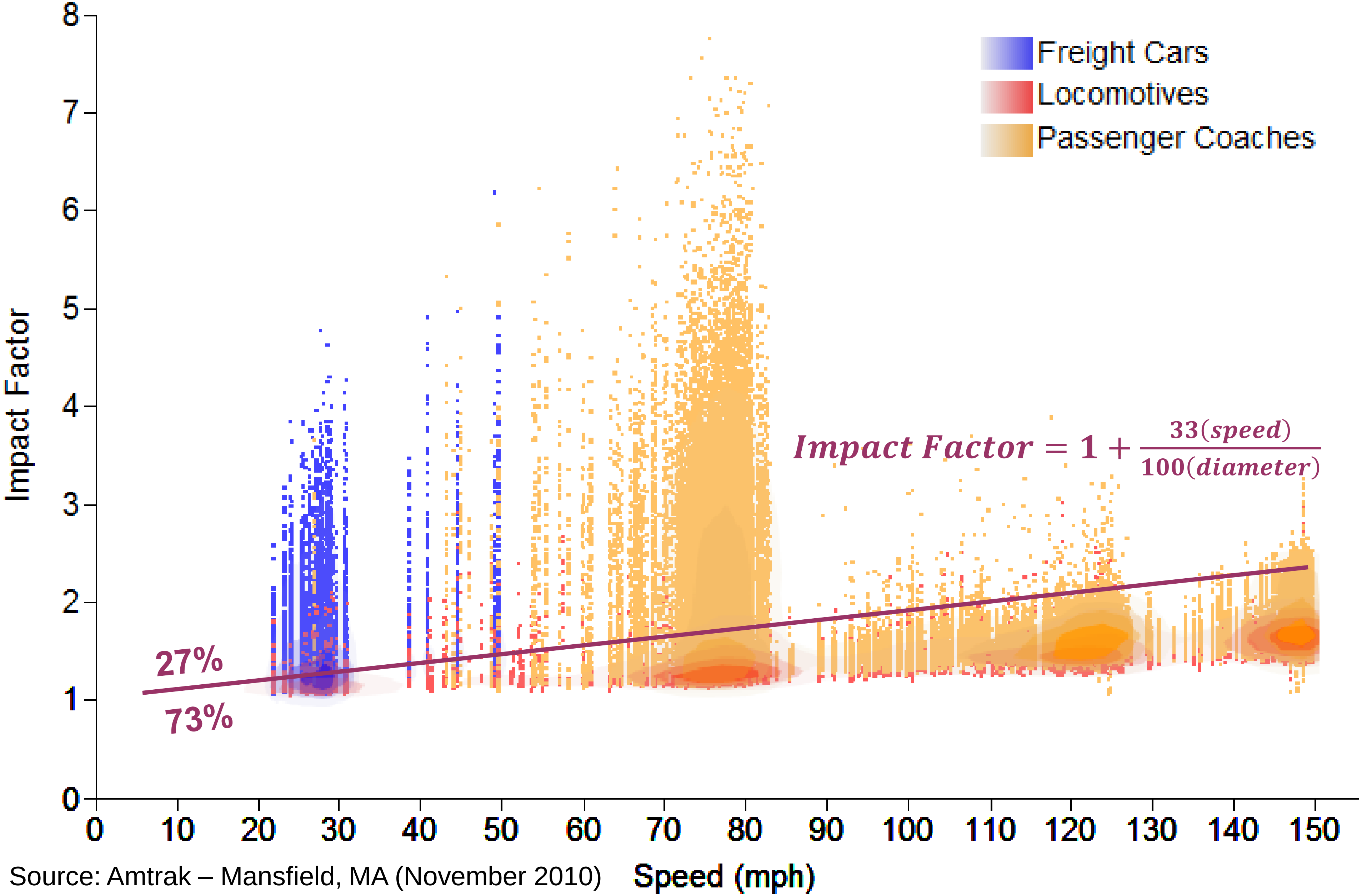
Source: Amtrak – Mansfield, MA (November 2010)

Effect of Speed on Impact Factor



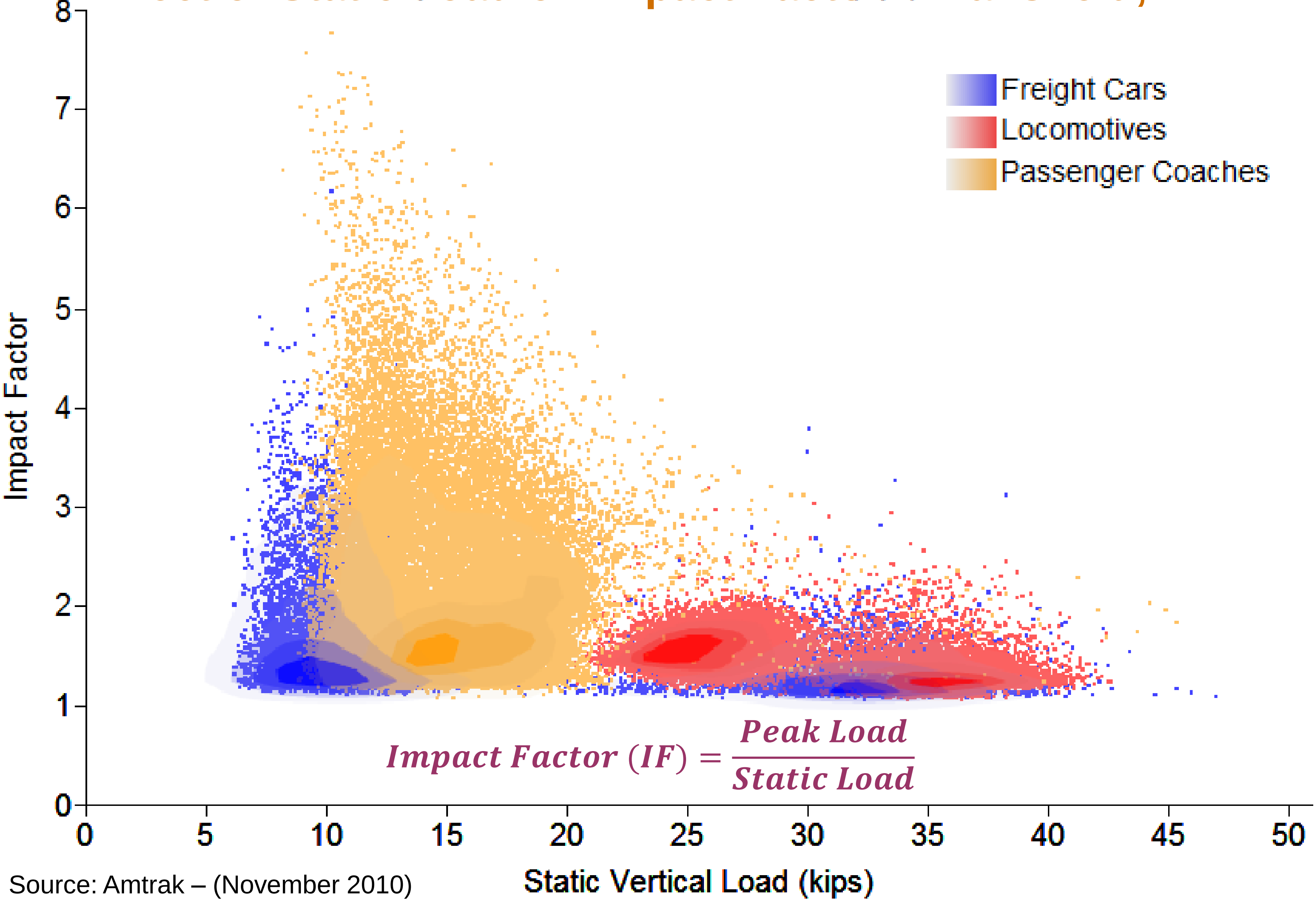
Source: Amtrak – Edgewood, MD (November 2010)

Effect of Speed on Impact Factor



Source: Amtrak – Mansfield, MA (November 2010)

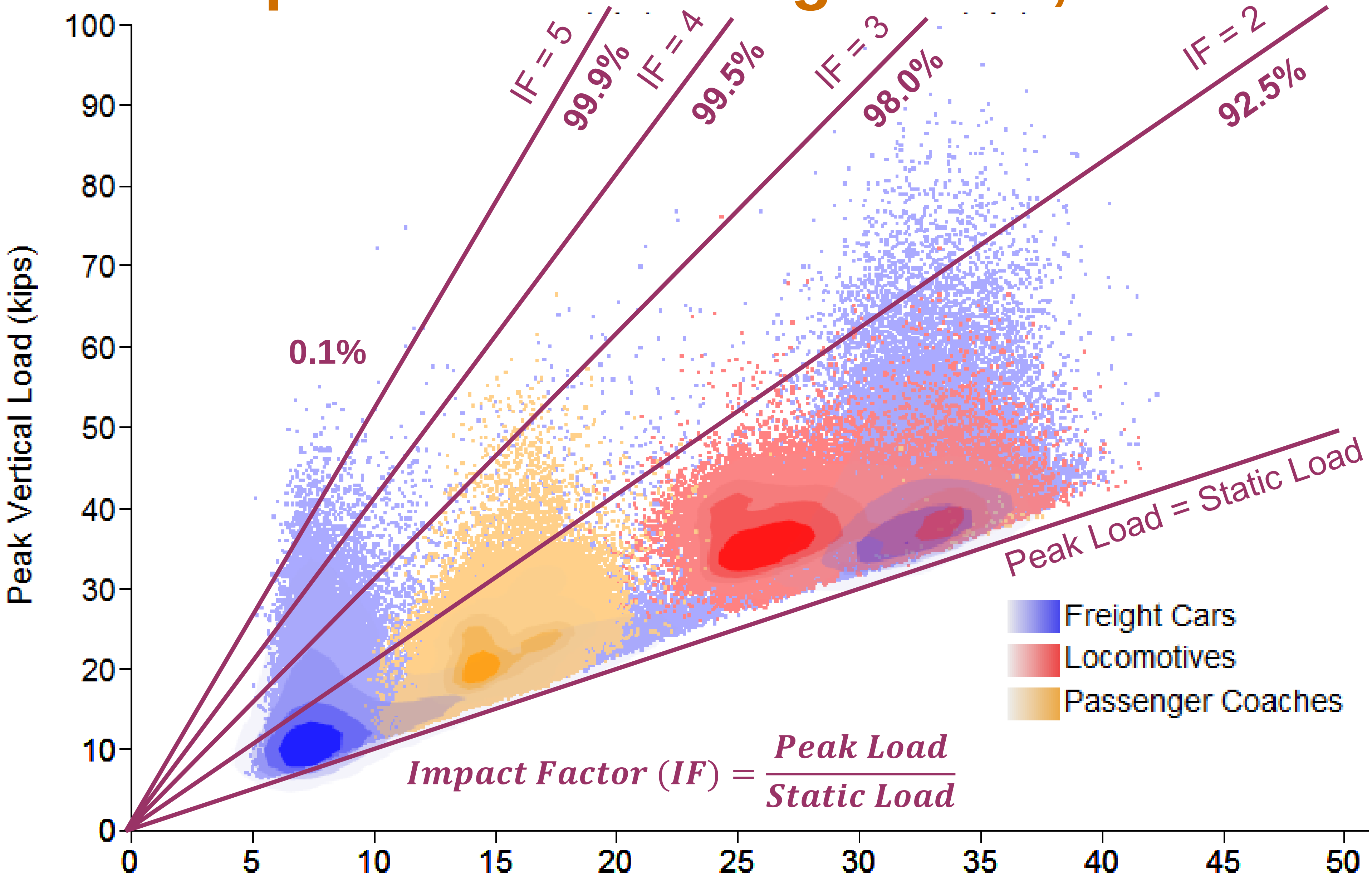
Effect of Static Load on Impact Factor – Mansfield, MA



$$\textit{Impact Factor (IF)} = \frac{\textit{Peak Load}}{\textit{Static Load}}$$

Source: Amtrak – (November 2010)

Impact Loads – Edgewood, MD



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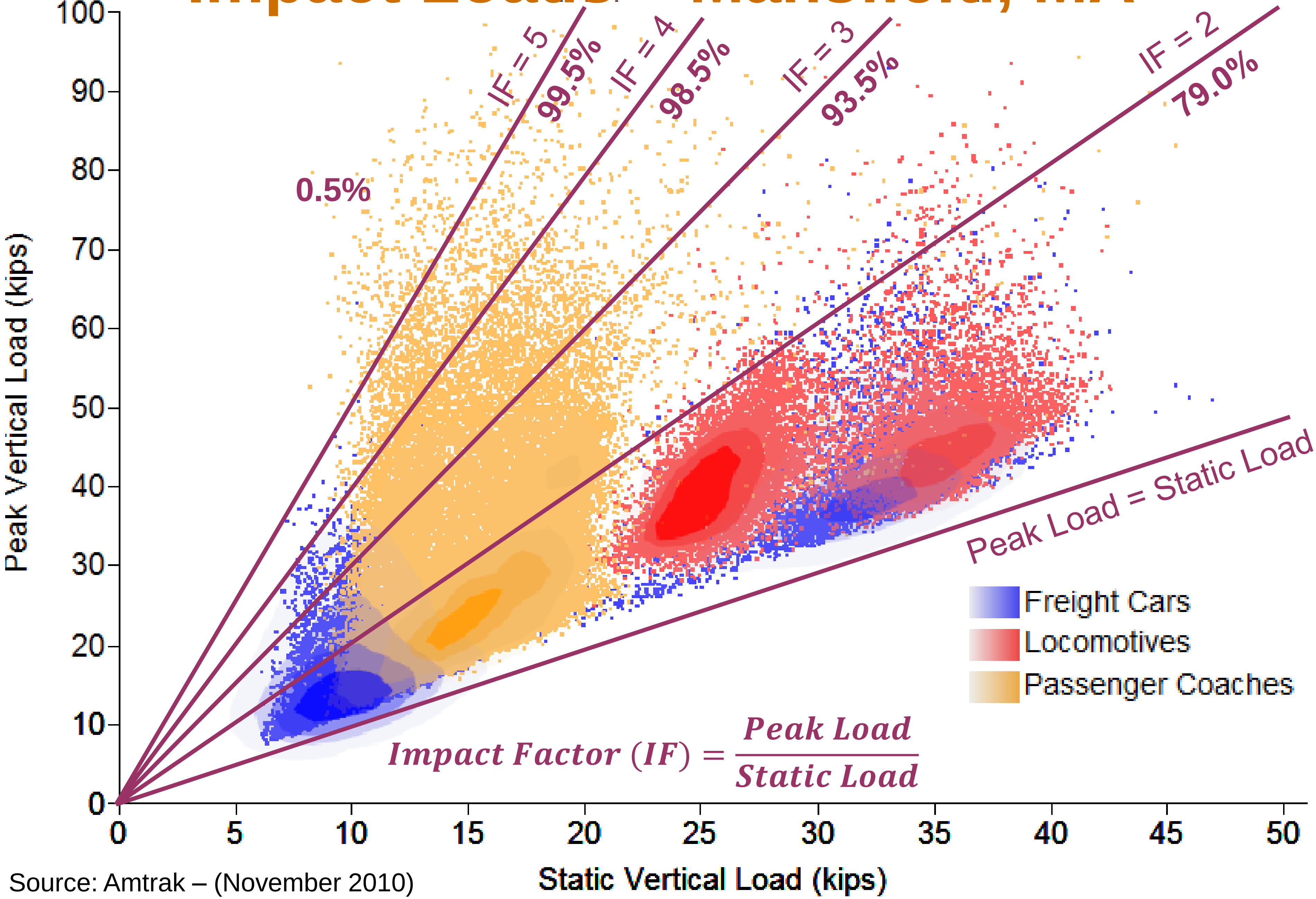
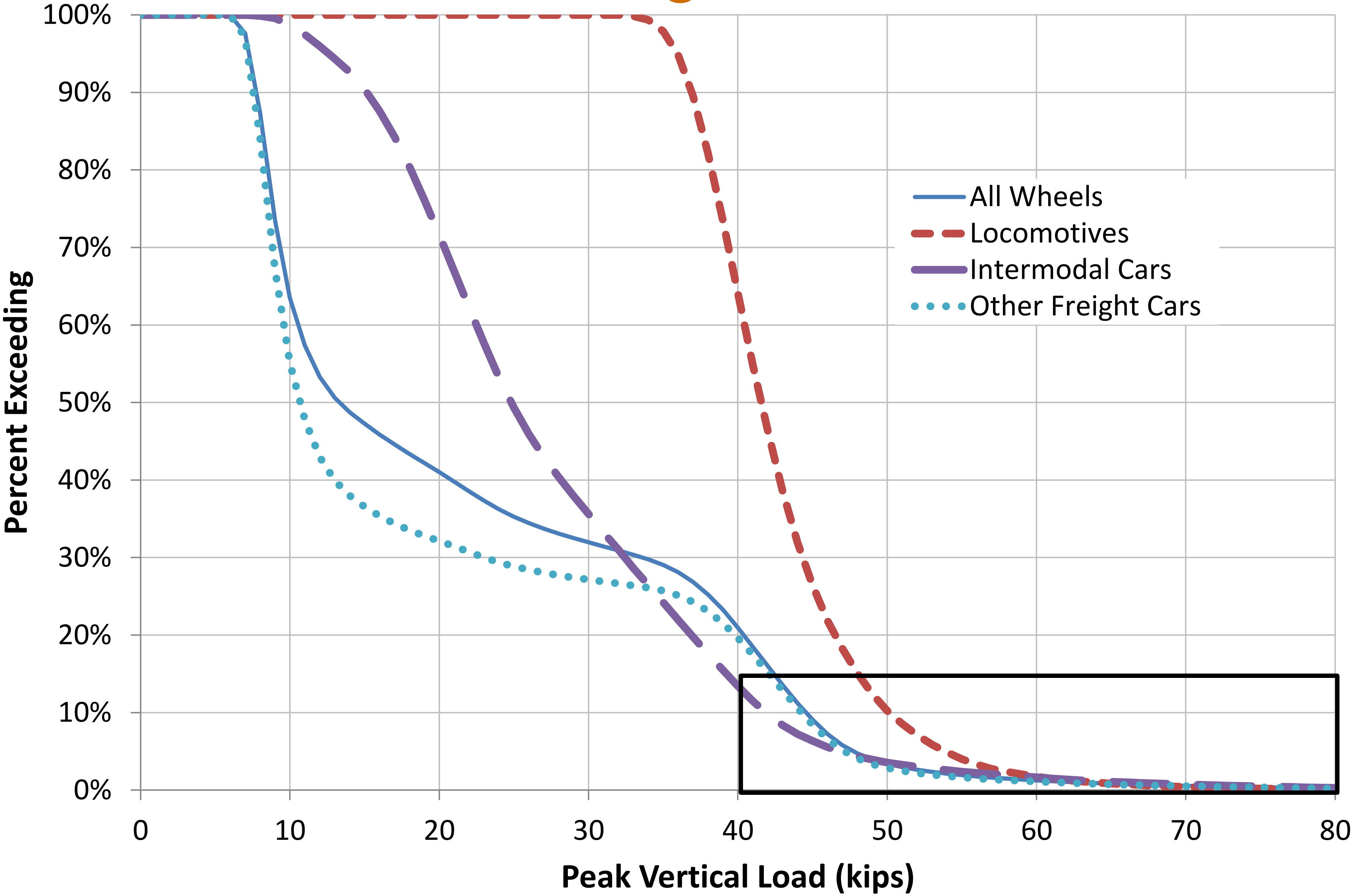
Impact Loads – Mansfield, MA



$$\textit{Impact Factor (IF)} = \frac{\textit{Peak Load}}{\textit{Static Load}}$$

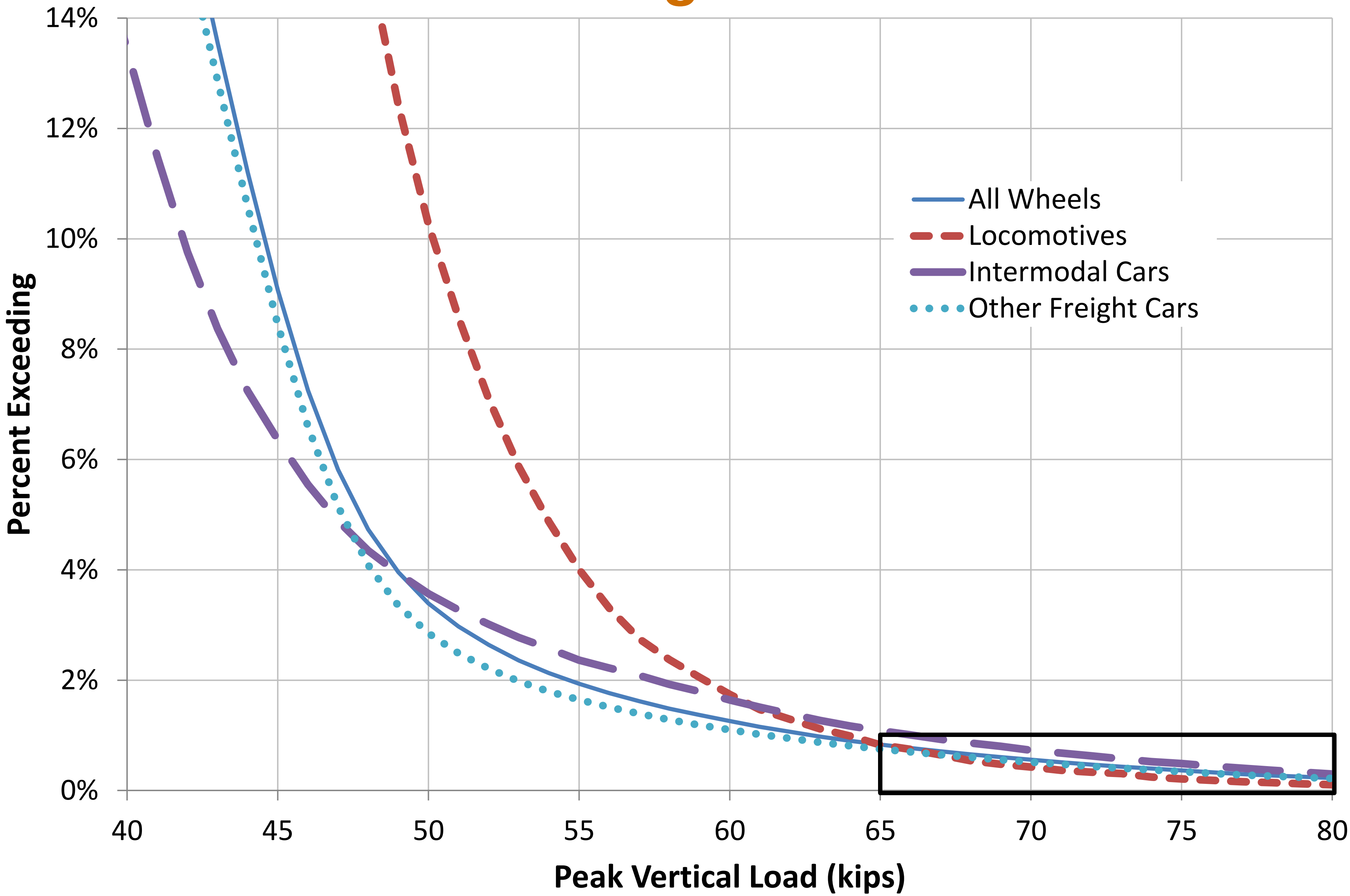
Source: Amtrak – (November 2010)

Variation of Freight Wheel Loads



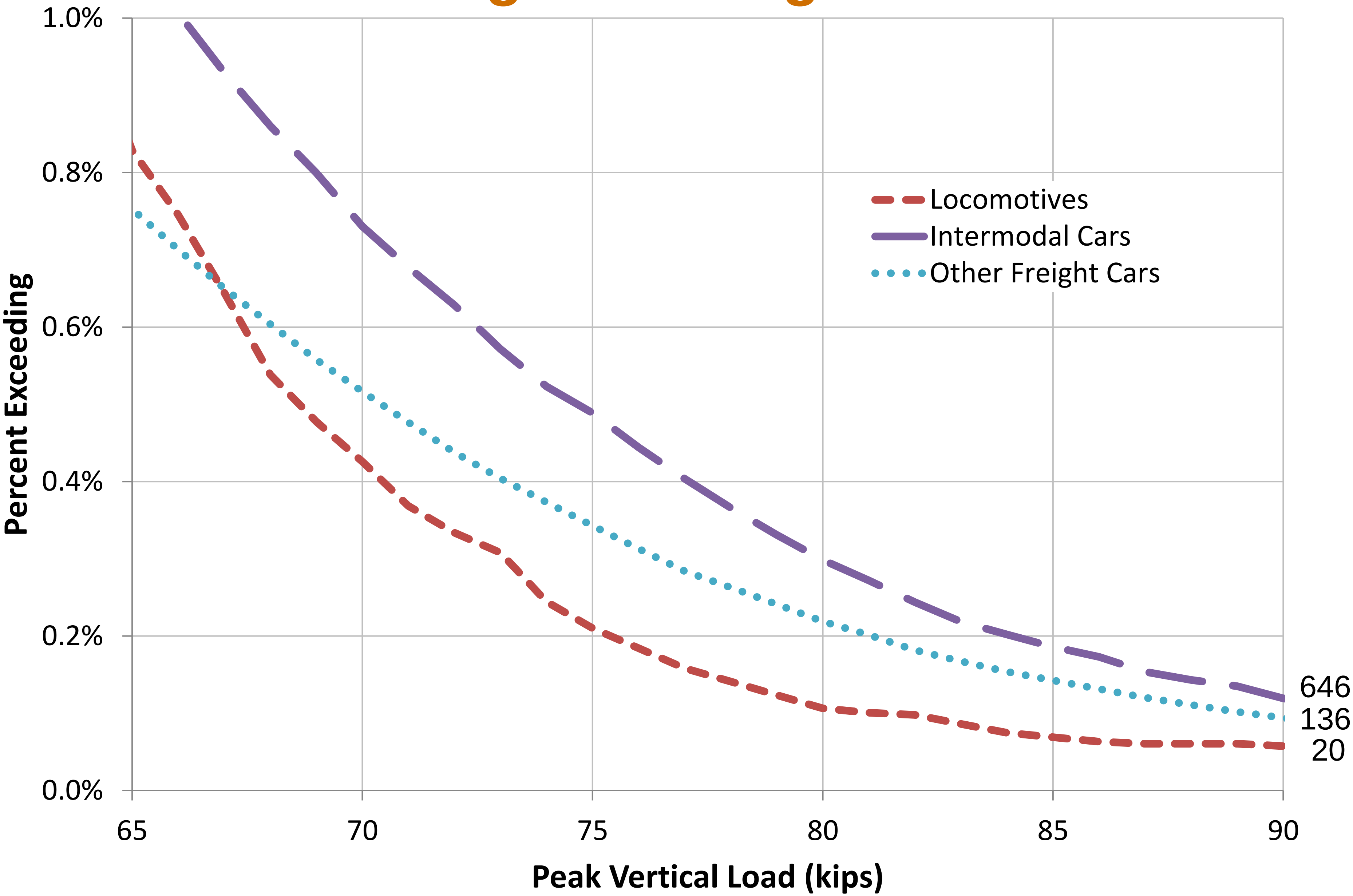
Source: Union Pacific – Gothenburg, NE (January 2010)

Variation of Freight Wheel Loads



Source: Union Pacific – Gothenburg, NE (January 2010)

Variation of Highest Freight Wheel Loads



Source: Union Pacific – Gothenburg, NE (January 2010)

Preliminary Conclusions

- Seasonal effects in load variation appear to be minimal
- Wheel condition has a significant effect on peak vertical wheel loads (often more than static load or speed)
- Impact factors may not be suitable as a design parameter
  - AREMA Chapter 16 Impact Factor mostly adequate at highest speeds
  - 200% increase (impact factor of 3) assumed for design not sufficient in some cases (overly conservative in most cases)
- Passenger and freight loads on shared infrastructure necessitate more challenging design practices

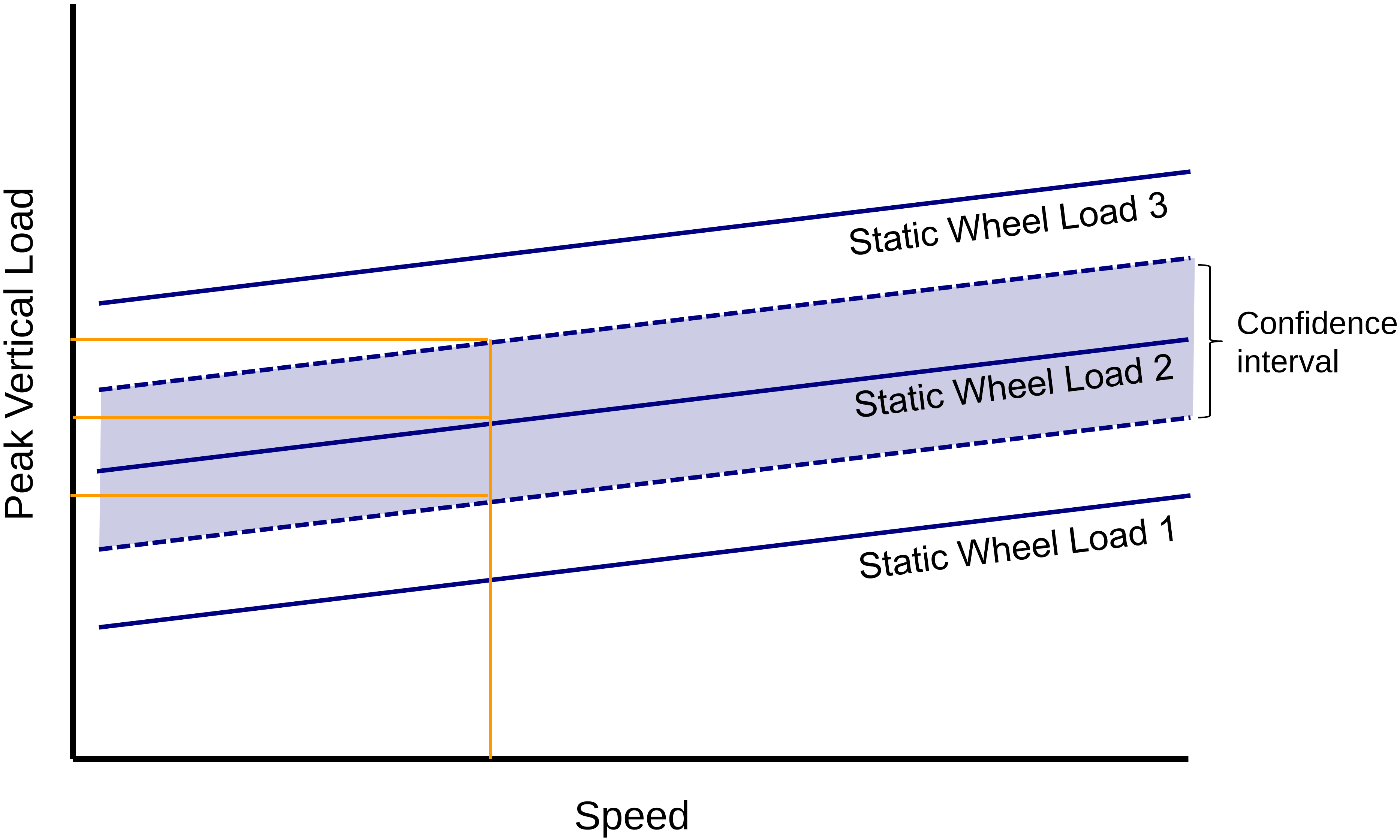
Future Work

- Investigate more locations with heavy axle load freight traffic
- Compare loads across US rail network (multiple WILDs)
- Utilize IWS and UIUC data for lateral load information
- Better quantify load path through track structure
- Develop model to predict loading environment

Future Work – Loading Environment Model

- Inputs
  - Expected static wheel loads
  - Expected speeds
  - Condition of wheel
  - Environmental conditions
  - Level of confidence
- Outputs
  - Peak wheel loads
  - Confidence intervals
  - Expected impact factors

Future Work – Loading Environment Model



Acknowledgements

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  - BNSF Railway
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FRA Tie and Fastener BAA Industry Partners:

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GIC INGENIERÍA Y CONSTRUCCIÓN S.A. DE C.V.

HANSON

LBFoster CXT Concrete Ties

Questions

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Appendix

Load Environment
AREMA Chapter 30 Section 1.2

- **Existing Content:**
  - Expected vertical, lateral, longitudinal loads at wheel/rail interface
  - Table 30-1-1 shows effects of traffic type, speed, and curvature
- **Proposed Improvements:**
  - Generally update based on current loading conditions
  - Complete areas where data are “estimated or interpolated”
  - Provide clearer definition and description of expected loads
- **Methodology:**
  - Use of existing wheel impact load detector (WILD) and instrumented wheel set (IWS) data
  - Define dynamic and impact loads based on data evidence
- **Timeline:**
  - Submit to full committee for ballot (Spring 2013)

SECTION 1.2 LOAD ENVIRONMENT

Table 30-1-1 defines the load environment expected to be encountered in North American Freight, High Speed Passenger and Transit Railroad segments of the industry. Specifically, Table 30-1-1 presents the available data in terms of vertical, horizontal and longitudinal loads that can be expected at the wheel/rail interface. The service categories are distinguished as follows. Mainline Freight represents lines other than Light Density Freight. Light Density Freight represents lines with less than five million gross tons and excludes A/C Traction. High Speed Passenger represents passenger loadings whether in mixed service or on dedicated routes. Speeds are given in miles per hour.

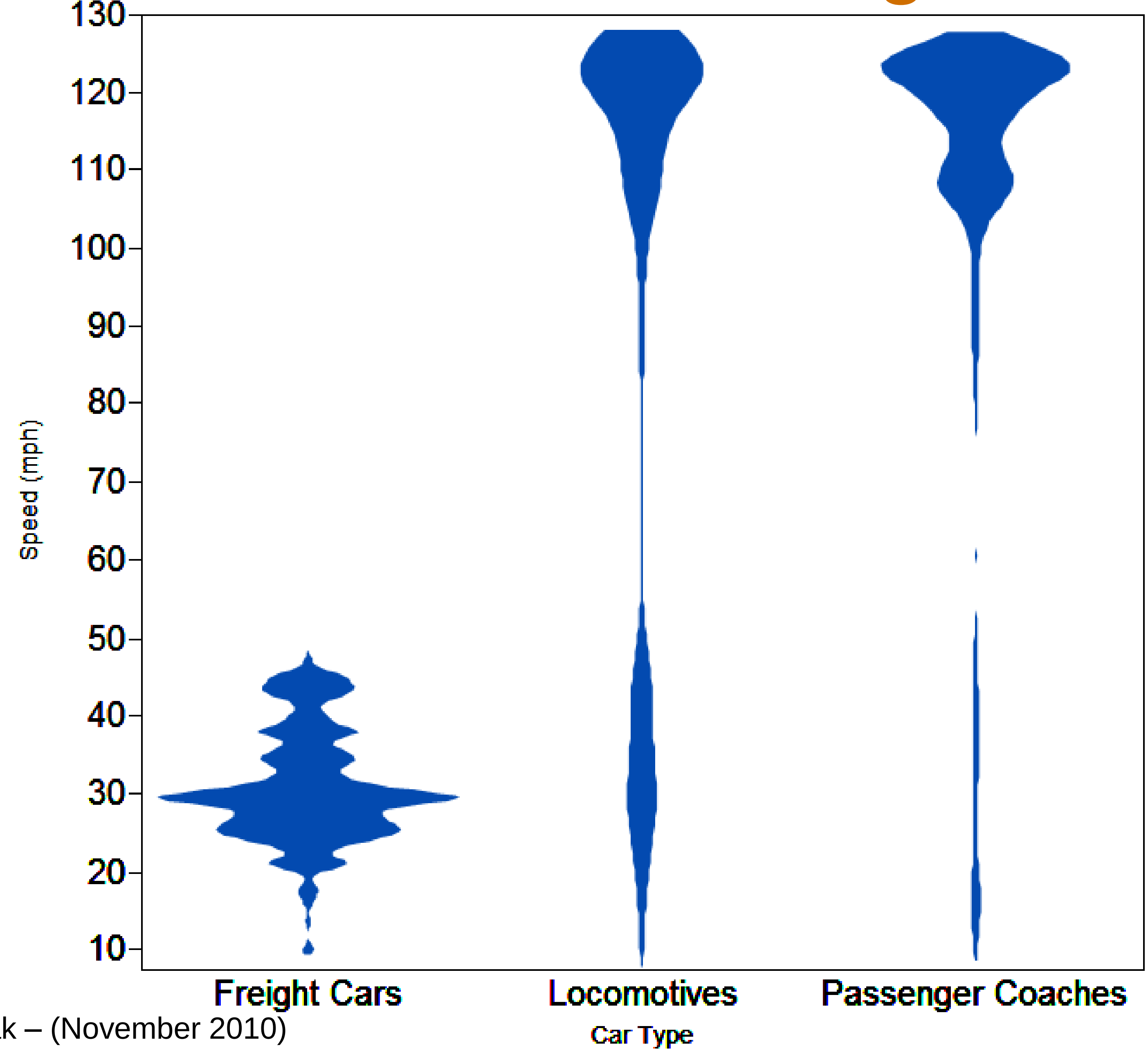
Table 30-1-1. Wheel to Rail Loads (kips)

CURVE	<2 DEG			2-5 DEG			>5 DEG		
SPEED	VERT	LAT	LONG	VERT	LAT	LONG	VERT	LAT	LONG
MAINLINE FREIGHT									
<40	80	20*	50	80	30*	50	80	30	50
40 to 60	120	30*	50	120	30*	50	120	30	50
>60	120	30	50	120	30	50	**	**	**
LIGHT DENSITY FREIGHT (no A/C Traction)									
<40	80	20	30	80	30*	30	80	30	30
40 to 60	120	30	30	120	30	30	120	30	30
>60	120	30	30	120	30	30	**	**	**
HIGH SPEED PASSENGER									
<90	100	10	25	100	18	25	100	20*	25
>90	100	18	25	100	18	25	**	**	**
TRANSIT									
No data available									

* This data estimated or interpolated

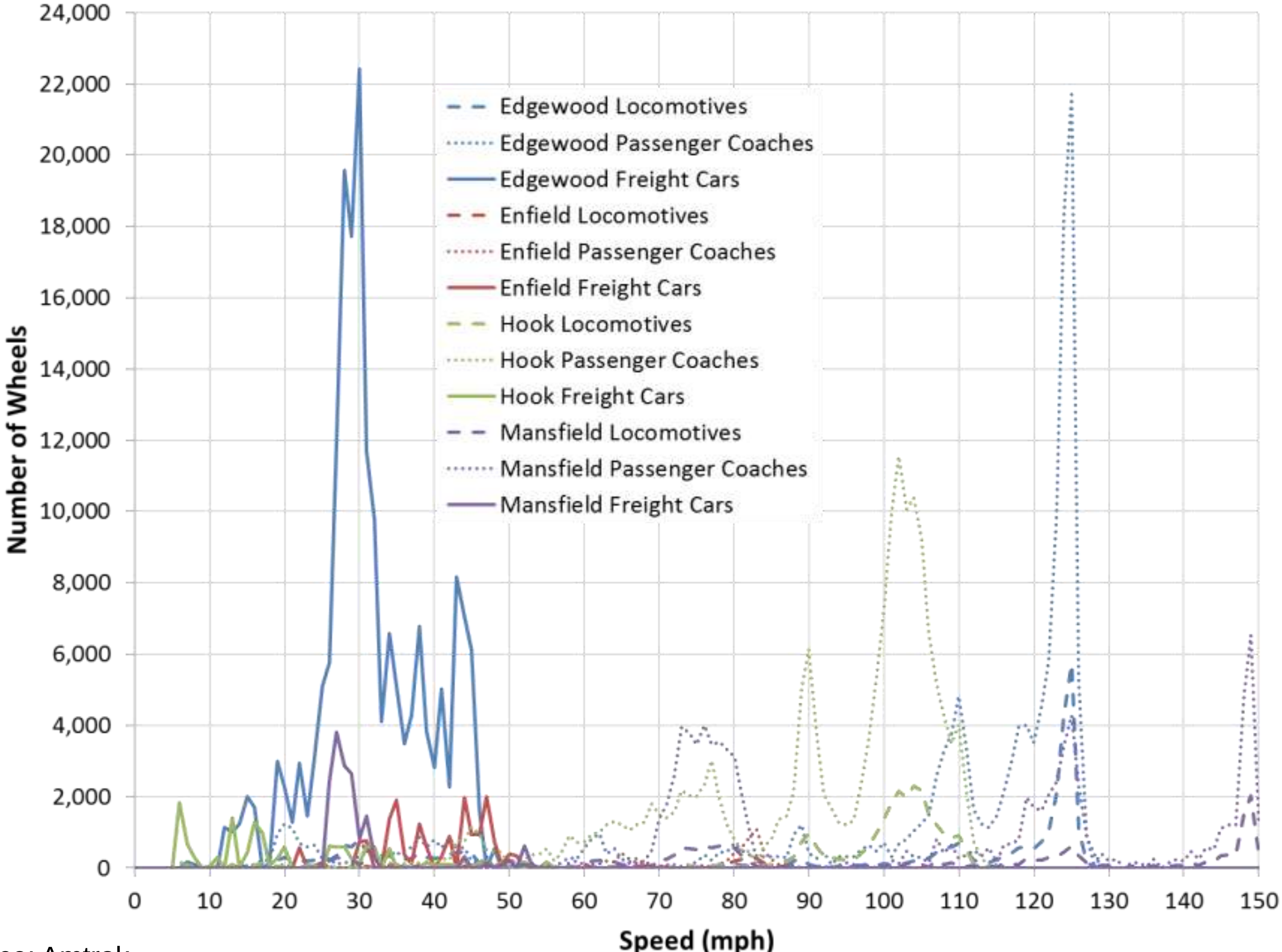
** Generally accepted superelevation practice excludes these values

Speed Characterization – Edgewood, MD



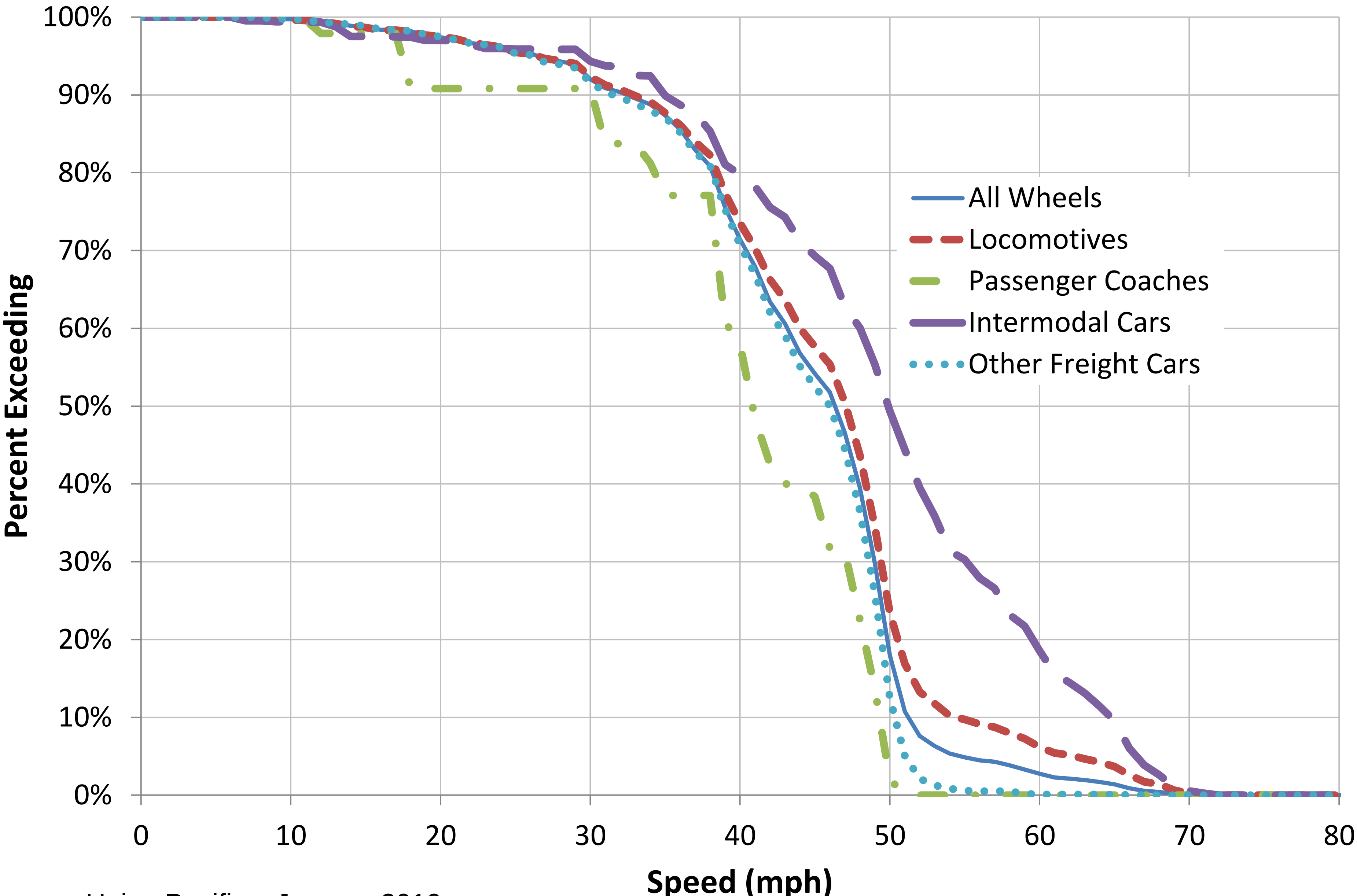
Source: Amtrak – (November 2010)

Characterization of Speeds on Amtrak's Northeast Corridor (April 2011)



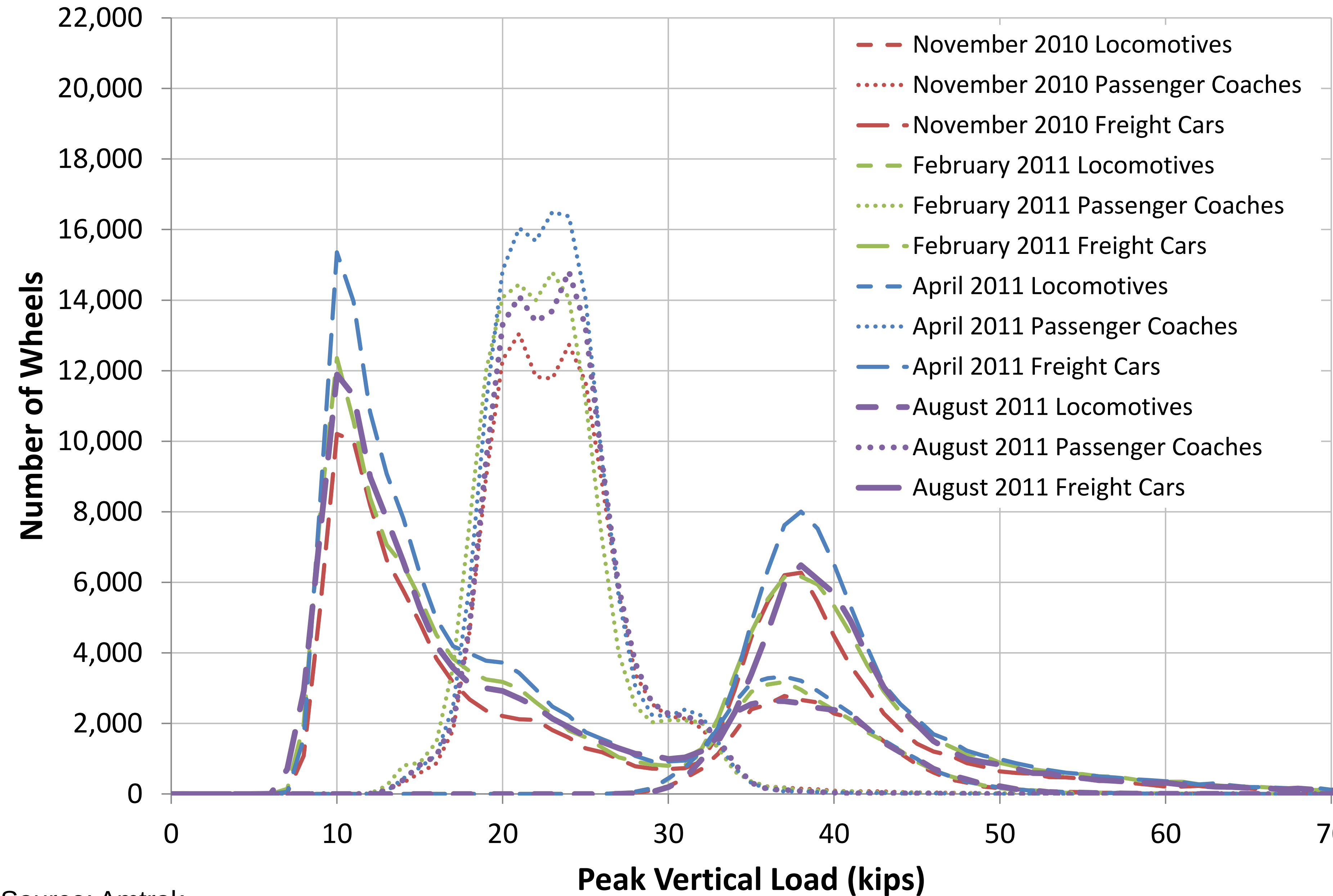
Source: Amtrak

Speed Characterization – Gothenburg, NE



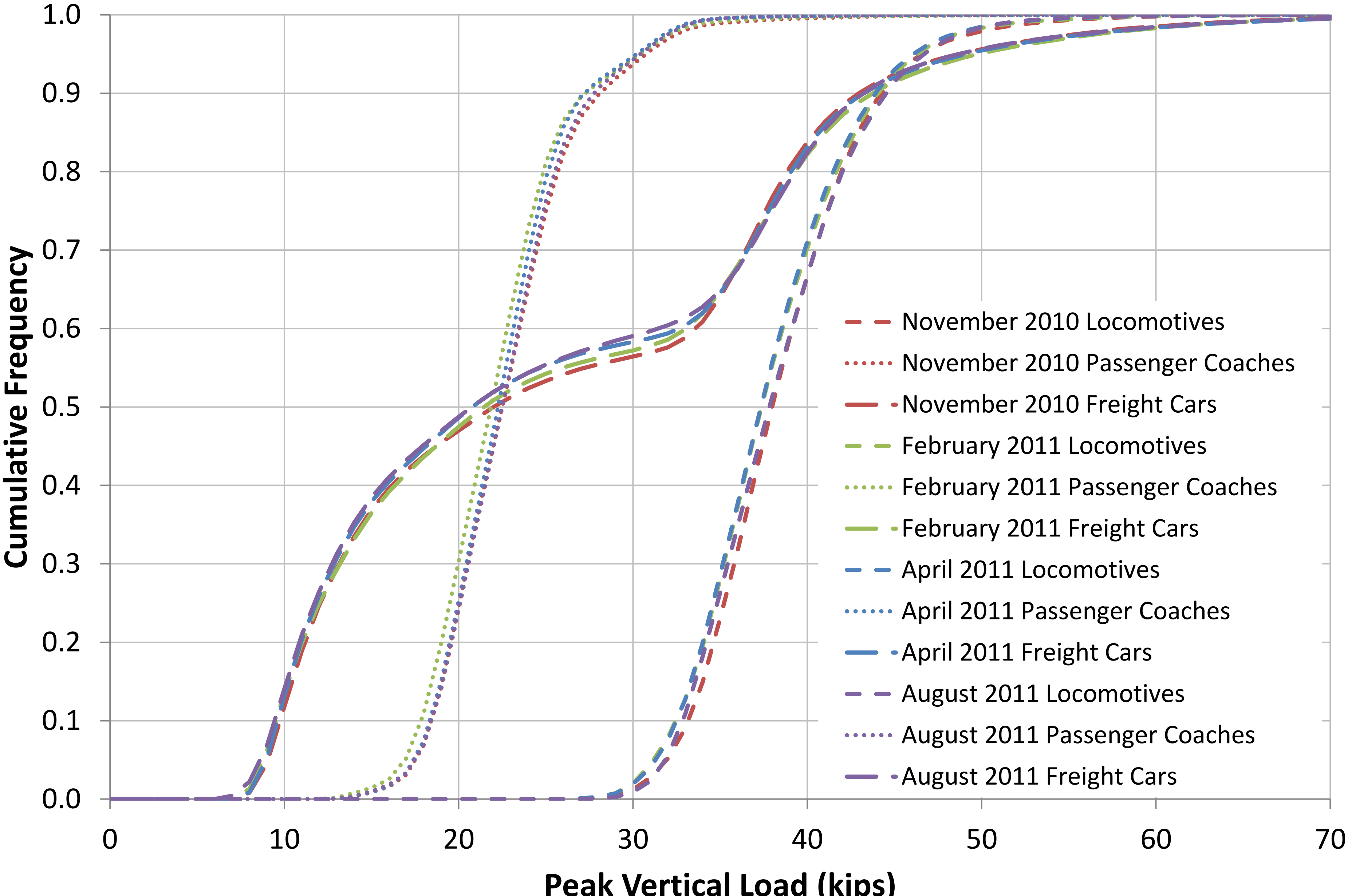
Source: Union Pacific – January 2010

Seasonal Effects on Peak Vertical Load – Edgewood, MD



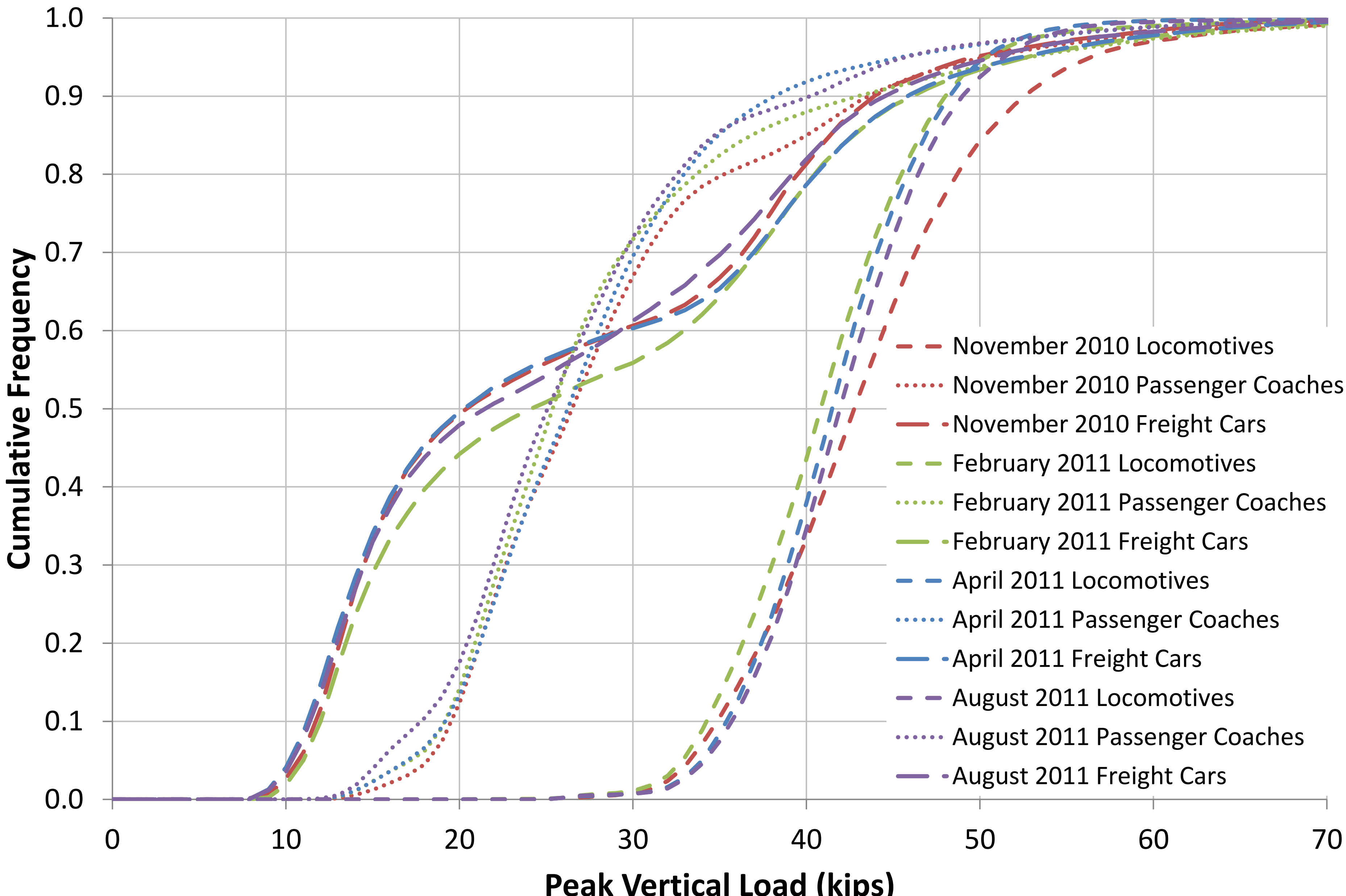
Source: Amtrak

Seasonal Effects on Peak Vertical Load – Edgewood, MD



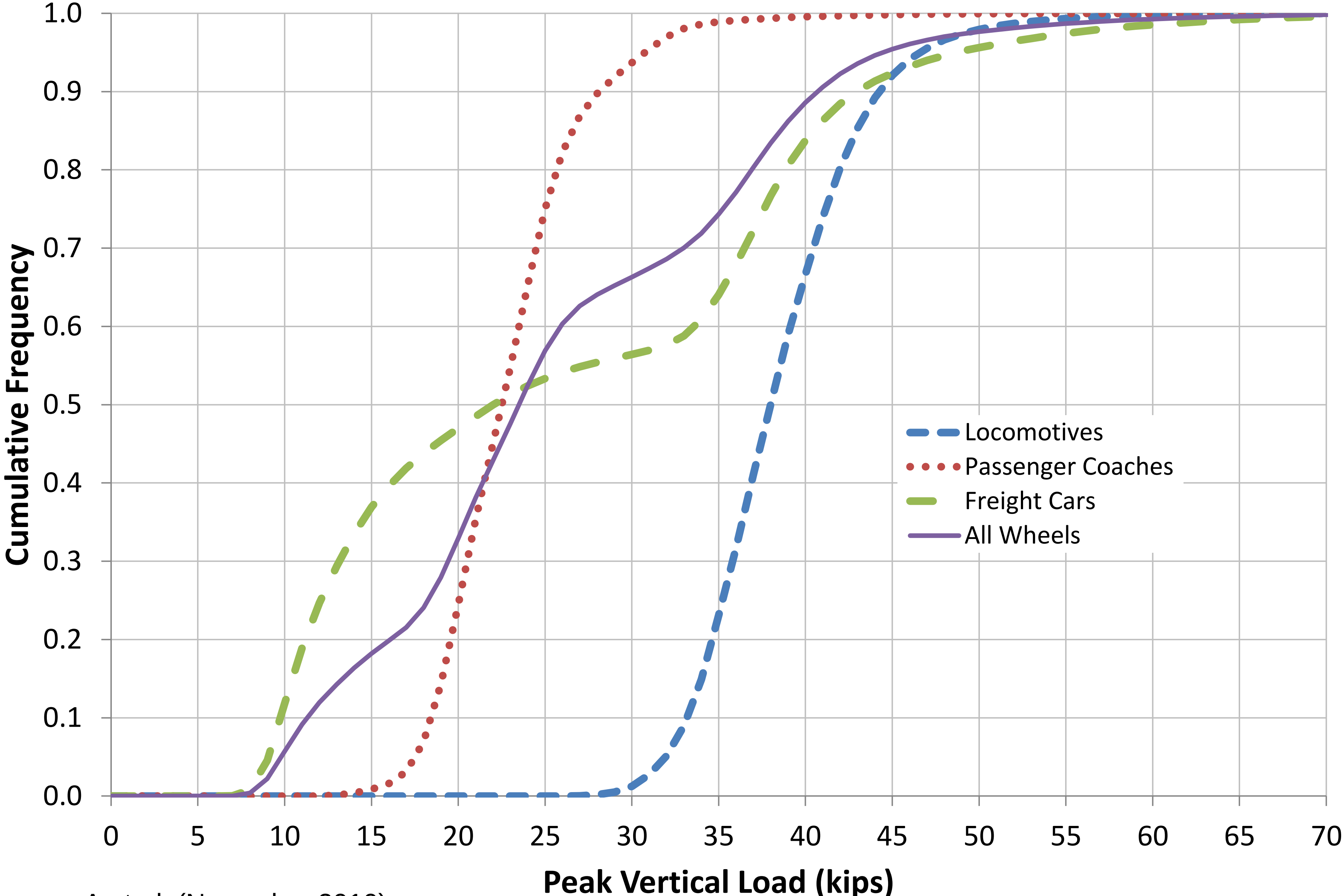
Source: Amtrak

Seasonal Effects on Peak Vertical Load – Mansfield, MA



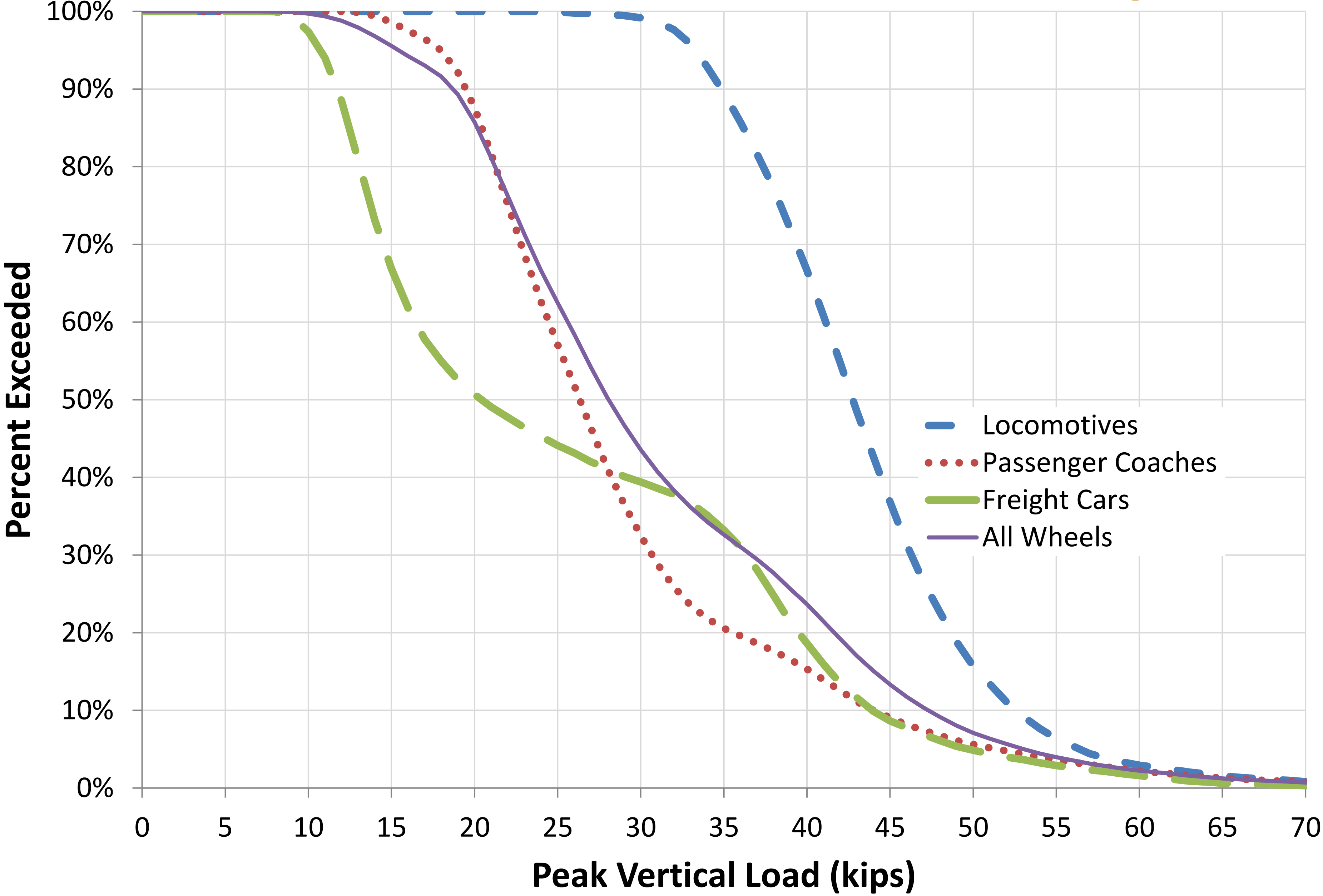
Source: Amtrak

Variations of Peak Vertical Load by Traffic – Edgewood, MD



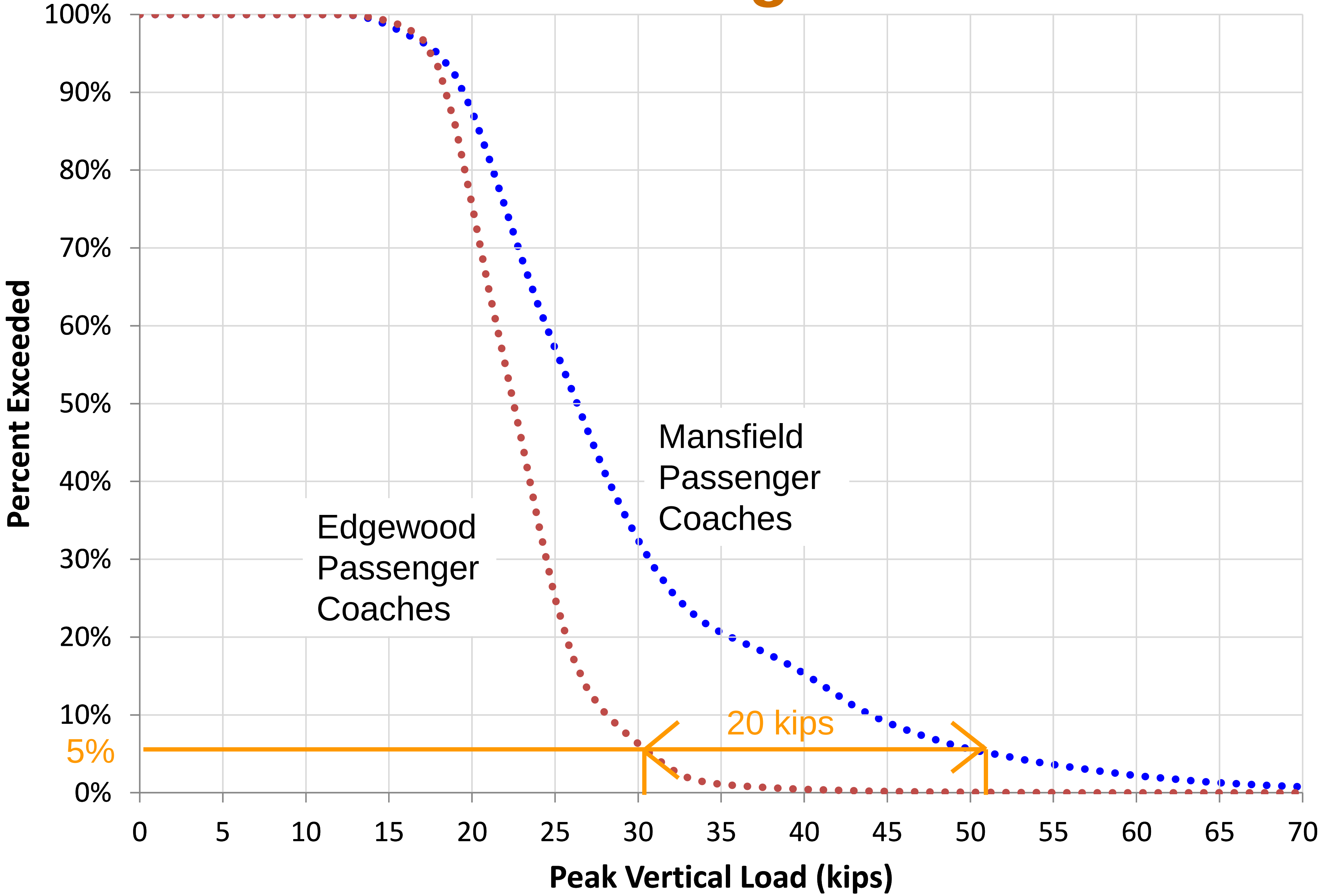
Source: Amtrak (November 2010)

Vertical Wheel Loads – Mansfield, MA



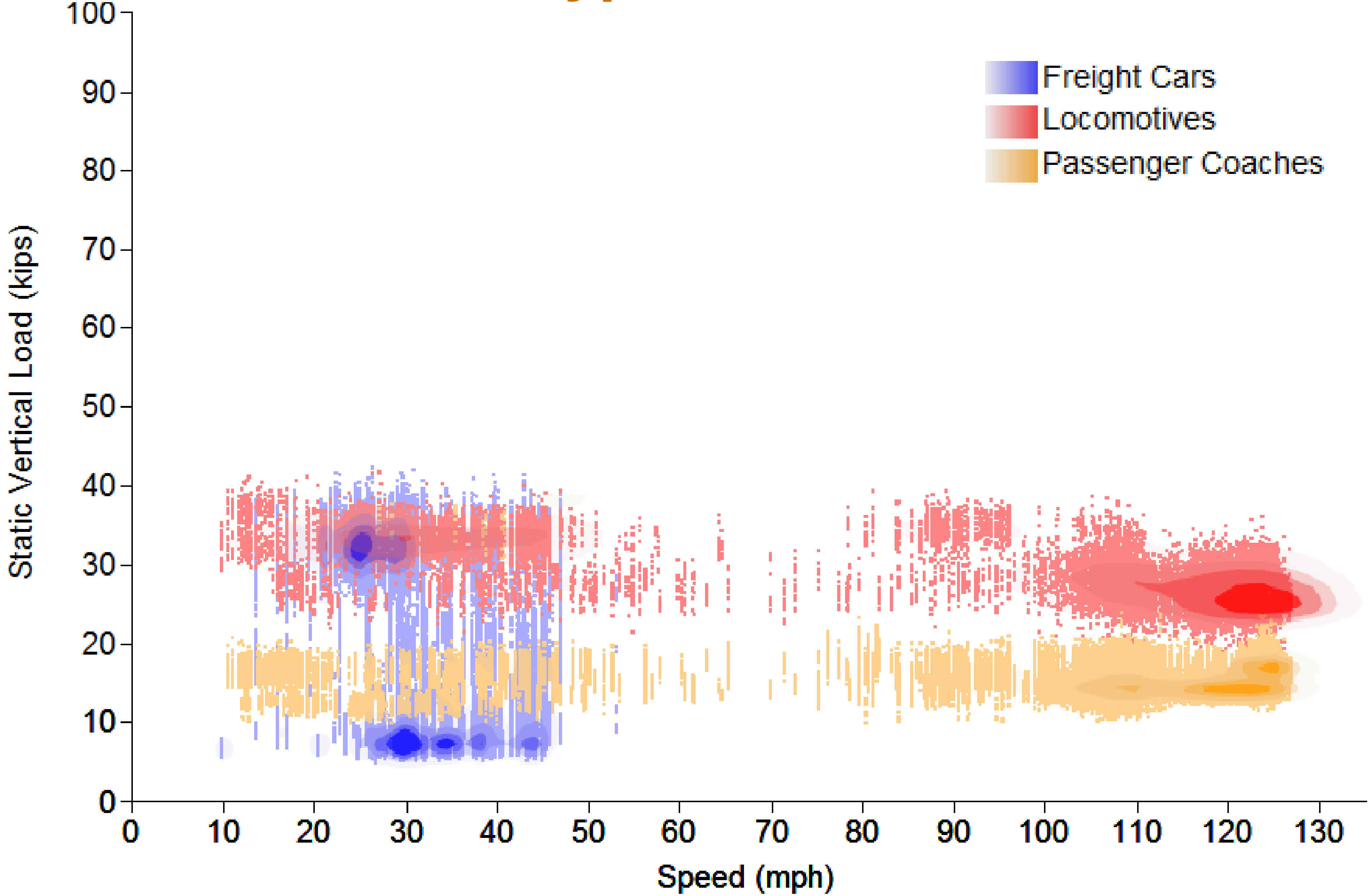
Source: Amtrak – Mansfield, MA (November 2010)

Distribution of Passenger Wheel Loads



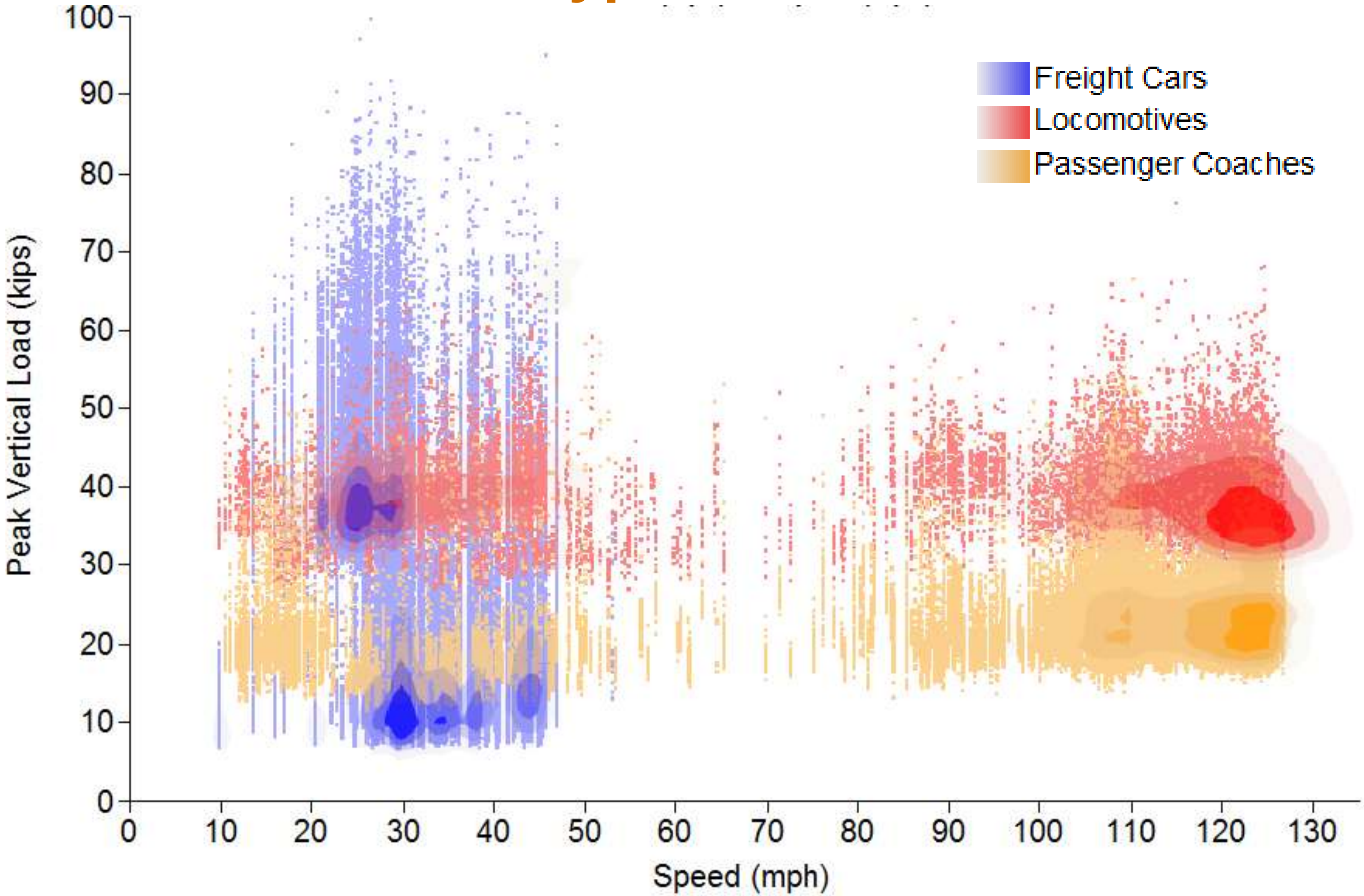
Source: Amtrak – November 2010

Effect of Traffic Type on Static Wheel Load



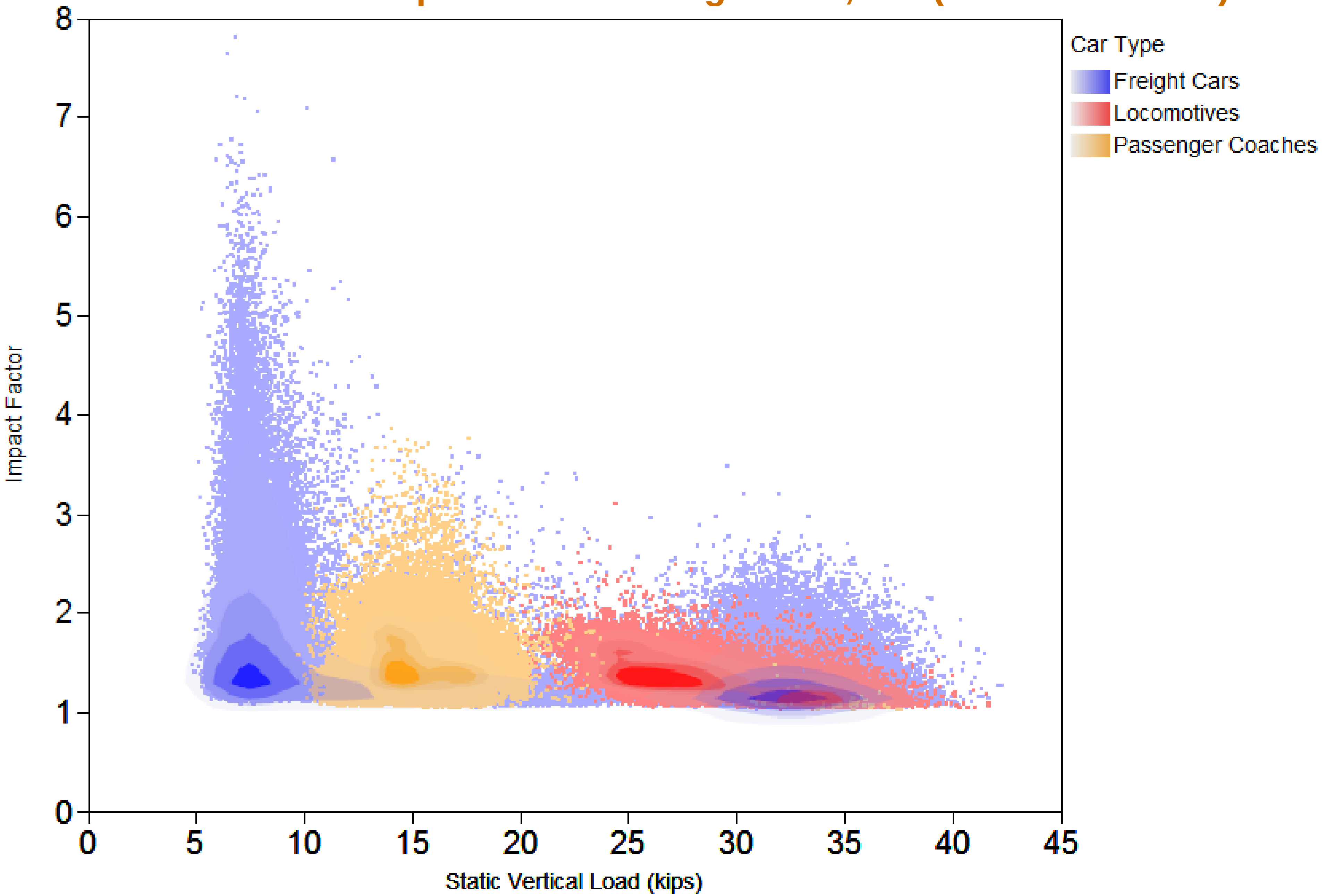
Source: Amtrak – Edgewood, MD (November 2010)

Effect of Traffic Type on Peak Wheel Load

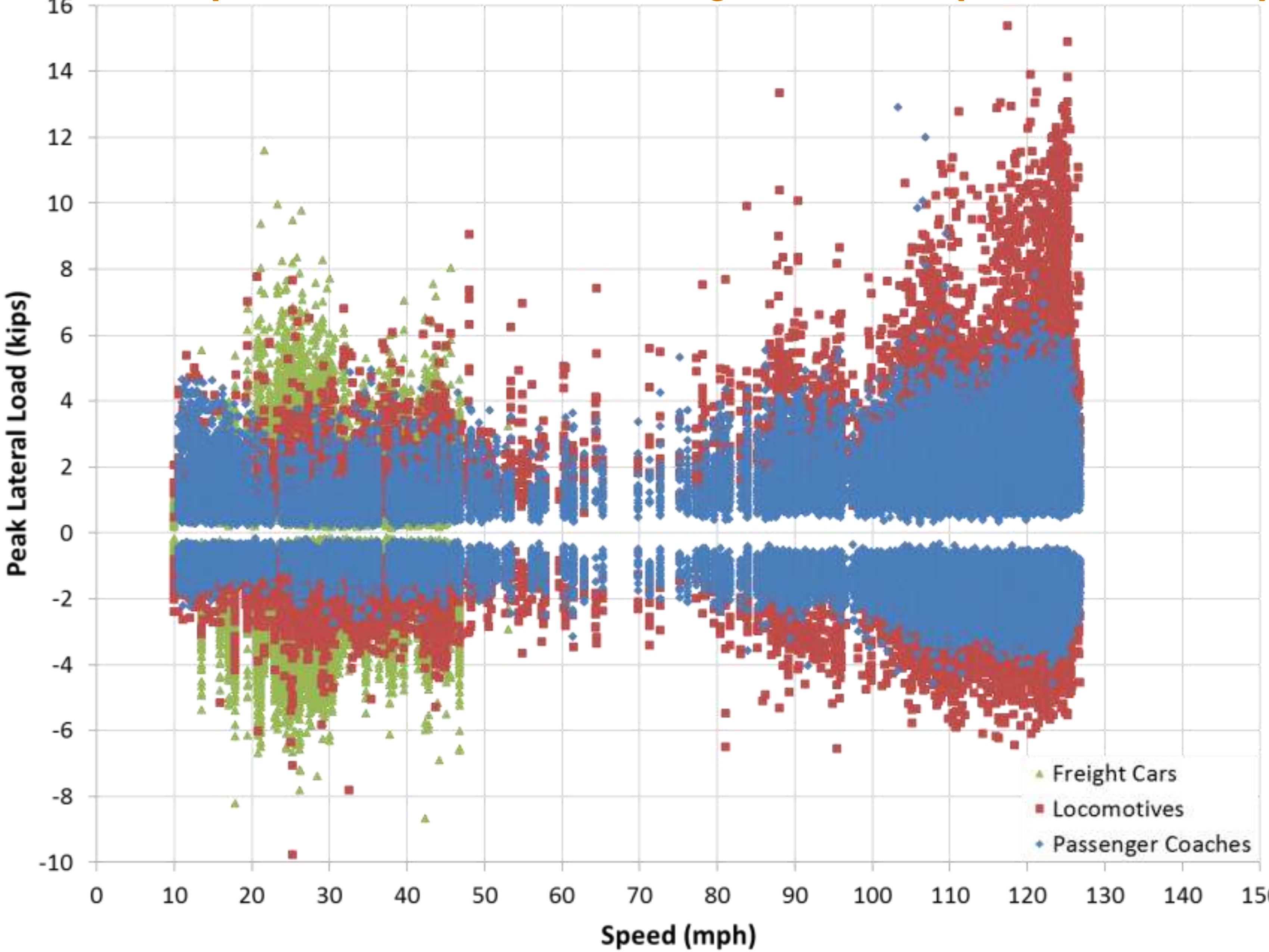


Source: Amtrak – Edgewood, MD (November 2010)

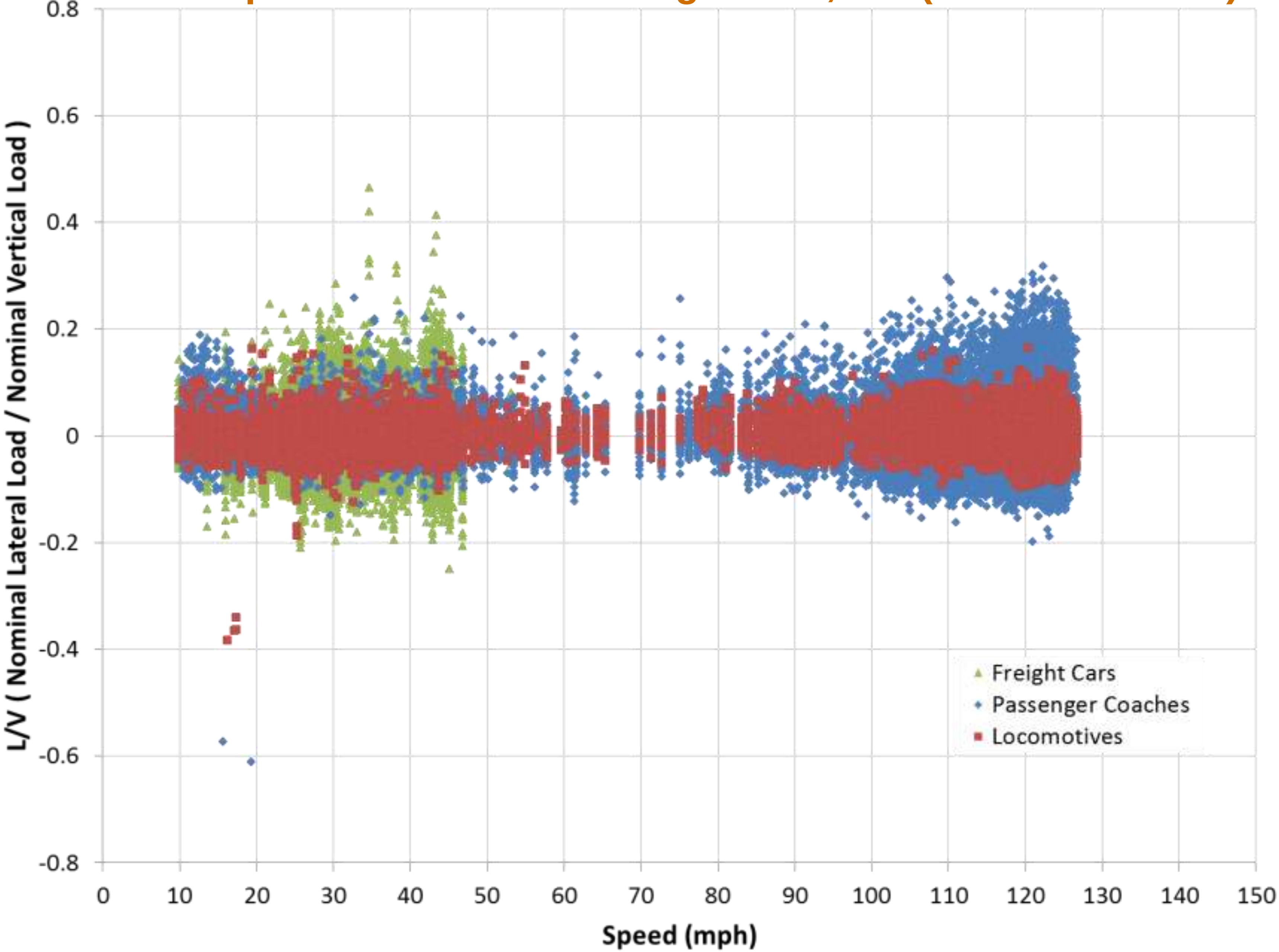
Load Effects on Impact Factor – Edgewood, MD (November 2010)



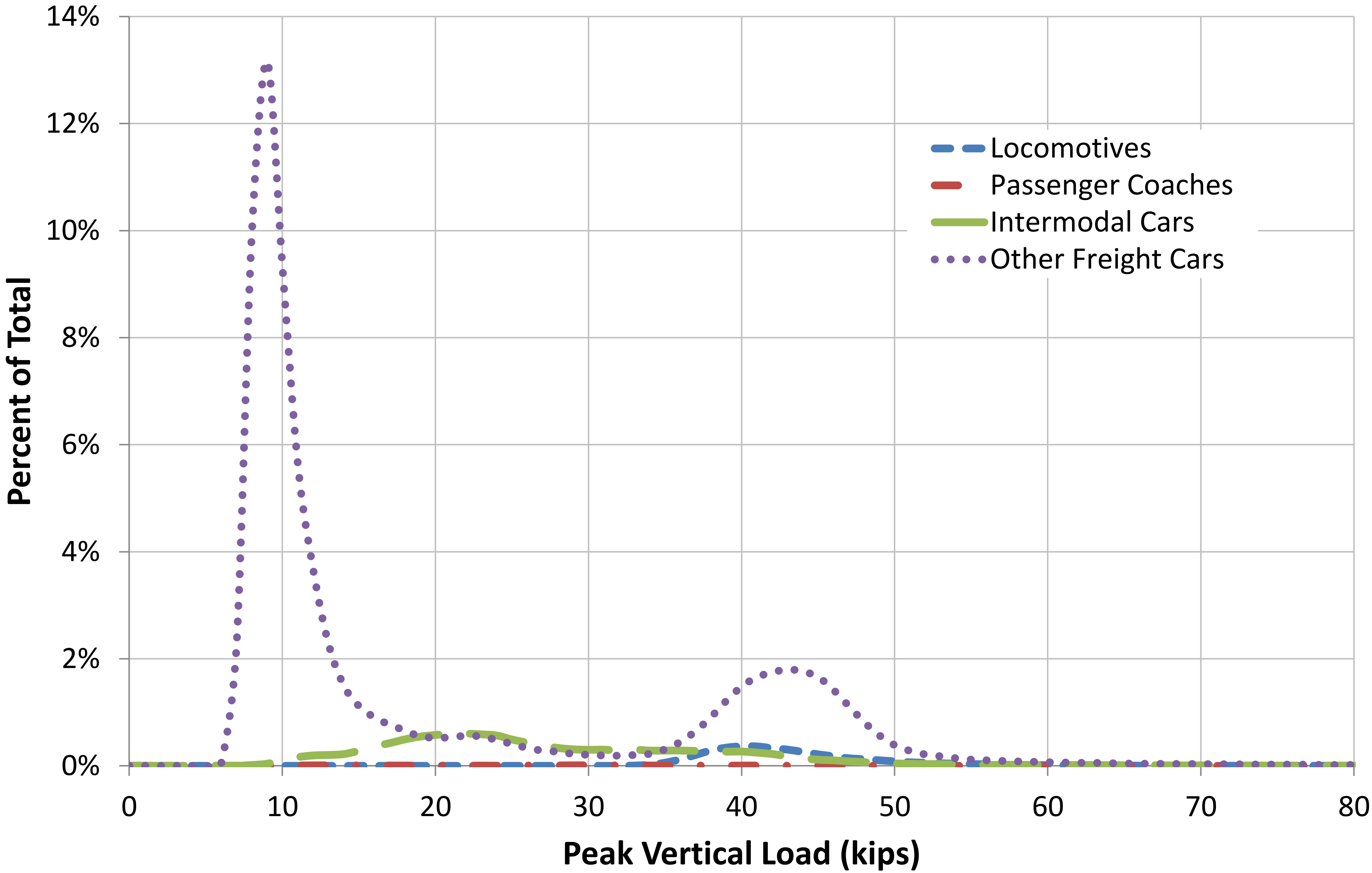
Effect of Speed on Lateral Load – Edgewood, MD (November 2010)



Effect of Speed on L/V Ratio – Edgewood, MD (November 2010)



Frequency of Peak Vertical Loads



Source: Union Pacific – Gothenburg, NE (January 2010)

Where the WILD Things Are

- Mansfield, MA (1)
- Enfield, CT (2)
- Hook, PA (3)
- Edgewood, MD (4)

Source: University of Virginia


Union Pacific Railroad Current and Proposed WILD Site Locations
Fields
Sunset
Baskin
Westvaco
Peru
Red Desert
Martin Bay
Gothenburg
New Cambria
Chamberlin
Wister
Donaldson
Stuttgart
Millican
Elton
All Sites (With the Exception of Fields, OR) Provide Vertical and Lateral Measurements
In Service WILD Locations
Parsons Sub WILD .. Under Construction
Proposed WILD Installations - 2008 and Beyond
Truck Performance Detector (TPD) Location(s)
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