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

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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 \( P_d \) = Dynamic/impact factor \( \phi \) = Static wheel load
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

<table>
<thead>
<tr>
<th>Dynamic Factor</th>
<th>Vehicle Parameters Included</th>
<th>Track Parameters Included</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Train Speed</td>
<td>Wheel Diameter</td>
</tr>
<tr>
<td>Talbot</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Indian Railways</td>
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<tr>
<td>Eisenmann</td>
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<td>ORE/Birmann</td>
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<td>German Railways</td>
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<td>British Railways</td>
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<td>South African Railways</td>
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<td>Clarke</td>
<td>●</td>
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<td>WMATA</td>
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<td>Sadeghi</td>
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</tr>
<tr>
<td>AREMA C30</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>
Comparison of Dynamic Wheel Load Factors

- Talbot
- Indian Railways
- Eisenmann
- ORE/Birmann
- German Railways
- South African Railways
- Clarke
- WMATA
- Sadeghi

Dynamic Factor, $\phi$

Speed (mph)

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

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

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

Predicted dynamic factor, given wheel’s speed
Ratio of peak to nominal vertical load
Number of wheels
Evaluation of Dynamic and Impact Wheel Load Factors and their Application for Design

Evaluation: Mean Signed Difference

- Mean Signed Difference
- Speed-Weighted Signed Difference
- Load-Weighted Signed Difference

Talbot
Indian Railways
Eisenmann
ORE/Birmann
German Railways
South African Railways
Clarke
WMATA
Sadeghi
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 – Mansfield, MA (November 2010)

10 kips ≈ 45 kN, 10 mph ≈ 16 kph
More than a Dynamic Factor: Impact Factor

Impact Factor (IF) = 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.

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

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
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Questions

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