Weigh-In-Motion Detection and Load Spectrum Analysis

Southeastern Pavement Management and Design Conference

Nashville, Tennessee

Mark P. Gardner, P.E.
Weng On Tam, Ph.D, P.E.
OVERVIEW

- WIM Systems
- Successful WIM Implementation
- Axle Load Spectra
WEIGHT-IN-MOTION

“the process of measuring dynamic tire forces of a moving vehicle and estimating the corresponding tire loads of the static vehicle”

- ASTM E 1318-02
ASTM E 1318-02

- **Purpose**—to aid the user and vendor in specifying, purchasing, installing and testing a WIM system.
- **Requires User** to provide smooth, durable pavement structure, in good condition.
- **Trucks should** be moving at constant speed in their travel lanes when crossing the sensors.
<table>
<thead>
<tr>
<th>WIM System</th>
<th>Speed Range</th>
<th>Application</th>
<th>Number of Lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>16 – 130 km/h (10 – 80 mph)</td>
<td>Traffic Data Collection</td>
<td>Up to 4</td>
</tr>
<tr>
<td>Type II</td>
<td>16 – 130 km/h (10 – 80 mph)</td>
<td>Traffic Data Collection</td>
<td>Up to 4</td>
</tr>
<tr>
<td>Type III</td>
<td>16 – 130 km/h (10 – 80 mph)</td>
<td>Weight Enforcement</td>
<td>Up to 2</td>
</tr>
<tr>
<td>Type IV</td>
<td>3 – 16 km/h (2 – 10 mph)</td>
<td>Weight Enforcement</td>
<td>Up to 2</td>
</tr>
</tbody>
</table>
TYPES OF WIM EQUIPMENT

• Piezoelectric Sensors
• Bending Plate Scale
• Deep Pit Load Cell
PIEZOELECTRIC SENSORS
BENDING PLATE

1. PAT bending plates
   175 or 125 cm
2. Fastening rails
3. Mounting frame
4. Drainage pit

Typical Bending Plate Installation

12 cm min.
65.5 cm

Image: Highway with bending plate installation.
LOAD CELL
## COST COMPARISON

<table>
<thead>
<tr>
<th>WIM System</th>
<th>% GVW Error – Highway Speeds</th>
<th>Initial Cost *</th>
<th>Maintenance Cost **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piezoelectric Sensor</td>
<td>+/- 10%</td>
<td>$9,500</td>
<td>$4,224</td>
</tr>
<tr>
<td>Bending Plate Scale</td>
<td>+/- 5%</td>
<td>$18,900</td>
<td>$4,990</td>
</tr>
<tr>
<td>Double Bending Plate Scale</td>
<td>+/- (3 - 5)%</td>
<td>$35,700</td>
<td>$7,709</td>
</tr>
<tr>
<td>Deep Pit Load Cell</td>
<td>+/- 3%</td>
<td>$52,500</td>
<td>$7,296</td>
</tr>
</tbody>
</table>

*Estimated initial cost per lane (equipment and installation)
**Estimated average cost per lane (12-year life span including maintenance)
SELECTING WIM EQUIPMENT

• “Site Design Life”
  – Type of Equipment
  – Site Location and Condition
  – Installation of Equipment
• Intended Use of Data
  – Data Analyses
  – Accuracy and Precision
SITE SELECTION

- Geometric Design
  - Horizontal Curvature
  - Roadway Grade
  - Cross Slope
  - Lane Width

- Pavement Condition
  - Smoothness
  - Deflection

- Site Location
  - Power & Phone
  - Drainage
  - Traffic
SYSTEM CALIBRATION

• Operation Check
  – Initial Calibration
  – Continuous Operations Check
• Fine Tuning/Recalibration
MINNESOTA EXAMPLE

• Automatic Recalibration
  – Front Axle of VC 9 Trucks
  – Adjustment Factors
  – Calibration Correction Factor
QUALITY ASSURANCE

- Vehicle Counts
- Vehicle Classification
- Weight-In-Motion
  - Gross Vehicle Weight
  - Axle Weight and Spacing
- AVC and WIM Volume and Class Comparison
CALTRANS EXAMPLE

- “Knowledge of Site Characteristics” Review
- “Real Time” Review
- First Level Data Review
  - Summary Report
  - Individual Truck Report
CALTRANS EXAMPLE

- Second Level Data Review
  - WIM Analysis Program
  - Determine Calibration Adjustments
Site Maintenance

- WIM Sensor Operation
- Loop Operation
- WIM Electronics and Equipment
- System Maintenance & Cleaning
- Visual Inspection of Site
- Software Maintenance
ESALS
TRAFFIC – 1993 GUIDE

- Truck Equivalency Factors (TEF)
- Equivalent Single Axle Loads (ESALs)
TRUCK EQUIVALENCY FACTOR

AC PAVEMENT
(SN=5, $P_t = 2.5$)

FHWA CLASS 9

GROSS WEIGHT = 80$^k$

$36^k$ tandem
LEF = 1.38

$36^k$ tandem
LEF = 1.38

$8^k$ single
LEF = 0.34

TF = 1.38 + 1.38 + 0.34 = 3.10 ESALS/TRUCK
TRUCK EQUIVALENCY FACTORS

• TEF
  – Pavement Type
  • Flexible & Rigid
  – Structural Number (SN)
  – Terminal Serviceability ($P_t$)
TEF – Flexible
SN = 5 & P_t = 2.5

![Bar chart showing data for Single, Tandem, and Tridem configurations with 18k and 34k values.]
AXLE LOAD SPECTRA
MECHANISTIC DESIGN

• ESALs Not Adequate
• Requires Axle Load Spectra
  – Same data source
  – Additional Processing
LOAD SPECTRA BY AXLE TYPE

- Single 95
- Tandem 95
- Tridem 95

Axle Load (lb)
Percent Axles

0 20 40 60 80 100
0 20000 40000 60000 80000
ANNUAL LOAD SPECTRA

Axle Load (lb)

Percent Axles

Tridem 92
Tridem 93
Tridem 94
Tridem 95
WIM DATA COLLECTION

• Good News
  – Already collected in your state
• Bad News
  – May not analyze/summarize it in the format needed
• NCHRP 1-39 software will help you with this analysis (but will not do it all)
NCHRP 1-39 SOFTWARE

- Take data already collected
- Help organize and summarize it
- Input it into the NCHRP 1-37A software
NCHRP 1-39 SOFTWARE

- Edit-Checked Short-term Site-Specific classification data
- Edit-checked Permanent Class Data
- Quality Checked WIM data
- User defined data groups
WHAT’S NEEDED?

- Resources to:
  - Collect data
  - Quality assure data
  - Analyze data
  - Summarize data
  - Report and make data available
<table>
<thead>
<tr>
<th>Level</th>
<th>Understanding of Traffic</th>
<th>Classification Data</th>
<th>Weight Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Good</td>
<td>Continuous at Site</td>
<td>Site Specific</td>
</tr>
<tr>
<td>Level 2</td>
<td>Modest</td>
<td>Site Specific, but Short</td>
<td>Regional Average</td>
</tr>
<tr>
<td>Level 3</td>
<td>Poor</td>
<td>No Actual Class Data</td>
<td>Statewide Average</td>
</tr>
</tbody>
</table>
Work with Traffic Data Collection Folks Early

In order to get the data collected at your locations in time for you to use it...
CONCLUSIONS

- There are various types of WIM equipment
- WIM data is required for M-E design
- WIM data can be successfully collected
- States already collect WIM data
- Additional analyses and formatting may be required
QUESTIONS