LA Design and Rating Vehicle based on WIM (Weigh-in-Motion) Study

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Outline

• LA WIM sites and data collection
• WIM data analysis for Strength I and Strength II
• Updating design load using WIM load effects
• Optimizing design load using reliability analysis
• DOTD load rating / posting / permit practices
• Updating legal & permit trucks using WIM data
• Posting recommendations for routine permits
Review of LA Design Loads using WIM

- WIM Study was performed to determine state specific design loads for Louisiana.
- Traffic data collected from Permanent (Interstate) & Temporary (State Routes) WIM sites
- Design Loads were investigated for both STRENGTH I and STRENGTH II limit states.
- Design load adjustments were made using WIM load effects and then verified using reliability analysis
Calibrating Bridge Design Loads using WIM

- Apply NCHRP 12-76 Protocols for calibration
- Two calibration procedures are available:
  - **Simplified**: Compare the 75-year max load effects used in LRFD calibration to that computed by statistically projecting WIM data
  - **Refined**: Reliability analysis using WIM data to meet target $b=3.5$
LA Vehicle Regulations

• Legal limit of a tridem axle is 83,400 pounds for interstate and 88,000 pounds for non-interstate highways.

• DOTD does not enforce the FHWA Bridge Formula on non-interstate highways.

• DOTD issues permits for overweight trucks up to 254,000 pounds without bridge analysis.

• These overload trucks are greater than AASHTO HL-93 and have more load effect on bridges.
Current Practice:

LADV-11

MF x HL-93 DESIGN LOAD

<table>
<thead>
<tr>
<th>LOAD EFFECT</th>
<th>RANGE OF APPLICABILITY</th>
<th>MAGNIFICATION FACTOR (MF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M+, V</td>
<td>S ≤ 240</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>240 &lt; S &lt; 600</td>
<td>1.30 – 0.00083(S - 240)</td>
</tr>
<tr>
<td></td>
<td>S ≥ 600</td>
<td>1.00</td>
</tr>
<tr>
<td>M-</td>
<td>S ≤ 100</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>100 &lt; S &lt; 240</td>
<td>1.30 – 0.00214(S - 100)</td>
</tr>
<tr>
<td></td>
<td>S ≥ 240</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Louisiana WIM Sites

- GREENWOOD
- DELTA
- TOOMEY
- BREAUX BRIDGE
- LAPLACE
- BAPTIST
- LA-84
- I-10
- BREAUX EB
- BREAUX WB
- LAPLACE EB
- LAPLACE WB
- TOOMEY EB
- I-12
- BAPTIST EB
- I-20
- DELTA EB
- DELTA WB
- GREENWOOD EB
- GREENWOOD WB
- LA-1
- US-61
- LA-84
### Truck Distributions For Each Site

#### PERCENTAGE OF TRUCKS

<table>
<thead>
<tr>
<th>SITE</th>
<th>3-AXLE</th>
<th>4-AXLE</th>
<th>5-AXLE</th>
<th>6-AXLE</th>
<th>7-AXLE</th>
<th>8-AXLE</th>
<th>9+ AXLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-12 BAPTIST</td>
<td>0.62%</td>
<td>1.59%</td>
<td>95.67%</td>
<td>2.01%</td>
<td>0.07%</td>
<td>0.03%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>I-10 BREAUX</td>
<td>0.54%</td>
<td>1.98%</td>
<td>93.68%</td>
<td>3.56%</td>
<td>0.13%</td>
<td>0.06%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>I-10 LAPLANE</td>
<td>1.03%</td>
<td>4.45%</td>
<td>90.32%</td>
<td>4.04%</td>
<td>0.09%</td>
<td>0.04%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>I-10 TOOMEY</td>
<td>0.27%</td>
<td>1.45%</td>
<td>95.62%</td>
<td>2.44%</td>
<td>0.15%</td>
<td>0.05%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>I-20 DELTA</td>
<td>2.13%</td>
<td>1.71%</td>
<td>92.88%</td>
<td>3.13%</td>
<td>0.09%</td>
<td>0.03%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>I-20 GREENWOOD</td>
<td>0.63%</td>
<td>2.50%</td>
<td>93.37%</td>
<td>3.29%</td>
<td>0.14%</td>
<td>0.04%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>LA-1</td>
<td>22.81%</td>
<td>5.27%</td>
<td>60.03%</td>
<td>11.51%</td>
<td>0.27%</td>
<td>0.09%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>US-84 EB</td>
<td>14.03%</td>
<td>3.26%</td>
<td>69.03%</td>
<td>12.95%</td>
<td>0.43%</td>
<td>0.25%</td>
<td>&lt;0.04%</td>
</tr>
<tr>
<td>US-84 WB</td>
<td>14.18%</td>
<td>2.49%</td>
<td>74.07%</td>
<td>8.46%</td>
<td>0.47%</td>
<td>0.28%</td>
<td>&lt;0.04%</td>
</tr>
</tbody>
</table>
## GVW Statistics

<table>
<thead>
<tr>
<th>5-AXLE TRUCKS</th>
<th></th>
<th>GVW [kips]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WIM SITE</td>
<td># Trucks</td>
</tr>
<tr>
<td>I-12 BAPTIST EB</td>
<td>2949459</td>
<td>56.5</td>
</tr>
<tr>
<td>I-10 BREAUX EB</td>
<td>1548921</td>
<td>54.6</td>
</tr>
<tr>
<td>I-10 BREAUX WB</td>
<td>365636</td>
<td>62.1</td>
</tr>
<tr>
<td>I-10 LAPLACE EB</td>
<td>281843</td>
<td>57.7</td>
</tr>
<tr>
<td>I-10 LAPLACE WB</td>
<td>434862</td>
<td>47.4</td>
</tr>
<tr>
<td>I-10 TOOMEY EB</td>
<td>333950</td>
<td>59.9</td>
</tr>
<tr>
<td>I-20 DELTA EB</td>
<td>1077628</td>
<td>60.8</td>
</tr>
<tr>
<td>I-20 DELTA WB</td>
<td>496269</td>
<td>64.3</td>
</tr>
<tr>
<td>I-20 GREENWOOD EB</td>
<td>897182</td>
<td>57.1</td>
</tr>
<tr>
<td>I-20 GREENWOOD WB</td>
<td>1282895</td>
<td>60.0</td>
</tr>
<tr>
<td>LA-1</td>
<td>75620</td>
<td>52.7</td>
</tr>
<tr>
<td>US-84 EB</td>
<td>32945</td>
<td>63.8</td>
</tr>
<tr>
<td>US-84 WB</td>
<td>40323</td>
<td>52.5</td>
</tr>
</tbody>
</table>
Strength II sorting criteria selected based on Louisiana Special Design Vehicles LASDV 1 thru LASDV 8. All other trucks in Strength I bin.

**STRENGTH II:**

- All trucks with 7 axles or more

- All trucks with GVW > 100 kips and the first axle weight > 20 kips

**STRENGTH I**

- All other trucks will be included in STRENGTH I
# STRENGTH I & STRENGTH II TRUCKS

<table>
<thead>
<tr>
<th>WIM SITE</th>
<th>STRENGTH I TRUCKS</th>
<th>STRENGTH II TRUCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERSTATES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GREENWOOD WB</td>
<td>1,370,961</td>
<td>3,077</td>
</tr>
<tr>
<td>STATE ROUTES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA – 1</td>
<td>125,369</td>
<td>597</td>
</tr>
<tr>
<td>US – 84</td>
<td>101,156</td>
<td>1,009</td>
</tr>
</tbody>
</table>
Moment and Shear Load Effects were calculated for:

- STRENGTH I and STRENGTH II trucks
- One Lane and Two Lane
- 20’ to 200’ spans.
Measured WIM Data for STRENGTH I

Maximum load effects from WIM Data and compare with LADV-11

NORMALIZE BY HL-93 LOAD EFFECTS:

<table>
<thead>
<tr>
<th>$M_{MAX,WIM}/M_{HL93}$</th>
<th>Span Length [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>GREENWOOD I-20</td>
<td>1.59</td>
</tr>
<tr>
<td>US-84 EB</td>
<td>1.69</td>
</tr>
<tr>
<td>US-84 WB</td>
<td>1.29</td>
</tr>
<tr>
<td>LA-1 SB</td>
<td>1.69</td>
</tr>
<tr>
<td>MAX WIM</td>
<td>1.69</td>
</tr>
<tr>
<td>LADV-11</td>
<td>1.30</td>
</tr>
</tbody>
</table>
Measured WIM Data for STRENGTH I

WIM Data exhibits higher load effects compared to LADV-11:

Needs modified load model to give higher load effects in spans < 120 ft

STRENGTH I MOMENTS NORMALIZED BY HL93

- LADV11
- WIM MAX
Statistical Projection for Life time Maximum Load Effects: Normal Probability Fit of Upper Tail

Moment Histogram for Individual Trucks in Drive Lane

- Blue circles: from field data
- Red line: from Normal pdf

Frequency vs. Moment/HL-93
# Projected 75-Year Loads for STRENGTH I

## STRENGTH I MOMENT
(One Lane)

<table>
<thead>
<tr>
<th></th>
<th>Span Length [ft]</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>160</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>M\textsubscript{75-YEAR,WIM} / M\textsubscript{HL93}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GREENWOOD I-20</td>
<td></td>
<td>1.75</td>
<td>1.77</td>
<td>1.51</td>
<td>1.40</td>
<td>1.36</td>
<td>1.34</td>
<td>1.30</td>
<td>1.23</td>
</tr>
<tr>
<td>US-84 EB</td>
<td></td>
<td>2.09</td>
<td>2.04</td>
<td>1.76</td>
<td>1.68</td>
<td>1.63</td>
<td>1.59</td>
<td>1.50</td>
<td>1.42</td>
</tr>
<tr>
<td>US-84 WB</td>
<td></td>
<td>1.59</td>
<td>1.54</td>
<td>1.40</td>
<td>1.37</td>
<td>1.37</td>
<td>1.34</td>
<td>1.37</td>
<td>1.26</td>
</tr>
<tr>
<td>LA-1 SB</td>
<td></td>
<td>2.00</td>
<td>2.06</td>
<td>1.78</td>
<td>1.69</td>
<td>1.65</td>
<td>1.61</td>
<td>1.52</td>
<td>1.40</td>
</tr>
<tr>
<td>MAX FOR STATE ROUTES</td>
<td></td>
<td><strong>2.09</strong></td>
<td><strong>2.06</strong></td>
<td><strong>1.78</strong></td>
<td><strong>1.69</strong></td>
<td><strong>1.65</strong></td>
<td><strong>1.61</strong></td>
<td><strong>1.52</strong></td>
<td><strong>1.42</strong></td>
</tr>
</tbody>
</table>
STRENGTH I (Two Lane)

STRENGTH I $M_{75\text{-YEAR,WIM}} / M_{HL93}$

PROJECTED 75-YEAR, TWO LANES

- GREENWOOD I -20
- STATE ROUTES LA-1 & US-84
- LRFD 75 YEAR CALIBRATION
STRENGTH I (One Lane)

STRENGTH I $M_{75\text{-YEAR,WIM}} / M_{HL93}$
PROJECTED 75-YEAR, ONE LANE

[Graph showing the comparison of different projects' strength indices over span length]
HL-93<sub>MOD</sub> MODIFIED HL-93 LIVE LOAD MODEL

- HS-20 TRUCK
  + 0.64 kips/ft LANE LOAD

- or

- 2.0 x DESIGN TANDEM
  + 0.64 kips/ft LANE LOAD

Modifying the tandem loading increases load effects in shorter spans < 120 FT
Proposed Live Load Model for STRENGTH I

Modified HL-93 Loading envelopes Maximum WIM Load Effects

STRENGTH I MOMENTS NORMALIZED BY HL93
Proposed Live Load Model for STRENGTH I

\[ \gamma_{LL} \times \text{HL-93}_{\text{MOD}} \]

\[ \gamma_{LL} = 1.75 \]

Design Tandem Load Effects are multiplied with 2 in HL-93_{MOD}
Load Model for STRENGTH II

Is calibration necessary for STRENGTH II?

Current Practice:

LADV-11

Previous Practice:

Louisiana Special Design Vehicles

LASDV1 thru LASDV8
Calibration for STRENGTH II using WIM

WIM Load Effects and LASDV 4 show a similar pattern

STRENGTH II MOMENTS NORMALIZED BY HL93

- LASDV1
- LASDV2
- LASDV3
- LASDV4
- LASDV5
- LASDV6
- LASDV7
- LADV11
- WIM MAX
Live Load Model for STRENGTH II using WIM

\[ \gamma_{LL} \times LADPV \]

\[ LADPV = 1.5 \times \frac{LASDV_4}{(GVW=142.5K)} \]

\[ \gamma_{LL} = 1.35 \]

LADPV is LASDV4 multiplied with 1.5
Reliability Analysis of Design Loads

Live load adjustments made based on WIM data & load effects need to be optimized using reliability analysis.

The objective was to review the reliability indices using current WIM data for different load models:

- AASHTO HL-93
- LADV 11 (current LRFD design load)
- HL-93 MOD (proposed Strength I based on WIM)
- LADPV (proposed for STRENGTH II)
Reliability Indices

AASHTO HL-93 --- Positive Flexure

One Lane  Two Lanes
Reliability Indices

LADV-11 Positive Flexure

One Lane

Two Lanes
Reliability Indices

HL-93 MOD -- Positive Flexure

One Lane

Two Lanes
Reliability Indices using LA WIM Data

• Reliability values for 1-lane bridges are significantly lower than those of 2-lane bridges.

• Multiple Presence factor MPF = 1.2 in the AASHTO LRFD is not sufficiently conservative for 1-Lane

• Two-lane loading has acceptable reliability indices

• AASHTO HL-93 one-lane reliability indices << 3.5

• HL-93 MOD can be overly conservative for short spans
LADV11 Live Load Model Optimization

- LADV-11 has generally acceptable reliability indices except for certain span ranges.

- LADV-11 is inadequate for span lengths less than 60 ft and more than 160 ft for positive flexure -- Load effect imposed by LADV-11 is 10% less than the magnitude corresponding to $\beta = 3.5$.

- LADV-11 can be considered as sufficient for all span lengths for shear.
**LADV11 Live Load Model Optimization**

Proposed Modification Factors for LADV-11

<table>
<thead>
<tr>
<th>SPAN</th>
<th>M+ [kips-ft]</th>
<th>V [kips]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.45</td>
<td>1.30</td>
</tr>
<tr>
<td>40</td>
<td>1.45</td>
<td>1.30</td>
</tr>
<tr>
<td>60</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>80</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>100</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>120</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>160</td>
<td>1.30</td>
<td>1.30</td>
</tr>
<tr>
<td>200</td>
<td>1.45</td>
<td>1.30</td>
</tr>
</tbody>
</table>
WIM Study – Load Rating & Posting

• Development of state-specific legal and routine permit load models for Louisiana based on the WIM data findings.

Do the legal and permit load models given in the LADOTD load rating manual adequately represent truck loads observed in the WIM data?

• LA State legal loads / SHVs:
  • LA Type 3
  • LA Type 3-S2
  • AASHTO Type 3-3
  • LA Type 6
  • LA Type 8
  • SU4
  • SU5
  • SU6
  • SU7
Louisiana Routine Legal Loads

LOUISIANA LEGAL LOADS

\( \frac{M_{\text{LEGAL}}}{M_{\text{HL93}}} \)

- Type 3
- Type 3S2
- Type 3-3
- Type 6
- Type 8

Span Length [ft]

\( \frac{M_{\text{LEGAL}}}{M_{\text{HL93}}} \)
Louisiana Specialized Hauling Vehicles

**SU4**
- 12k
- 8k
- 17k
- 17k
- GVW = 54 kips

**SU5**
- 12k
- 8k
- 8k
- 17k
- 17k
- GVW = 62 kips

**SU6**
- 11.5k
- 8k
- 8k
- 17k
- 17k
- 8k
- GVW = 69.5 kips

**SU7**
- 11.5k
- 8k
- 8k
- 17k
- 17k
- 8k
- GVW = 77.5 kips
Truck Configurations from WIM Data

- The WIM data was parsed to extract representative truck configurations for **US-84** and **I-20 Greenwood** sites.

- Truck, crane, and permit type loads were derived from the WIM data.

- The moment and shear envelopes were calculated for these vehicles and compared with:
  - LA legal loads, SHVs,
  - OFRD and OVLD vehicles,
## Comparison of WIM Load Effects: Top 20%

<table>
<thead>
<tr>
<th>Site</th>
<th>Truck</th>
<th>Span Length [ft]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>I-20</td>
<td>4-AXLE</td>
<td>0.574</td>
</tr>
<tr>
<td>US-84</td>
<td>4-AXLE</td>
<td>1.200</td>
</tr>
<tr>
<td>I-20</td>
<td>5-AXLE</td>
<td>0.694</td>
</tr>
<tr>
<td>US-84</td>
<td>5-AXLE</td>
<td>0.485</td>
</tr>
<tr>
<td>I-20</td>
<td>6-AXLE</td>
<td>0.764</td>
</tr>
<tr>
<td>US-84</td>
<td>6-AXLE</td>
<td>0.656</td>
</tr>
<tr>
<td>I-20</td>
<td>7-AXLE</td>
<td>1.054</td>
</tr>
<tr>
<td>US-84</td>
<td>7-AXLE</td>
<td>1.051</td>
</tr>
</tbody>
</table>

Normalized using HL-93
## Truck Configurations from WIM Data

### 4-AXLE TRUCK

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average GVW [kips]</td>
<td>37.5</td>
</tr>
<tr>
<td>Average Top 20% GVW [kips]</td>
<td>59.3</td>
</tr>
</tbody>
</table>

- 34,382 trucks, 2.5% of the truck population

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average GVW [kips]</td>
<td>49.7</td>
</tr>
<tr>
<td>Average Top 20% GVW [kips]</td>
<td>90.8</td>
</tr>
</tbody>
</table>

- 2914 trucks, 2.85% of the truck population
I-20 Load Effects Normalized by HL-93

GREENWOOD I-20 TRUCK CONFIGURATIONS MOMENT LOAD EFFECTS
(Based on Top 20% GVW)
US-84 TRUCK CONFIGURATIONS MOMENT LOAD EFFECTS
(Based on Top 20% GVW)
4-Axle Truck

- The load effects for the 4-axle trucks on US-84 are nearly twice that for the same trucks on I-20.
- Some of this difference may be due to the fact that the Federal Bridge Formula B is applied on I-20 but not on US-84. Another factor is the level of weight enforcement on the Interstates.
- The plots show that the 4 axle truck is adequately enveloped by current SHVs. So a new 4 axle truck would not be required for rating.
- US-84 sees a lot of illegally overloaded 4 axles.
Rating and Posting for Permits

• LADOTD LRFR load rating manual provides vehicle configurations and load factors for:
  • Annual Permits OFRD
  • Trip Permits OVLD
• NBIS regulations require the rating and posting of bridges when the maximum legal loads or state routine permit loads exceed the Operating rating.
• Currently LADOTD procedures do not address the posting of bridges for permits.
Permit Posting Practices

New York
R Posting for Permits

Minnesota
Single Tonnage
DOTD Annual Permits OFRD
Provided in the Load Rating Manual
Annual Permits Derived using WIM Data
Recommended Annual Permits

• The 4 axle truck is adequately enveloped by current SHVs.

• For the other common permit vehicle types, T6, T7-b and T8 may be added as annual permit vehicles for rating.

• If a single rating vehicle is desired for 6, 7 and 8 axles, the T8 (GVW = 152 kip) truck could serve as an envelope vehicle for load rating and posting for annual permits.

• These would represent truck loads derived from recent WIM data and supplement the OFRD vehicles currently in the load rating manual.
Posting Recommendations for Permits

Recommended Posting Truck if a single tonnage is used:

*Louisiana Envelope Permit Truck -- T8*

GVW = 152 kips
THANK YOU