Evaluation of Dynamic and Impact Wheel Load Factors and their Application for Design

Transportation Research Board 93rd Annual Meeting

Washington, D.C.

13 January 2014

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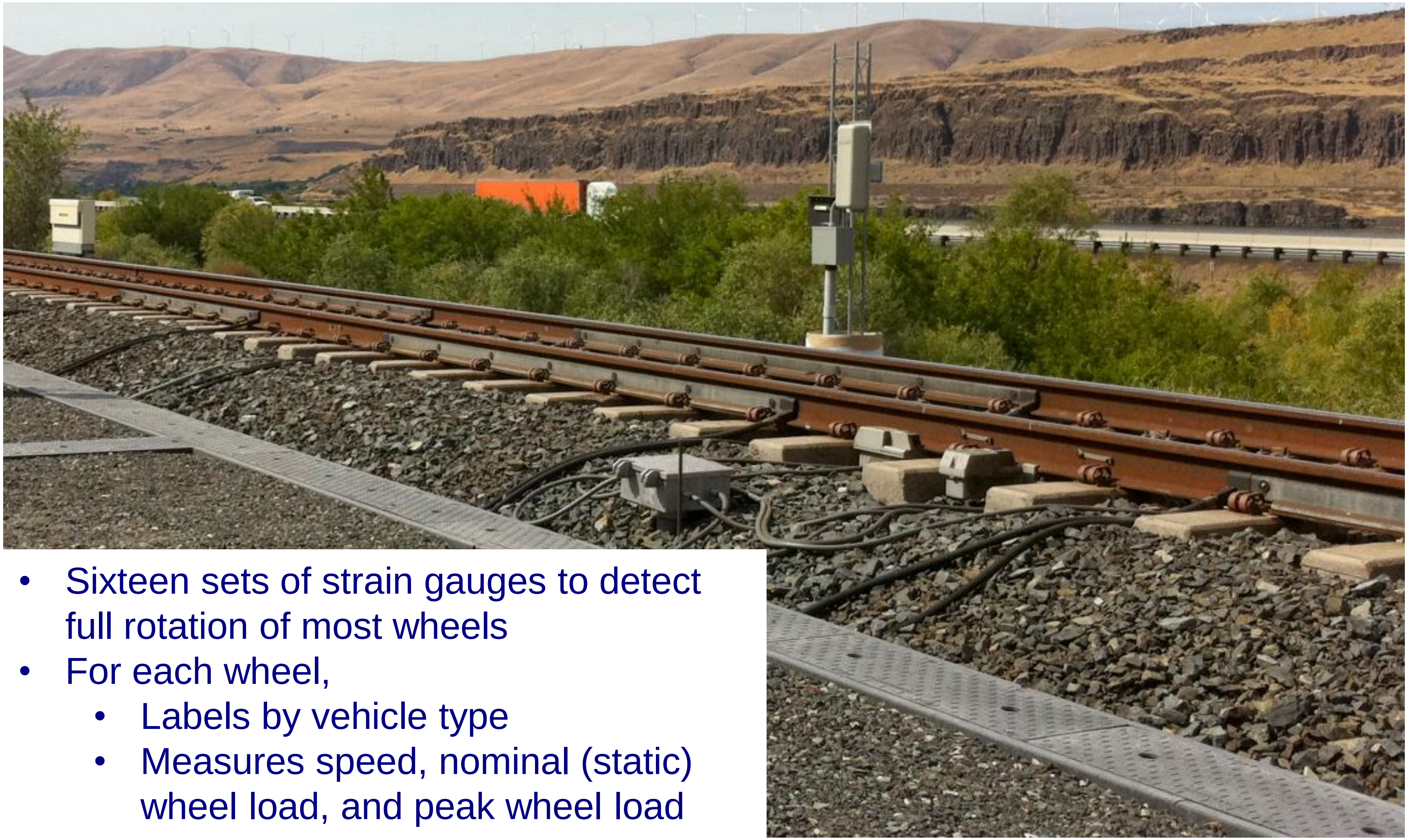
Outline

- Motivation for design factor evaluation
- Dynamic factor definition and evaluation
  - Dynamic factor parameters
  - Evaluative metrics
- Impact factor evaluation
- Alternative design parameter: peak tonnage
- Conclusions and Acknowledgements

Motivation

- Design guidelines often use historical wheel loads and several design factors
- To improve track structure design, the nature of these loads and how well the design process reflects them must be thoroughly understood
- There are many parameters that contribute to the variation in wheel loading, some of which are considered in multiple factors
- These factors can be evaluated and compared using actual loading data to determine their effectiveness in the design process

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

WILD Data Provided by Amtrak and UP

Dynamic vs. Impact Load

- Static load – load of vehicle at rest
- Quasi-static load – static load at speed, independent of time
- Dynamic load – high-frequency effects of wheel/rail interaction, dependent on time
- Impact load – high-frequency and short duration load caused by track and vehicle irregularities

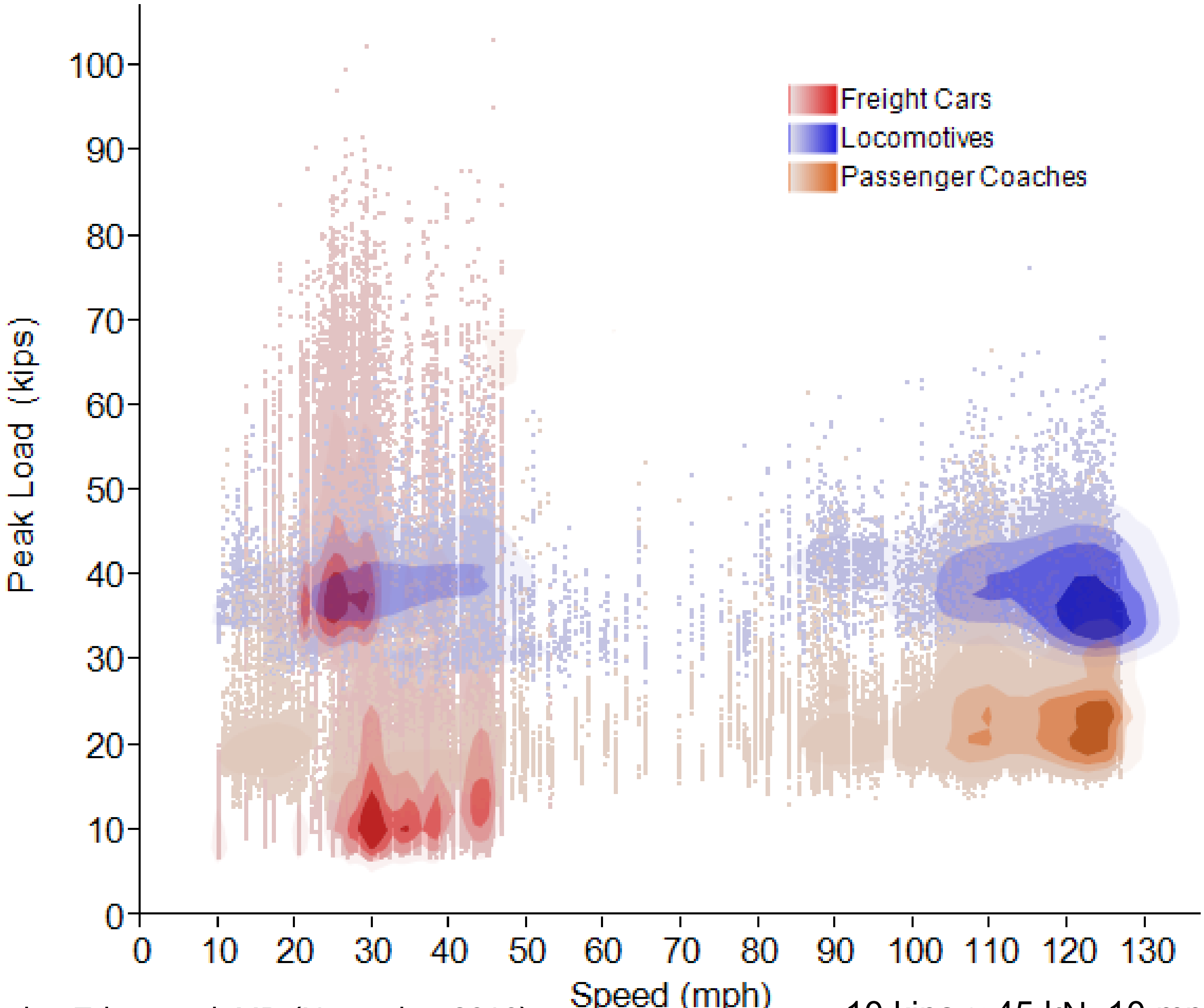
$$P_d = \phi P_s$$

Design wheel load

Static wheel load

Dynamic/impact factor

Effect of Speed on Wheel Load



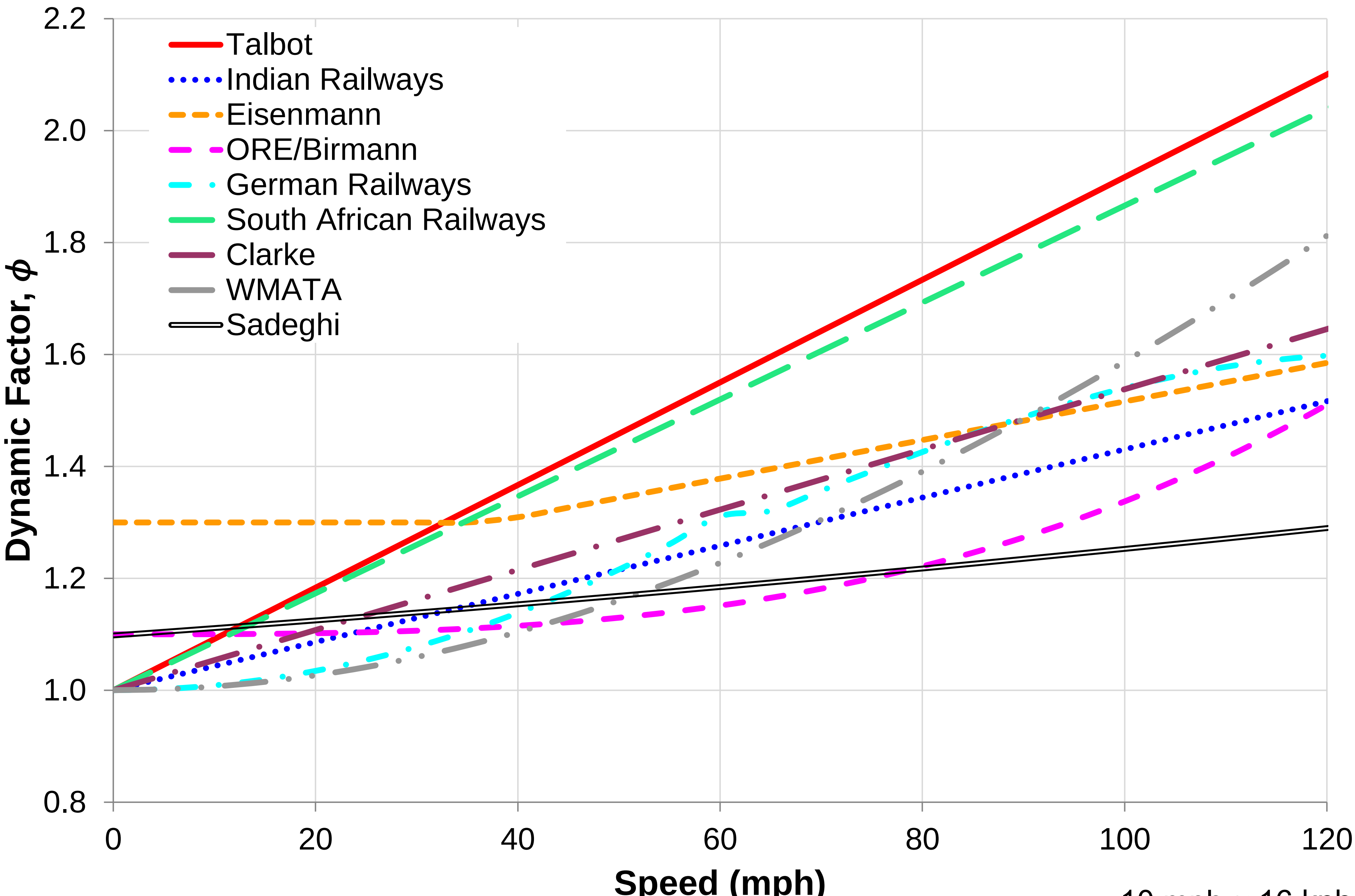
Source: Amtrak – Edgewood, MD (November 2010)

10 kips ≈ 45 kN, 10 mph ≈ 16 kph

Parameters Included in Dynamic Factors

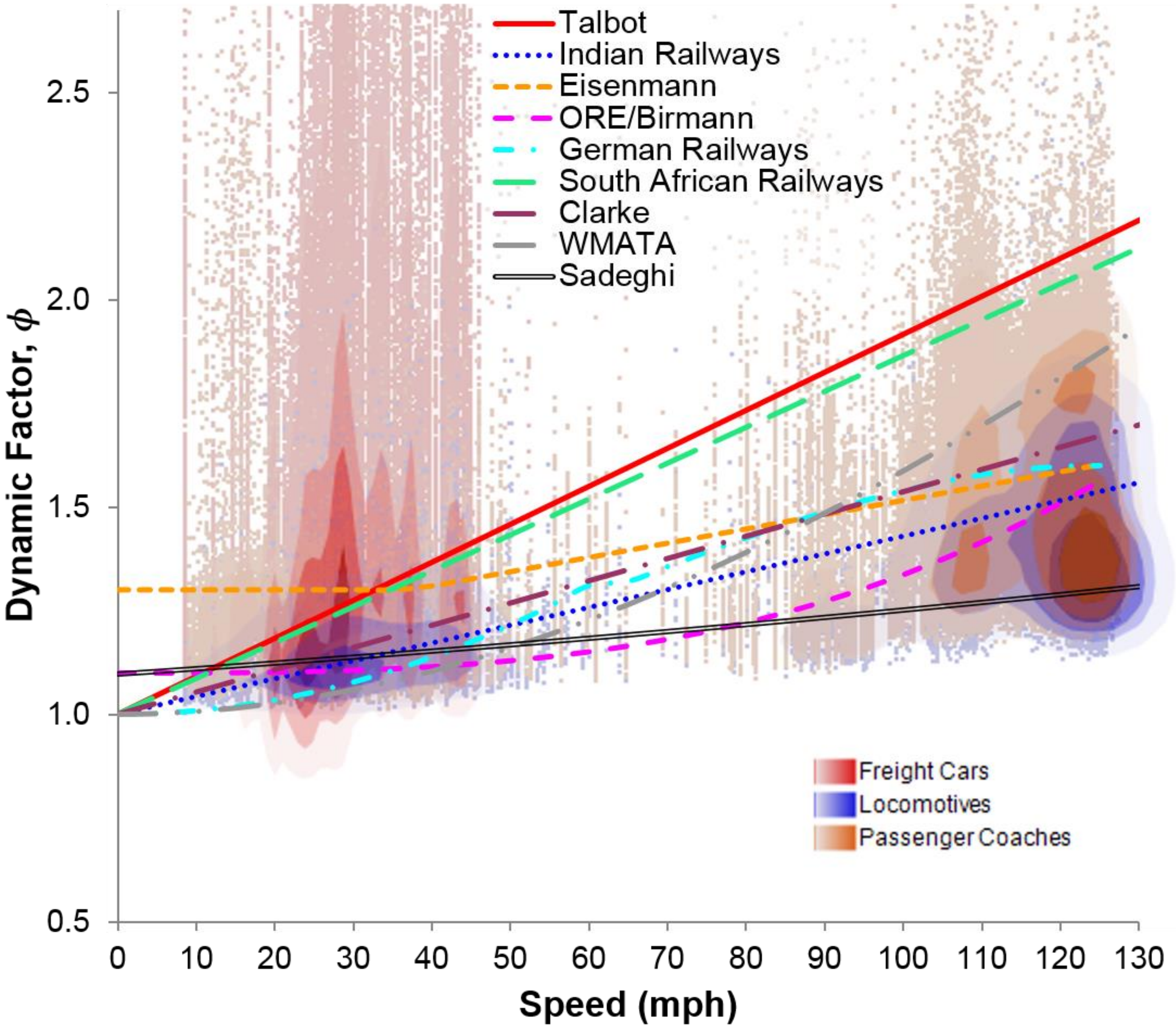
Dynamic Factor	Vehicle Parameters Included						Track Parameters Included					
	Train Speed	Wheel Diameter	Static Wheel Load	Unsprung Mass	Vehicle Center of Gravity	Locomotive Maintenance Condition	Track Modulus	Track Stiffness at Rail Joint	Track Joint Dip Angle	Cant Deficiency in Curves	Curve Radius	Track Maintenance Condition
Talbot	●	●										
Indian Railways	●						●					
Eisenmann	●											●
ORE/Birmann	●				●	●				●	●	●
German Railways	●											
British Railways	●		●	●				●	●			
South African Railways	●	●										
Clarke	●	●					●					
WMATA	●											
Sadeghi	●											
AREMA C30	●											

Comparison of Dynamic Wheel Load Factors



10 mph ≈ 16 kph

Dynamic Wheel Load Factors



Source: Amtrak – Edgewood, MD (November 2010)

10 mph ≈ 16 kph

Evaluative Metric: Mean Signed Difference

- Summarizes how well an estimator matches the quantity that it is supposed to estimate

$$\sum_{i=1}^{n} \frac{f(x_i) - y_i}{n}$$

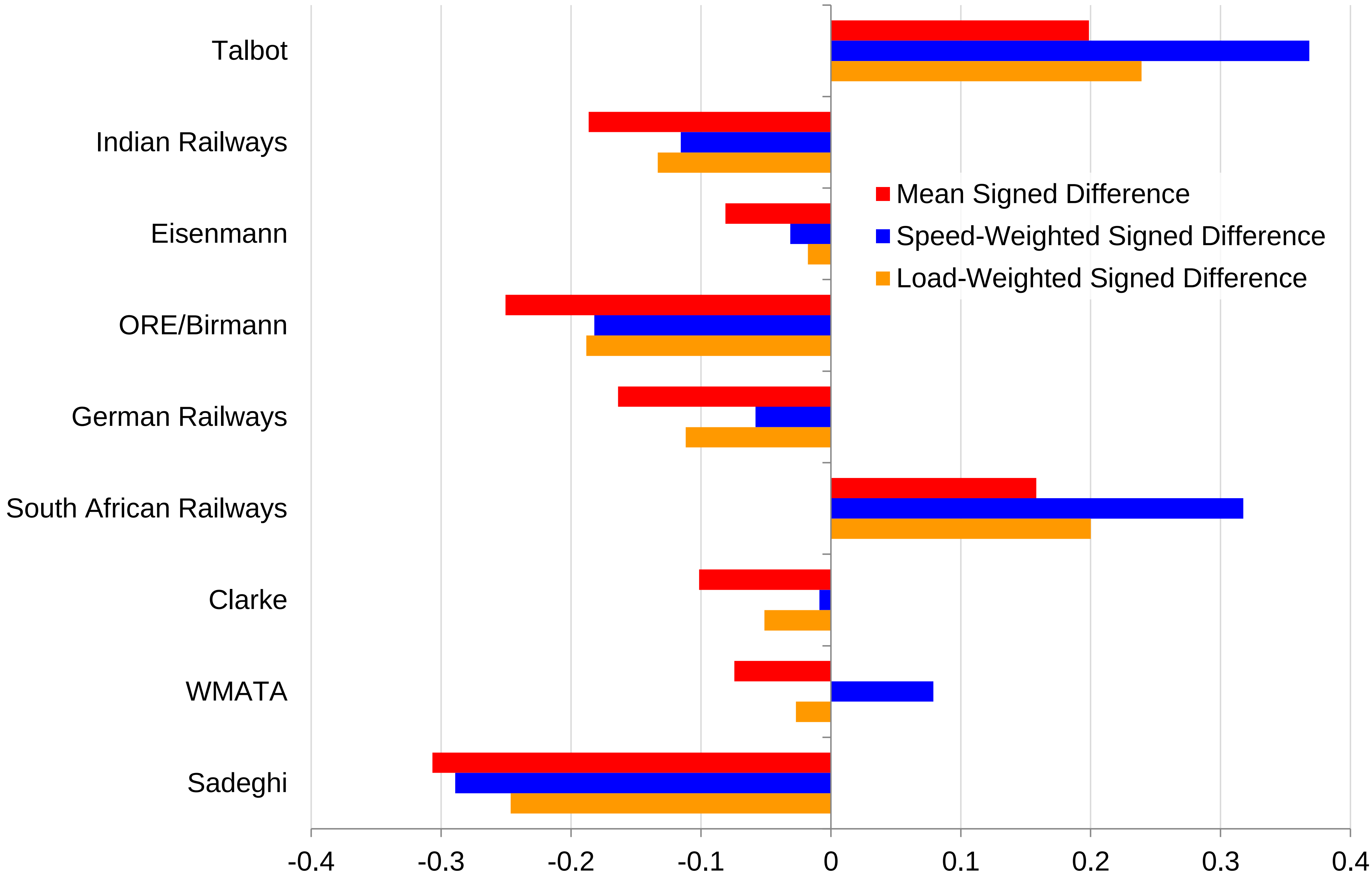
Predicted dynamic factor, given wheel's speed

Ratio of peak to nominal vertical load

Number of wheels

- Additional "signed difference" metrics were developed, with weight given each for vehicle speed and nominal wheel load

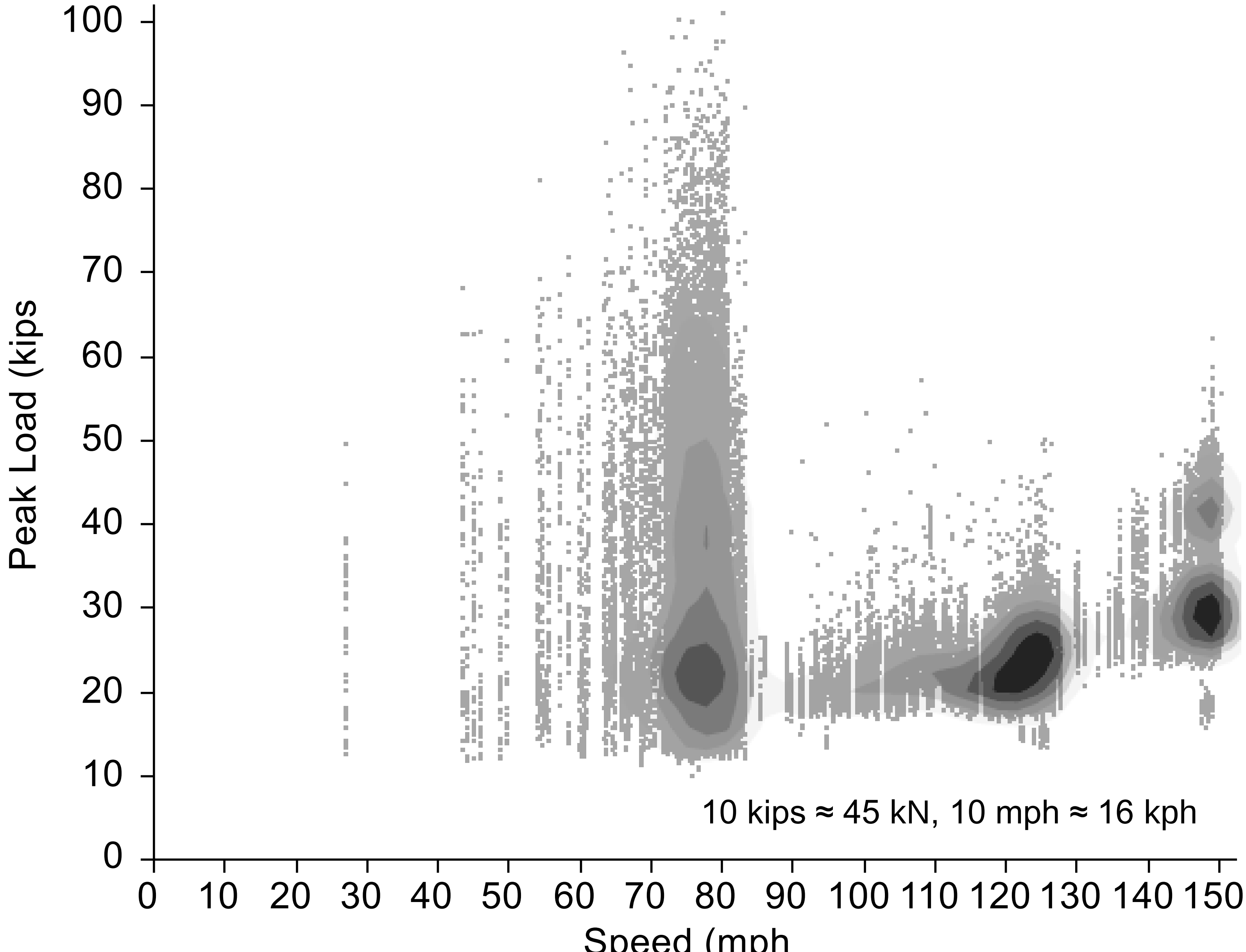
Evaluation: Mean Signed Difference



Dynamic Factor Evaluation Thoughts

- The Talbot and South African Railways dynamic factors were generally more conservative when compared to actual loading data
- The WMATA dynamic factor becomes conservative when evaluated using the speed-weighted signed difference (factor increases exponentially with speed)
- Using several evaluative metrics, the Eisenmann dynamic factor generally estimated the actual loading data well
- Multiple evaluative metrics can be used to evaluate and compare dynamic factors in determining which may be appropriate for design

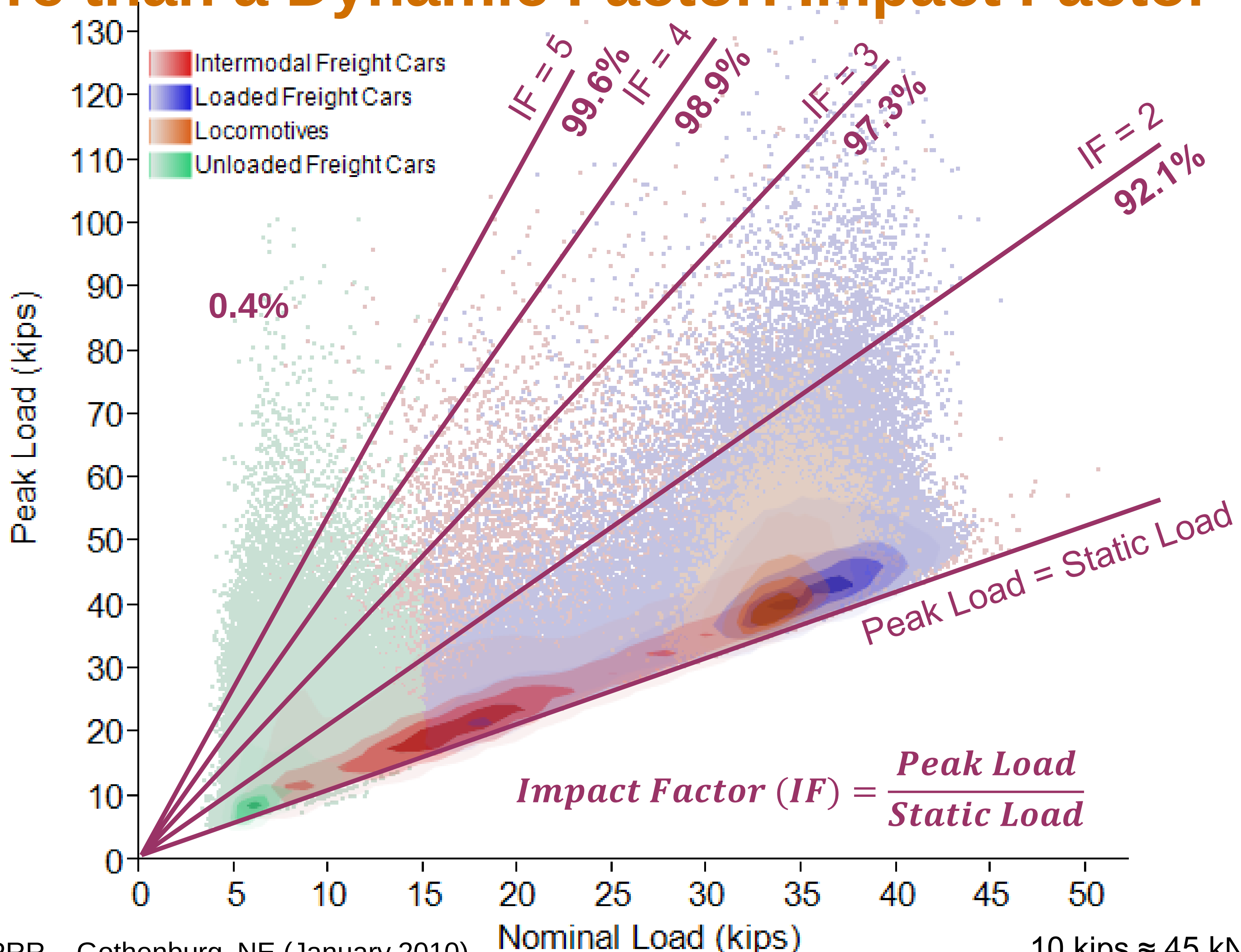
Effect of Wheel Condition on Peak Wheel Load



Source: Amtrak – Mansfied, MA (November 2010)

Passenger Coaches

More than a Dynamic Factor: Impact Factor



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

Source: UPRR – Gothenburg, NE (January 2010)

10 kips ≈ 45 kN

Alternative Design Parameter: Peak Tonnage

- There may be too much variability to design for entire rail networks with a single factor
- Alternative design parameters (e.g., “peak tonnage”) can supplement existing factors

Car Type	Number of Wheels	Nominal Tonnage (tons)	Peak Tonnage (tons)	Difference (tons)	Difference per Wheel (tons)
Locomotives	965,718	16,291,645	20,293,696	4,002,051	4.14
Intermodal Freight Cars	3,001,656	28,778,161	38,562,442	9,784,281	3.26
Other Freight Cars	20,204,202	144,556,403	197,330,434	52,774,031	2.61
Total	24,171,576	189,626,209	256,186,572	66,560,363	2.75

Source: UPRR – Gothenburg, NE (2010)

1 ton ≈ 0.9 tonnes

Conclusions

- Many factors have been developed for track design to address amplification above static wheel load
- Dynamic wheel load design factors can be compared using many evaluative metrics
- Impact factor to account for wheel and track irregularities appropriate in many instances; possibly may be used in combination with dynamic factors
- Design of infrastructure (including ties and fastening systems) may require the use of multiple design factors to adequately represent actual loading

Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

- Funding for this research has been provided by the Federal Railroad Administration (FRA)
- 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 in data acquisition
  - Steve Crismer, Jonathan Wnek (Amtrak)
  - Steve Ashmore, Bill GeMeiner, Michael Pfeifer (Union Pacific)
- For assistance in data processing and interpretation
  - Anna Delheimer, Alex Schwarz, Andrew Scheppe, Andrew Stirk, Anusha Suryanarayanan (UIUC)

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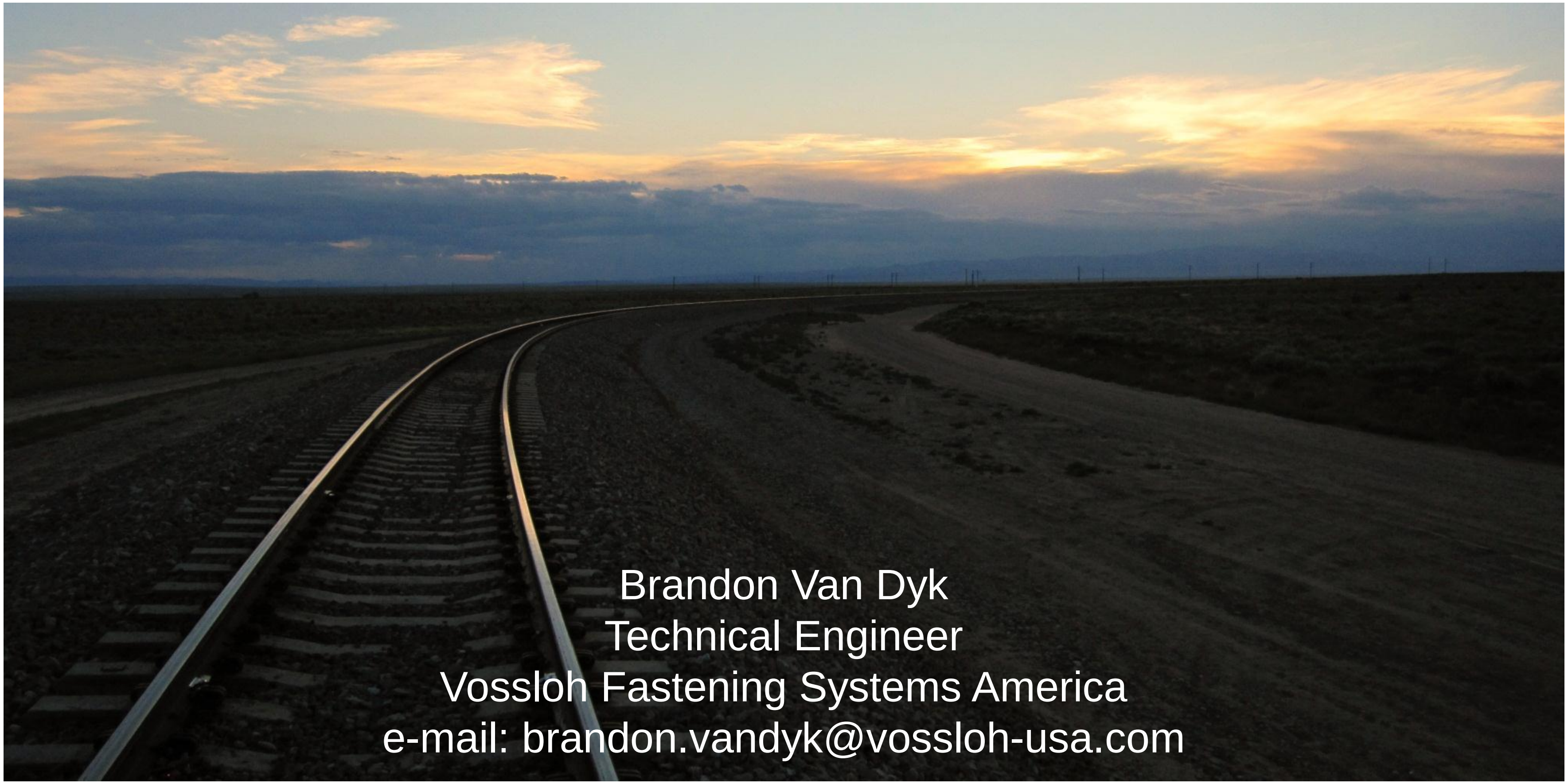
Questions



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