Truck Loads
What is an ESAL anyway?

Ken Nysether, PE (ND)

SEH

Reaching New Heights

34th Annual North Central Local Roads Conference

Rapid City, SD - October 16-17, 2019

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Reaching New ~~Heights~~ Weights

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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

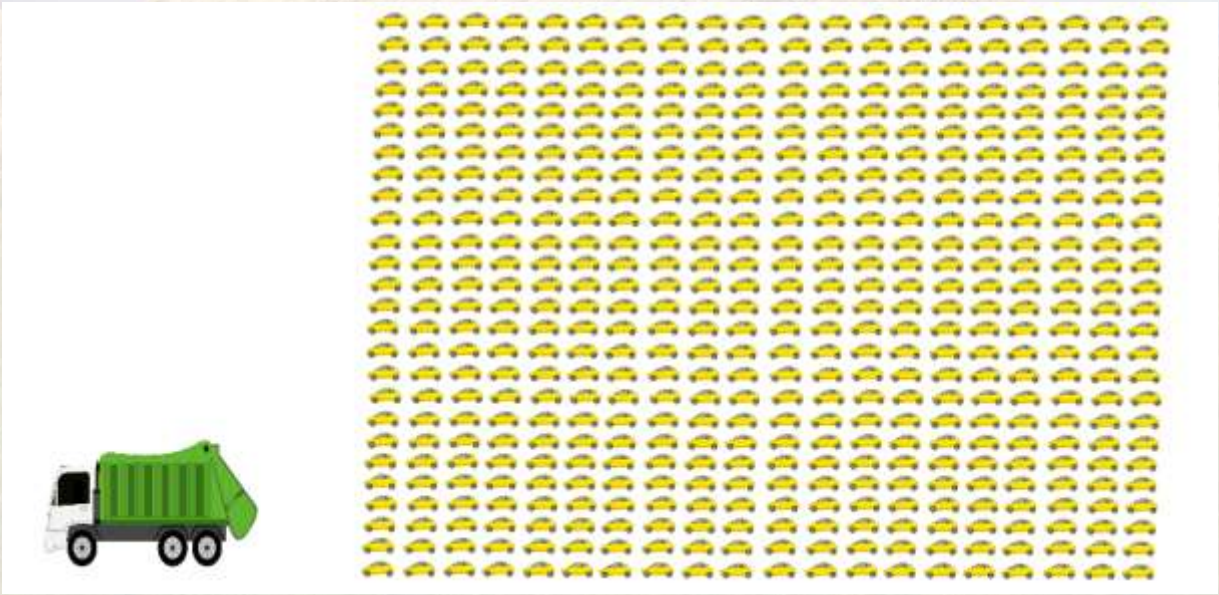
“Fancy” Terms Cont.

- 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!

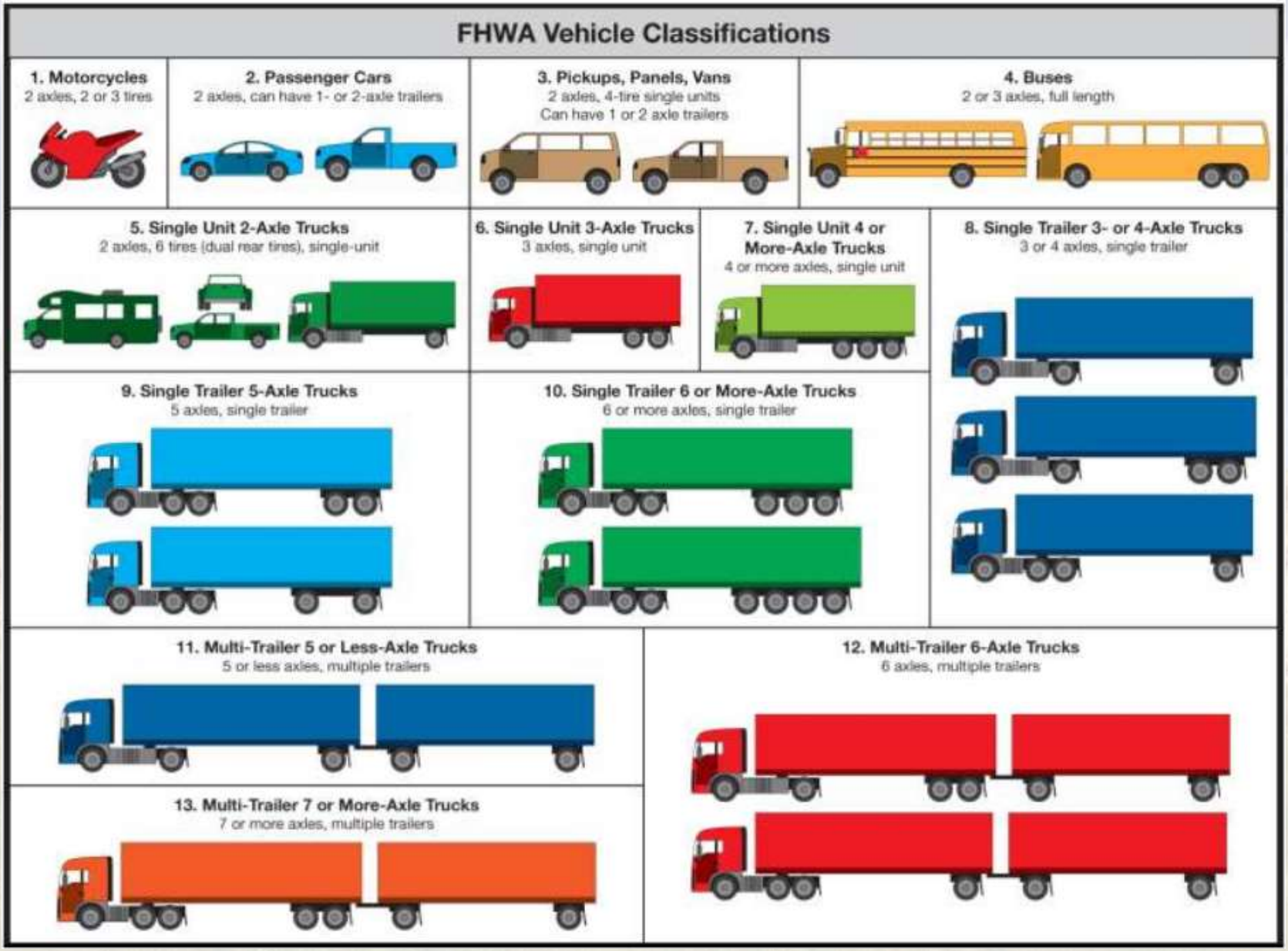


Load Equivalency Factors

Table 1. Some Typical Load Equivalency Factors

Axle Type (lbs)	Axle Load		Load Equivalency Factor (from AASHTO, 1993)	
	(kN)	(lbs)	Flexible	Rigid
Single axle	8.9	2,000	0.0003	0.0002
	44.5	10,000	0.118	0.082
	62.3	14,000	0.399	0.341
	80.0	18,000	1.000	1.000
	89.0	20,000	1.4	1.57
	133.4	30,000	7.9	8.28
Tandem axle	8.9	2,000	0.0001	0.0001
	44.5	10,000	0.011	0.013
	62.3	14,000	0.042	0.048
	80.0	18,000	0.109	0.133
	89.0	20,000	0.162	0.206
	133.4	30,000	0.703	1.14
	151.2	34,000	1.11	1.92
	177.9	40,000	2.06	3.74
	222.4	50,000	5.03	9.07

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


FHWA Vehicle Classifications
1. Motorcycles
2 axles, 2 or 3 tires
2. Passenger Cars
2 axles, can have 1- or 2-axle trailers
3. Pickups, Panels, Vans
2 axles, 4-tire single units
Can have 1 or 2 axle trailers
4. Buses
2 or 3 axles, full length
5. Single Unit 2-Axle Trucks
2 axles, 6 tires (dual rear tires), single-unit
6. Single Unit 3-Axle Trucks
3 axles, single unit
7. Single Unit 4 or More-Axle Trucks
4 or more axles, single unit
8. Single Trailer 3- or 4-Axle Trucks
3 or 4 axles, single trailer
9. Single Trailer 5-Axle Trucks
5 axles, single trailer
10. Single Trailer 6 or More-Axle Trucks
6 or more axles, single trailer
11. Multi-Trailer 5 or Less-Axle Trucks
5 or less axles, multiple trailers
12. Multi-Trailer 6-Axle Trucks
6 axles, multiple trailers
13. Multi-Trailer 7 or More-Axle Trucks
7 or more axles, multiple trailers

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

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

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

Pavement Design

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

Traffic ESAL

Standard Deviation

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Normal Deviation

Structural Number

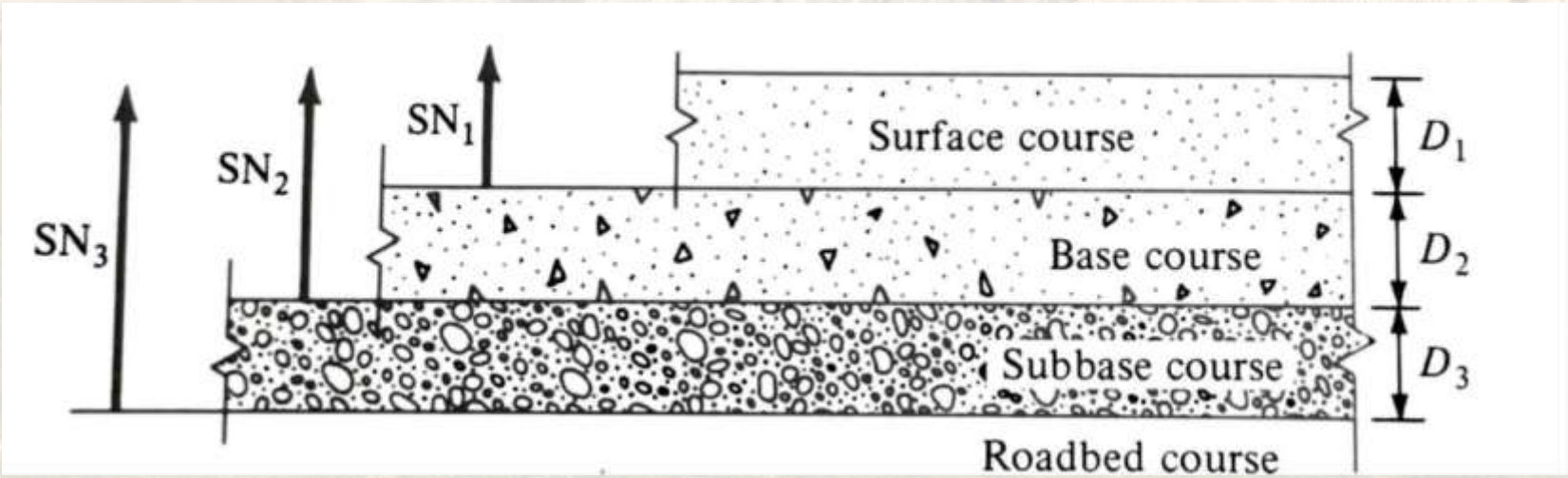
Soil resilient modulus
(Current strength values of the underlying soil)

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

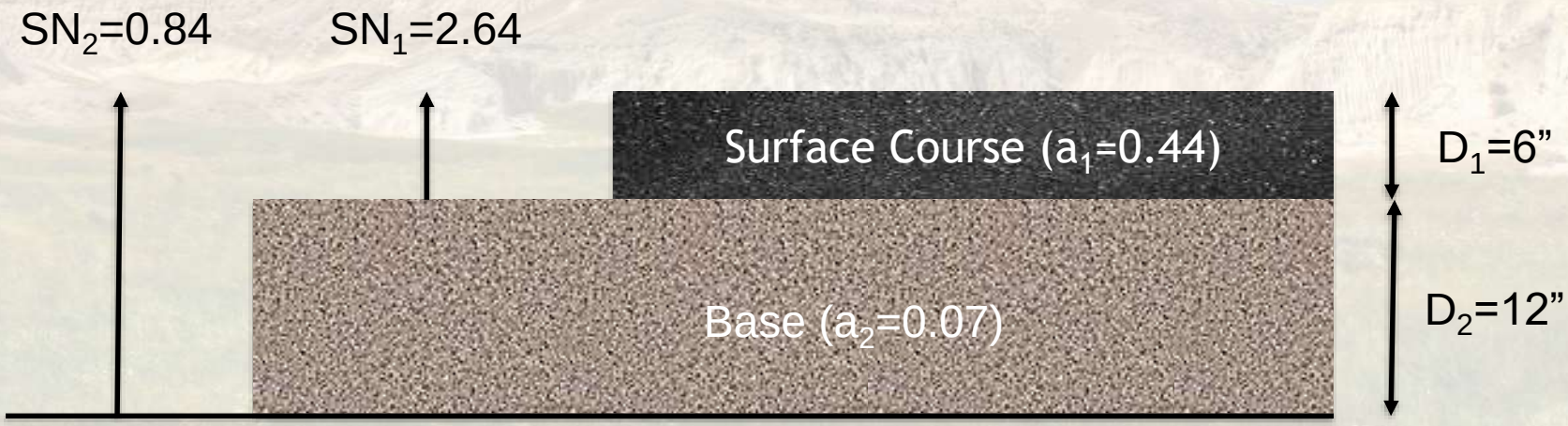
- Garbage Truck
- Makes one trip per week
- 52 trips per year
- Load equivalency factor = 0.58

- ESAL – 30.16

- Total ESAL – 41.55

Design 1

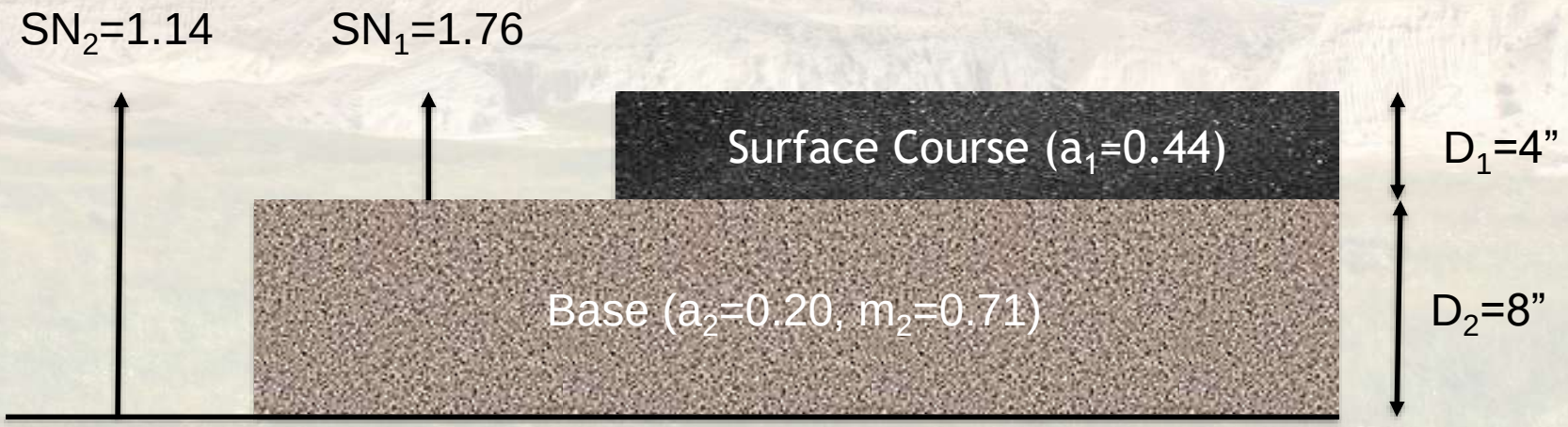
- 6” Hot Mix Asphalt (HMA) on 12” Base
- $SN_{total} = D_1a_1+D_2a_2m_2=3.48$
- $18,100 per STA



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

Design 2

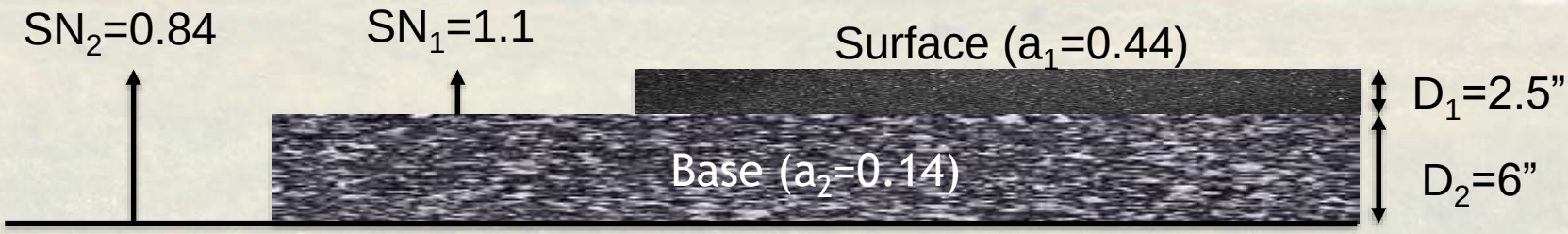
- 4” HMA on 8” of Cement Stabilized Base
- $SN_{total} = D_1a_1+D_2a_2m_2=2.90$
- $10,600 per STA



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

Design 3

- 2.5” HMA on 4”-6” Crushed Asphalt Base
- $SN_{total} = D_1a_1+D_2a_2m_2=1.94$
  - 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

Design	1	2	3
Cost per STA	$18,100	$10,600	$5,700
Structural Number	3.48	2.90	1.94
ESAL/ year	9500	2800	250
Total ESALs	190,000	56,000	5,000
Factor of Safety	190	56	5

More Information/Resources

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