Truck Loads
What is an ESAL anyway?

Ken Nysether, PE (ND)
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What is an ESAL anyway?
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“Fancy” Terms

• **Average Daily Traffic (ADT)** - Average traffic volume without bias based on day of the week or season

• **Structural Number (SN)** - Required strength of each layer of material in the design

• **Equivalent Single Axle Load (ESAL)** - Traffic behavior in terms of a standard axle weight
“Fancy” Terms Cont.

- Load Equivalency Factor (LEF)
  - Trucks vs. Cars - not a direct relationship
  
  Standard Garbage Truck: 0.58
  Passenger car or pickup: 0.0003

Nearly a ratio of 1:2000!
# Load Equivalency Factors

## Table 1. Some Typical Load Equivalency Factors

<table>
<thead>
<tr>
<th>Axle Type (lbs)</th>
<th>Axle Load</th>
<th>Load Equivalency Factor (from AASHTO, 1993)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(kN)</td>
<td>(lbs)</td>
</tr>
<tr>
<td>Single axle</td>
<td>8.9</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td>44.5</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>62.3</td>
<td>14,000</td>
</tr>
<tr>
<td></td>
<td>80.0</td>
<td>18,000</td>
</tr>
<tr>
<td></td>
<td>89.0</td>
<td>20,000</td>
</tr>
<tr>
<td></td>
<td>133.4</td>
<td>30,000</td>
</tr>
<tr>
<td>Tandem axle</td>
<td>8.9</td>
<td>2,000</td>
</tr>
<tr>
<td></td>
<td>44.5</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>62.3</td>
<td>14,000</td>
</tr>
<tr>
<td></td>
<td>80.0</td>
<td>18,000</td>
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<tr>
<td></td>
<td>89.0</td>
<td>20,000</td>
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<tr>
<td></td>
<td>133.4</td>
<td>30,000</td>
</tr>
<tr>
<td></td>
<td>151.2</td>
<td>34,000</td>
</tr>
<tr>
<td></td>
<td>177.9</td>
<td>40,000</td>
</tr>
<tr>
<td></td>
<td>222.4</td>
<td>50,000</td>
</tr>
</tbody>
</table>

https://www.pavementinteractive.org/reference-desk/design/design-parameters/equivalent-single-axle-load/
1967 Lincoln Continental

LEF = 0.0004
Standard Logging Truck
LEF Example

• Assume logging trucks have 3 axles:
  - Tractor
    • Steering axle (single axle) = 14,000 lb
    • Drive axle (tandem axle) = 34,000 lb
  - Trailer
    • Pole trailer axle (tandem axle) = 30,000 lb

• Total ESALs would be*:
  - Steering axle @ 14,000 lb = 0.47 ESAL
  - Drive axle @ 34,000 lb = 1.15 ESAL
  - Pole axle @ 30,000 lb = 0.79 ESAL
  TOTAL = 2.41 ESAL

*Assumes p_t = 3.0, SN = 3

https://www.pavementinteractive.org/reference-desk/design/design-parameters/equivalent-single-axle-load/
Pavement Design

- Utilizing the factors mentioned and a few others, engineers use this equation to determine the total Structural Number (SN) required to meet design life span.

\[
\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{1094} + 2.32 \times \log_{10}(M_R) - 8.07
\]

- AASHTO design equation for flexible pavements. The Structural Number is indicated as SN.
Pavement Design

Traffic ESAL

Standard Deviation

Design Serviceability index
(how much the road can deform before improvements occur)

Normal Deviation

Structural Number

Soil resilient modulus
(Current strength values of the underlying soil)

\[
\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{1094} + 2.32 \times \log_{10}(M_E) - 8.07
\]
Pavement Design:

- Once the SN is determined, it is used to determine the pavement thickness

\[ SN = D_1 a_1 + D_2 a_2 m_2 + D_3 a_3 m_3 \]

- Where \( a \) and \( m \) are material specific coefficients
- \( m \) is a drainage coefficient
- \( a \) is a layer coefficient
Traffic Estimate

- 13 houses
- 2 cars per house
- Each car making 4 trips per day
- 104 trips per day (ADT)
- 37,960 trips each year
- Load equivalency factor = 0.0003

- ESAL - 11.39

- Garbage Truck
- Makes one trip per week
- 52 trips per year
- Load equivalency factor = 0.58

- ESAL - 30.16

- Total ESAL - 41.55
Design 1

- 6” Hot Mix Asphalt (HMA) on 12” Base
- \( SN_{\text{total}} = D_1 a_1 + D_2 a_2 m_2 = 3.48 \)
- $18,100 per STA

\( SN_2 = 0.84 \quad SN_1 = 2.64 \)

Note: Subgrade is neglected in these calculations for clarity of design comparisons
Design 2

- 4” HMA on 8” of Cement Stabilized Base
- $10,600 per STA
- $10,600 per STA
- $10,600 per STA

SN_{total} = D_1a_1+D_2a_2m_2 = 2.90

SN_2 = 1.14  
SN_1 = 1.76

Note: Subgrade is neglected in these calculations for clarity of design comparisons
Design 3

- 2.5” HMA on 4”-6” Crushed Asphalt Base
- $SN_{total} = D_1 a_1 + D_2 a_2 m_2 = 1.94$
  - $SN_{total} = 1.66$ for 4” crushed asphalt base
- $5,700$ per STA

Note: Subgrade is neglected in these calculations for clarity of design comparisons
# Design Comparison

<table>
<thead>
<tr>
<th>Design</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per STA</td>
<td>$18,100</td>
<td>$10,600</td>
<td>$5,700</td>
</tr>
<tr>
<td>Structural Number</td>
<td>3.48</td>
<td>2.90</td>
<td>1.94</td>
</tr>
<tr>
<td>ESAL/ year</td>
<td>9500</td>
<td>2800</td>
<td>250</td>
</tr>
<tr>
<td>Total ESALs</td>
<td>190,000</td>
<td>56,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Factor of Safety</td>
<td>190</td>
<td>56</td>
<td>5</td>
</tr>
</tbody>
</table>
More Information/Resources

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