WIM Data Analysis Procedures and Reasonableness Checks to Assure Quality of Axle Loading Data

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Presentation Outline

- Background – LTPP Program and WIM data
- Objective of LTPP WIM data review
- WIM data assessment methodology and reasonableness checks
- Benefits of WIM data reasonableness checks beyond LTPP
Long-Term Pavement Performance (LTPP) Program

- Pavement research program
- TRB SHRP → FHWA
- Supports national and local studies of pavement performance under real traffic and environmental loads
- Experiment sites on in-service roads in all U.S. states and Canadian provinces
LTPP Database

- Over 30 years of road inventory, pavement, traffic, and climatic data
- Over 2,500 pavement research sites in U.S. and Canada

https://infopave.fhwa.dot.gov/
WIM Data in LTPP Database

- From 1990
- Over 800 WIM sites (U.S., Canada)
- Majority of WIM data submitted by
  - State and provincial highway agencies
- Subset collected by LTPP program through TPF 5(004) and SPS-10 experiment
  - Research-quality data from SPS WIM sites
  - ASTM 1318-09 Type I
  - Continuous monitoring, consistent QC/QA, calibration
  - 26 states
Why WIM Data Were Collected?

➢ To support LTPP studies of pavement deterioration in presence of traffic loads
➢ To understand the effect of traffic loading on pavement longevity, ride quality, and structural deterioration
➢ To develop improved pavement design methods

FHWA Class 9 Truck (18 Wheeler)
Challenges with LTPP WIM Data

➢ Quality of WIM data is not uniform and not well documented
  ▪ Collected by different agencies
  ▪ Variety of WIM equipment and sampling methods
  ▪ Very limited WIM calibration and data validation records

➢ Previous studies raised concerns with data quality and applicability for LTPP analyses
  ▪ Limited use in pavement analyses
  ▪ No means for identifying high and low accuracy data in the database
Objective of LTPP Historical WIM Data Review

➢ **Goal:**
  - Improve confidence in the WIM data and traffic loading statistics by informing users about data quality and usability

➢ **Approach:**
  - Assess rationality of the undocumented historical WIM data
  - Qualify usability of site-specific WIM data for LTPP studies
  - Develop indices and rate WIM data based on data quantity, accuracy, and reasonableness
WIM Data Assessment Methodology

➢ Develop WIM data reasonableness/rationality checks and data ranking system
  ▪ Use LTPP research-quality WIM data from TPF 5(004)

➢ Test/verify checks using WIM data of known accuracy
  ▪ Use state-collected WIM data from LTPP database

➢ Apply reasonableness checks to WIM data with unknown accuracy

➢ Rank LTPP WIM sites based on quantity, quality, and reasonableness of the available data
## WIM Data Ranking for LTPP Studies

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Best</strong></td>
<td>Satisfies ASTM E1318-09 Type I WIM performance requirements. Passed LTPP rudimentary QC and data reasonableness checks. At least 1 of each 12 calendar months with at least 1 of each DOW.</td>
</tr>
<tr>
<td><strong>Better</strong></td>
<td>Satisfies ASTM E1318-09 Type I WIM performance requirements. Passed LTPP rudimentary QC and data reasonableness checks. Data collected for 1+ years, but not all calendar months.</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>No calibration record or not ASTM E1318-09 Type I. Passed LTPP rudimentary QC and data reasonableness checks. Data is sufficient to construct NALS for pavement analyses.</td>
</tr>
<tr>
<td><strong>Fair</strong></td>
<td>No calibration record or not ASTM E1318-09 Type I. Passed the LTPP rudimentary QC and most reasonableness checks. Datasets manually selected to minimize low precision and bias.</td>
</tr>
<tr>
<td><strong>Poor</strong></td>
<td>No calibration record or not ASTM E1318-09 Type I. Passed the LTPP rudimentary QC checks but failed most reasonableness checks. Data not recommended for direct input.</td>
</tr>
</tbody>
</table>
Objective of WIM Data Reasonableness Checks

➢ Identify WIM data sets likely affected by
  ▪ Low measurement precision (high data variability)
  ▪ Measurement bias (WIM calibration drift, shift in truck or axle weight distribution statistics)
  ▪ Atypical patterns (atypical load distributions)

➢ Identify datasets that are
  ▪ recommended as a direct input for detailed pavement analysis or design (Best, Better, Good, possibly Fair)
  ▪ likely to result in differences meaningful for pavement design (changes in heavy loads >10%)
WIM Data Accuracy, Precision, and Bias

Accurate WIM data has no bias and high precision

- High bias
- Low Precision
- No bias
- Low Precision
- High bias
- High Precision
- Accurate WIM data:
  - No bias
  - High Precision

low accuracy
sensor, poor
traffic or road
condition

good sensor,
good traffic &
road condition
Identifying WIM Measurement Errors Based on Class 9 NALS Attributes

- **NALS** = Normalized Axle Load Spectrum
- Summary statistic: axle load frequency distribution
- Shows % of axle loads accumulated over time in different load bins
- Class 9 has a stable NALS
Attributes of Class 9 NALS Based on WIM Data from Calibrated Type I WIM System

- >8 & <13
- <10%
- <20% (7%)

Axle load, kips

% Axles

10-16
28-34
Effect of Low Precision of WIM Measurement on Class 9 NALS

low precision = high variability
Effect of Bias in WIM Measurement on Class 9 NALS

high bias = shifted distribution
Effect of Low Precision and High Bias of WIM Measurement on Class 9 NALS

high bias + low precision = shifted distribution with thick light or heavy tail
Statistical Parameters for Class 9 vehicles (3S2) Supporting Reasonableness Checks

➢ Single axle NALS statistics:

- $\sum %$ loads < 5 kips
- $\sum %$ loads > 20 kips
- Peak load bin and % of loads
- Average axle weight
Statistical Parameters for Class 9 vehicles (3S2) Supporting Reasonableness Checks

- $\sum$ % loads <8 kips
- $\sum$ % loads >34 kips (38 kips for Canada)
- Peak load bin and % of loads for empty and loaded trucks
- Average weight of loaded (>26 kips) axle, kips

![Graph showing statistical parameters for Class 9 vehicles (3S2).](image)
Class 9 Single Axle Reasonableness Checks

➢ Flag single axle NALS:

- Avg axle load < 9 kips
- Avg axle load > 12.5 kips
- > 3% axles > 20 kips
  (>10% if split tandems)
- >= 10% axles < 5 kips
- Peak load <= 8 kips
- Peak load >= 13 kips
Class 9 Tandem Axle Reasonableness Checks

- Flag tandem axle NALS:
  - Avg loaded axle < 28 kips or > 34,000 lb.
  - > 20% of axles > 34 kips 38 (U.S.)
  - > 20% of axles > 38 kips (Canada)
  - > 7% of axles > 34 kips for roads with mostly empty trucks (U.S.)
  - > 10% of axles < 8 kips
Class 9 Tandem Axle Reasonableness Checks

- Flag tandem axle NALS:
  - 1st peak (empty trucks)  
    \(< 10 \text{ or } > 16 \text{ kips}\)
  - 2nd peak (loaded trucks)  
    \(< 28 \text{ or } > 34 \text{ kips}\)
  - axles 30 to 36 kips  
    \(< \text{ axles 36 to 42 kips}\)
    (overestimation of loads)
  - axles 26 to 34 kips  
    \(< \text{ axles 22 to 28 kips for sites with}\)
    \(< 30 \% \text{ of axles between}\)
    \(< 10 \text{ and 16 kips}\)
    (underestimation of loads)
Data Reasonableness Assessment Procedure for LTPP Historical WIM Data

1. Compute axle loading statistics for Class 9 vehicles (monthly NALS preferred)

2. Run automated reasonableness checks to flag sites with biased, imprecise, or atypical monthly and/or annual Class 9 NALS

3. Manually review flagged sites, identify years and months with WIM data suitable for LTPP analyses

4. Assign WIM data rank to each LTPP site (Best, Better, Good, Fair, Poor)
Benefits of LTPP WIM Data Reasonableness Checks beyond LTPP

1. Identify deviations or anomalies in WIM data that can’t be seen in daily reviews
2. Aid in historical and/or current WIM data review
3. Rank WIM data to help users make informed decisions about its applicability for their analyses
4. Can be programmed and integrate in existing automated WIM data QC procedures
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