Load Rating for the Fast Act Emergency Vehicles Ev-2 and Ev-3

Bala Sivakumar. P.E. (HNTB)

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Project Team / Schedule

- **Principal Investigator:** Bala Sivakumar, P.E.
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- **HNTB Corp., New York**
- **NCHRP Program Officer:** Dr. Waseem Dekelbab, P.E.
- **Project Schedule:** March 2018 --- March 2019
Definition:

“A vehicle designed under emergency conditions to transport personnel and equipment; and to support the suppression of fires and mitigation of other hazardous situations.”
Fire Truck Characteristics

- Fire suppression necessitates lots of water (also industrial foam) requiring tankers with sufficient capacity.

- Aerial platform trucks need a large mass to counterbalance weight/moment of aerial device.

- Tankers and aerial platform trucks typically have tandem rear axles with high capacity axles.

- Average number of miles traveled by a fire apparatus is about 5,000 miles per year.
Fire Truck Guidelines

International Association of Fire Chiefs

Emergency Vehicle Size and Weight Regulation Guideline
Emergency Vehicle Size and Weight Guide

CUSTOM CHASSIS PUMPER – SINGLE REAR AXLE

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front GAWR (lbs)</td>
<td>18000</td>
<td>24000</td>
</tr>
<tr>
<td>Rear GAWR (lbs)</td>
<td>24000</td>
<td>31000</td>
</tr>
<tr>
<td>Width (in.)</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Height (in.)</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Length (ft.)</td>
<td>30</td>
<td>34</td>
</tr>
</tbody>
</table>

COMMERCIAL CHASSIS TANKER – TANDEM REAR AXLE

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
<td>Front GAWR (lbs)</td>
<td>12000</td>
<td>18000</td>
</tr>
<tr>
<td>Rear GAWR (lbs)</td>
<td>34000</td>
<td>56000</td>
</tr>
<tr>
<td>Width (in.)</td>
<td>98</td>
<td>100</td>
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<tr>
<td>Height (in.)</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Length (ft.)</td>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

AERIAL PLATFORM REAR MOUNT – TANDEM REAR AXLE

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front GAWR (lbs)</td>
<td>21500</td>
<td>24000</td>
</tr>
<tr>
<td>Rear GAWR (lbs)</td>
<td>46000</td>
<td>62000</td>
</tr>
<tr>
<td>Width (in.)</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>Height (in.)</td>
<td>11.5</td>
<td>13</td>
</tr>
<tr>
<td>Length (ft.)</td>
<td>46</td>
<td>48</td>
</tr>
</tbody>
</table>
US Fire Department Profile

Ref. National Fire Protection Association (NFPA)

Total departments: 29,727
- 9% All Career
- 6% Mostly Career
- 18% Mostly Volunteer
- 67% All Volunteer

However, 49% of the U.S. population is protected by the "All Career" fire departments.

Apparatus & Stations:
- Pumpers: 71,800
- Aerial Apparatus: 7,300
- Other Suppression Vehicles: 79,050
- Stations: 58,750

Number of apparatus & stations in the U.S.: 29,727

www.nfpa.org/research

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FHWA EV Memorandum – 2016

- **FHWA Office of Bridges and Structures** investigated maximum moments and shears of typical EV configurations.
- **Two configurations (EV2, EV3)** produce load effects in typical bridges that envelop effects of typical emergency vehicles covered by FAST Act.
- **Type EV2** – for single rear axle emergency vehicles

```
24k  33.5k
15 ft
```

**GVW = 57,500 lbs.**

- **Type EV3** – for tandem rear axle emergency vehicles

```
24k  31k  31k
15 ft  4 ft
```

**GVW = 86,000 lbs.**

Note: EV2 and EV3 do not meet the FBF criteria.
• Emergency vehicle needs only to be considered in a single lane of a bridge with other unrestricted legal vehicles in other lanes.

• **Live load factor = 1.3** may be utilized in Load and Resistance Factor Rating (LRFR) or Load Factor Rating (LFR) method

• FHWA Recommendation was not based on reliability criteria.
EV Load Effects

- EVs have heavier axle loads and do not comply with Federal Bridge Formula B.
- FAST Act exempts EVs from Federal weight limits.
- EVs can create greater load effects in certain bridges than AASHTO legal loads.
- Moments and shears in girders created by EV-3 with a gross vehicle weight of 86,000 lbs. may be 82% greater than those caused by an AASHTO Type 3 vehicle.
EV Load Effects Compared to AASHTO Legal Loads

**EV2 and EV3 configurations**

- EV2: 24k at 15 ft, 33.5k at 15 ft
- EV3: 24k at 15 ft, 31k at 15 ft, 31k at 4 ft

Comparison of EV and Max. Legal Load Effect

- max legal
- EV2
- EV3

Moment (kip-ft) vs. Span (ft) graph
NCHRP Project 20-07/Task 410

- **OBJECTIVE:** Propose modifications to load factors for Emergency Vehicles in the *AASHTO MBE* (“LFR” and “LRFR”). For the LRFR, load factors shall be calibrated to the reliability analysis in the *AASHTO MBE* with appropriate modifications.

- **MAIN TASKS:**
  - Review FAST Act provisions.
  - Establish **multiple presence factors** appropriate for FAST Act emergency vehicles using recent traffic data.
  - Determine the necessity to include EVs in combination with **lane loads for longer spans** and appropriate use of **dynamic load impact**.
  - Perform standard **reliability calibration** consistent with the *AASHTO MBE* to determine LRFR load factors corresponding to current resistance factors.
LRFR Rating Approach for EV Trucks

**EV LRFR rating can take two alternate formats: (Format A and Format B).**

**FORMAT A: (Use with DF)**

- Format A applies EV in its lane and a lane load (0.2 klf) only for continuous spans to represent the effect of trucks ahead and behind the EV in the same lane (lane load not required for simple spans up to 300 ft)

- Multiple presence of other random vehicles in adjacent lanes is implicitly accounted for through a calibrated live load factor for the EV and the **use of the multi-lane DF.**

- This format is consistent with the format currently implemented in the AASHTO MBE LRFR for Routine or Annual permits

- Easier to apply analytically
Rating Equation Format A

- Goal of calibration is to determine appropriate live load factor:

\[ RF = \frac{\phi R_n - \gamma_{DW} D_w - \gamma_{DC} D_c}{\gamma_{EV} (\text{truck} + \text{lane} + \text{IM}) \times mp \times DF} \]

- Bridges that produce R.F. = 1.0 should meet a reliability index \( \beta_{\text{target}} = 2.5 \).
FORMAT B: (Use with Refined Analysis)

- Alternative Format B also applies EV in its lane and a lane load (0.2 klf) in the same lane only for continuous spans (lane load not required for simple spans up to 300 ft).
- But accounts for multiple presence in adjacent lanes by placing a legal truck parallel to the EV.
- Adjusted LRFD DF is used (LRFD Eq 4.6.2.2.5-1) or Refined structural analysis can be performed.
- This format is consistent with the loading in the FHWA memo on Emergency Vehicle load rating (2016).
Goal of calibration is to determine appropriate live load factor:

\[ RF = \frac{\phi R_n - \gamma_{DW} D_w - \gamma_{DC} D_c}{\gamma_{EV} \left[ (EV + \text{lane}) \times DF_1 + \text{Legal} \times DF_2 + IM \right]} \]

- \( DF_1 \) = load distribution factor for EV in main lane
- \( DF_2 \) = load distribution factor for legal truck in other lane.
- Bridges that produce R.F. = 1.0 should meet a reliability index \( \beta_{\text{target}} = 2.5 \).
Reliability Equation

Normal distribution model

\[
\beta = \frac{\overline{Z}}{\sigma_Z} = \frac{\overline{R} - \overline{S}}{\sqrt{\sigma_R^2 + \sigma_S^2}}
\]

Lognormal distribution model

\[
\beta = \frac{\ln \left( \frac{\overline{R}}{\overline{S}} \right)}{\sqrt{V_R^2 + V_S^2}}
\]
Bridge Population for Reliability Calibration

- **Configurations:**
  - Simple span girder bridges (30-ft to 300-ft)
  - Continuous span girder bridges (30-30 ft to 300-300 ft)
- **Materials:**
  - Concrete T-beams
  - Prestressed concrete girders
  - Composite steel girders
- **Beam Spacings:**
  - 4-ft. 6-ft. 8-ft. 10-ft. 12-ft.
- **Load Effects:**
  - Shear
  - Positive bending moment for simple spans and continuous spans
  - Negative bending moment for continuous spans
Multiple Presence of Trucks

- Maximum applied load effects on bridge members may actually be due to the simultaneous crossing of multiple trucks.
  - Side-by-side for multi lanes
  - In lane for longer spans and continuous spans
- Effect of most critical combination of trucks is accounted for through the determination of multiple presence probabilities.
- NCHRP 20-07/Task 410 established EV multiple presence probabilities based on likely traffic situations.
- Truck Traffic simulations were based on data from 3 Weigh-In-Motion (WIM) sites.
- Analysis of Multi-lane simple span and continuous bridges for span lengths up to 300-ft.
Weigh-In-Motion (WIM) Truck Data Sites

Recent data from three Interstate WIM sites

- I-95 in New York City. 90 days of data
  - Heavily congested urban area. ADTT 5500
  - Significant number of very heavy single units and semi-trailers
- I-95 New Jersey Turnpike. 90 days of data
  - Suburban area ADTT 7000 free flowing
  - Significant number of single unit trucks.
- I-90 in Idaho. 113 days of data
  - Rural area ADTT 600
  - Largely semi-trailer trucks
### Summary of WIM Data

**Number of trucks in each WIM data set and ADTT per lane and per site**

<table>
<thead>
<tr>
<th>DATA ANALYZED</th>
<th>NJ I-95</th>
<th>NY I-95</th>
<th>ID I-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANE 1</td>
<td>351324</td>
<td>320871</td>
<td>67542</td>
</tr>
<tr>
<td>LANE 2</td>
<td>275083</td>
<td>187839</td>
<td>2771</td>
</tr>
<tr>
<td>TOTAL</td>
<td>626407</td>
<td>508710</td>
<td>70313</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of days data collected</th>
<th>90</th>
<th>90</th>
<th>113</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANE 1 ADTT</td>
<td>3904</td>
<td>3565</td>
<td>598</td>
</tr>
<tr>
<td>LANE 2 ADTT</td>
<td>3056</td>
<td>2087</td>
<td>25</td>
</tr>
<tr>
<td>Combined ADTT</td>
<td>6960</td>
<td>5652</td>
<td>622</td>
</tr>
</tbody>
</table>
Multiple Presence

- WIM data timestamps and speeds are used to look at snapshots of multiple truck presence within bridge span length
- Replace one of the trucks by EV

Establish Train of Truck Axles

Multiple presence in two lanes
Determine Load Effect for Truck Axle Train

Send truck axle train representing multiple presence events through influence line

Assemble histogram for bridge response for each multiple presence event
### Percentage of trucks in multiple presence situations

Multiple presence for trucks following each other in one lane (lane 1 or lane 2)
Multiple presence in multiple lanes (combination of trucks side-by-side and following)

<table>
<thead>
<tr>
<th>Span Length [ft]</th>
<th>SIMPLE SPAN</th>
<th>CONTINUOUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LANE 1</td>
<td>LANE 2</td>
</tr>
<tr>
<td>30</td>
<td>0.14%</td>
<td>0.06%</td>
</tr>
<tr>
<td>60</td>
<td>0.99%</td>
<td>0.50%</td>
</tr>
<tr>
<td>100</td>
<td>5.03%</td>
<td>2.40%</td>
</tr>
<tr>
<td>150</td>
<td>10.96%</td>
<td>5.58%</td>
</tr>
<tr>
<td>200</td>
<td>15.85%</td>
<td>8.61%</td>
</tr>
<tr>
<td>250</td>
<td>19.77%</td>
<td>11.39%</td>
</tr>
<tr>
<td>300</td>
<td>22.91%</td>
<td>14.02%</td>
</tr>
</tbody>
</table>
Live Load Modeling – Multiple Presence Events

Truck in Lane 1

Bin I

Truck in Lane 2

Bin II
Maximum Load Modeling over Rating Period

• Frequency Histogram of truck Load Effects from WIM data
• Tail representing heavy trucks is of most interest
• Tail approaches that of Normal probability distribution

• Cumulative Histogram of truck Load Effects from WIM data
• Tail representing heavy trucks is raised to power $N$ to give extreme value distribution
• $N =$ number of multiple presence events in rating period equal to 5 years

$$F_{\text{max}} N = (F_{\text{one event}})^N$$
Plot Cumulative Distribution Histogram

Example: Tail End of Cumulative Distribution for NY Data on 200-ft Span

Plot on Normal Probability Scale

$F_{\text{one event}}$

Tail end of histogram is critical for verifying bridge safety
Lower Range of EV Bridge Crossings

• *International Association of Fire Chiefs Association: Emergency Vehicle Size and Weight Regulation Guideline*
  
  – Each EV averages about 5,000 miles of runs/year = 14 miles/day or 7 miles each way.

  – USA has 4.12 million center-line miles of roads and over 600,000 US bridges or roughly one bridge every 7 miles of roadway.

  – Average EV likely to cross at least one bridge per run.

  – A bridge near a fire station could possibly be crossed once everyday.
Upper Range of EV Bridge Crossings

- One emergency call may require dispatching several EV’s.
  - 226,724 calls required an average of 1.3 EV/run.
  - 61,952 FDNY calls were for structural fires requiring 5 engines/call
    - In New York, each FDNY EV averaged 5 runs per day
- Top 100 busiest US fire engine companies easily exceeded 9 runs/day.
- Busiest engine company in San Francisco averages 30 runs/day.
- Bridges near busy urban fire stations could possibly be exposed to ten or more crossings of EV’s per day.
Cases Considered in Calibration

• Three WIM sites:
  – New York City I-95 WIM data representing high ADTT traffic in **congested urban conditions**
  – New Jersey I-95 Turnpike representing high ADTT traffic in **free flowing conditions**
  – Idaho I-90 site representing low ADTT traffic in **rural area**

• Average Number of EV crossings:
  – 1 crossing per day for regions with low emergency calls
  – 10 crossings per day for high emergency call regions
Two Alternative EV Load Rating Formats

- **Format (A) - EV loading using 2-lane LRFD load distribution**
  - Placing one EV in one lane and for continuous spans adding distributed lane load in the same lane.
  - Multiple truck presence is implicitly accounted for in the live load factor and the multi-lane AASHTO load distribution factors.

- **Format (B) - EV in one lane and Legal Truck in adjacent lane.**
  - Placing one EV in one lane and for continuous spans adding distributed lane load in the same lane and placing AASHTO Legal Truck in adjacent lane.
  - Two sub-cases are considered:
    - Using adjusted AASHTO distribution factors
    - Using refined structural analysis
Calibration Criteria

- Rating period: 5-years
- 1 crossing of EV per day or 10 crossings per day
- Target reliability index: $\beta_{\text{target}}=2.50$ (same as AASHTO LRFR)
- Minimum reliability index: $\beta_{\text{minimum}}=1.50$
- Minimum load factor: $\gamma_{EV}=1.10$
- EV in only one lane
- Simple spans to 300 ft --- no lane load
- Lane load only for continuous beams in same lane as EV: $q=0.2\text{kip/ft}$ (same as AASHTO LRFR)
- Dynamic amplification on EV and lane load
- Multi-lane bridges: use 2-lane DF
- Single-lane bridges: use 1-lane DF after removing $mp=1.2$
## Calibration for Format A (Two lane DF)

<table>
<thead>
<tr>
<th>10 crossings per day</th>
<th>EV2</th>
<th>EV3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idaho site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple span no lane load</td>
<td>1.09</td>
<td>0.95</td>
</tr>
<tr>
<td>continuous span w. lane</td>
<td>0.91</td>
<td>0.83</td>
</tr>
<tr>
<td>New Jersey site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple span no lane load</td>
<td>1.42</td>
<td>1.11</td>
</tr>
<tr>
<td>continuous span w. lane</td>
<td>1.21</td>
<td>1.00</td>
</tr>
<tr>
<td>New York site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple span no lane load</td>
<td>1.53</td>
<td>1.18</td>
</tr>
<tr>
<td>continuous span w. lane</td>
<td>1.33</td>
<td>1.08</td>
</tr>
<tr>
<td>only 1 crossing per day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Idaho site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple span no lane load</td>
<td></td>
<td></td>
</tr>
<tr>
<td>continuous span w. lane</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Jersey site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple span no lane load</td>
<td>1.23</td>
<td>0.98</td>
</tr>
<tr>
<td>continuous span w. lane</td>
<td>1.07</td>
<td>0.86</td>
</tr>
<tr>
<td>New York site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simple span no lane load</td>
<td>1.32</td>
<td>1.03</td>
</tr>
<tr>
<td>continuous span w. lane</td>
<td>1.14</td>
<td>0.93</td>
</tr>
</tbody>
</table>
Reliability Calibration – Format A (10 EV Crossings)

FORMAT A - New Jersey Site Multi lane – EV3 (as example)

\[ RF = \frac{\phi R_n - \gamma_{DW} D_w - \gamma_{DC} D_c}{\gamma_{EV}(EV + \text{lane} + IM) \times DF} \]

\[ \gamma_{EV} = 1.11 \quad \gamma_{EV} = 1.00 \]
<table>
<thead>
<tr>
<th>EV Frequency</th>
<th>Truck traffic condition</th>
<th>DF</th>
<th>EV2</th>
<th>EV3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 EV crossings per day</td>
<td>ADTT &lt; 1000 free flowing</td>
<td></td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 free flowing</td>
<td></td>
<td>1.40</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 congested</td>
<td></td>
<td>1.50</td>
<td>1.20</td>
</tr>
<tr>
<td>1 EV crossing per day</td>
<td>ADTT &lt; 1000 free flowing</td>
<td></td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 free flowing</td>
<td></td>
<td>1.20</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 congested</td>
<td></td>
<td>1.30</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Criteria: Min LF = 1.1
### Proposed EV factors < MBE Legal Load Factors for same ADTT

**EV factors lower than Legal Load factors**
Interpolate for ADTT=5000

EV2 Load effects not higher than AASHTO legal loads

<table>
<thead>
<tr>
<th>ADTT</th>
<th>$\gamma_{LL}$ Legal</th>
<th>$\gamma_{LL}$ EV2</th>
<th>$\gamma_{LL}$ EV3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>1.45</td>
<td>1.35</td>
<td>1.10</td>
</tr>
<tr>
<td>1000</td>
<td>1.30</td>
<td>1.10</td>
<td>1.10</td>
</tr>
</tbody>
</table>
## Calibration for Format B - Refined Analysis

<table>
<thead>
<tr>
<th>10 crossings per day</th>
<th></th>
<th>EV2</th>
<th></th>
<th>EV3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Idaho site</strong></td>
<td>Simple span no lane load</td>
<td>1.20</td>
<td></td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>continuous span w. lane</td>
<td>1.05</td>
<td></td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td><strong>New Jersey site</strong></td>
<td>Simple span no lane load</td>
<td>1.49</td>
<td></td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>continuous span w. lane</td>
<td>1.40</td>
<td></td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td><strong>New York site</strong></td>
<td>Simple span no lane load</td>
<td>1.65</td>
<td></td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>continuous span w. lane</td>
<td>1.53</td>
<td></td>
<td>1.36</td>
<td></td>
</tr>
<tr>
<td>only 1 crossing per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Idaho site</strong></td>
<td>Simple span no lane load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>continuous span w. lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>New Jersey site</strong></td>
<td>Simple span no lane load</td>
<td>1.31</td>
<td></td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>continuous span w. lane</td>
<td>1.24</td>
<td></td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td><strong>New York site</strong></td>
<td>Simple span no lane load</td>
<td>1.43</td>
<td></td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>continuous span w. lane</td>
<td>1.32</td>
<td></td>
<td>1.19</td>
<td></td>
</tr>
</tbody>
</table>
Reliability Calibration of Format B – (10 EV Crossings)

Eq. B - New Jersey Multi lane –EV3 plus NJ Legal Load

$$RF = \frac{\phi R_n - \gamma_{DW} D_w - \gamma_{DC} D_c}{\gamma_{EV} \left[ (EV + lane)DF_{EV} + Legal \times DF_{Lgl} \right] IM}$$

$$\gamma_{EV} = 1.33$$

$$\gamma_{EV} = 1.23$$

Reliability of Moment Effect with Span Length

Negative Moment of Cont. Bridges
## Recommendation LRFR Format B

<table>
<thead>
<tr>
<th>EV Frequency</th>
<th>Truck traffic condition</th>
<th>DF</th>
<th>EV2</th>
<th>EV3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 EV crossings per day</td>
<td>ADTT &lt; 1000 free flowing</td>
<td>From refined structural analysis*</td>
<td>1.20</td>
<td>1.15</td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 free flowing</td>
<td>1.50</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 congested</td>
<td>1.65</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>1 EV crossing per day</td>
<td>ADTT &lt; 1000 free flowing</td>
<td>From refined structural analysis*</td>
<td>1.20</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 free flowing</td>
<td>1.30</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ADTT &gt; 6000 congested</td>
<td>1.45</td>
<td>1.30</td>
<td></td>
</tr>
</tbody>
</table>

* Subtract 0.10 from live load factors of Table B when using adjusted AASHTO load distribution
Implementation of Proposed EV Factors in LFR

Using the same proposed EV load factors for LFR leads to low reliability levels $\beta<0.80$ for short spans and above target reliabilities for longer spans.

Reliability of Moment Effect with Span Length

low reliability when using LFR
• A set of EV load factors were calibrated for emergency vehicle load ratings of simple span and continuous bridges up to 300-ft.

• The calibration is based on meeting target reliability levels consistent with AASHTO MBE LRFR criteria.

• Load factors are proposed for different numbers of crossings of EV2 and EV3.

• EV load factors reflect differences in multiple presence based on ADTT, EV weight and expected number of EV crossings.

• Different factors are calibrated for rating with AASHTO LRFD load distribution factor or with refined structural analysis.

• Use same load factors for LFR ---- but rating of EV leads to reliability levels that are not consistent.