

ESAL Cheat Sheet: Quick Reference for Pavement Engineers

What is an ESAL?

- **Definition:** ESAL = Equivalent Single Axle Load
- **Standard:** One ESAL is the damage from a single **18,000-lb (80 kN) single axle with dual tires**.
- **Purpose:** Convert mixed traffic into a **common damage unit** for pavement design.

ESAL Formula

$$ESAL = \sum (N_i \times LEF_i)$$

Where:

- N_i = number of passes for vehicle class i
- LEF_i = Load Equivalency Factor for vehicle class i

ESAL Conversion Table (based on AASHTO & typical LEFs)

Vehicle Type	Axles	Typical Load (kips per axle)	Approx. ESAL per Pass
Passenger Car (sedan)	2	2–3	0.0004
Pickup / SUV	2	3–4	0.001
Delivery Van (2-axle, light)	2	4–5	0.005
Single-Unit Truck (2-axle, 6-tire)	2	6–9	0.02
Single-Unit Truck (3-axle)	3	8–10	0.40
City Bus	2–3	10–12	0.50 – 1.50
Tractor-Trailer (4-axle)	4	12–14	0.80 – 1.50
Tractor-Trailer (5-axle standard semi)	5	16–18	1.0 – 4.0
Tractor-Trailer (6-axle)	6	18–20	3.0 – 6.0
Heavy Haul Truck (7+ axles, overloaded)	7+	20+	5.0 – 10.0+

How to Use This Table

1. **Classify vehicles** (cars, pickups, buses, trucks, semis, heavy haul).
2. **Multiply the number of vehicles by the ESAL factor** in the table.
3. **Sum across all vehicle classes** to get the total daily ESALs.
4. Apply **growth factor & design life** to get design ESALs.



Extended ESAL Conversion Table (by Vehicle & Load Condition)

Vehicle Type	Axles	Load Condition	Typical Axle Load (kips)	Approx. ESAL per Pass
Passenger Car	2	Normal	2–3	0.0004
Pickup / SUV	2	Empty	3–4	0.0005
	2	Loaded	4–5	0.001
Delivery Van (2-axle, light)	2	Empty	4–5	0.003
	2	Loaded	5–6	0.005
Single-Unit Truck (2-axle, 6-tire)	2	Empty	6–7	0.01
	2	Medium	8–9	0.02
	2	Fully Loaded	10–12	0.05
Single-Unit Truck (3-axle)	3	Empty	8–10	0.2
	3	Medium	10–12	0.4
	3	Fully Loaded	12–14	0.8
City Bus	2–3	Light Load (off-peak)	10–11	0.5
	2–3	Peak Load (crowded)	12–14	1.0 – 1.5
Tractor-Trailer (4-axle)	4	Empty	10–12	0.3
	4	Medium	12–14	0.8
	4	Fully Loaded	14–16	1.5
Tractor-Trailer (5-axle, standard semi)	5	Empty	12–14	0.5

Vehicle Type	Axes	Load Condition	Typical Axle Load (kips)	Approx. ESAL per Pass
	5	Medium	14–16	1.5
	5	Fully Loaded	16–18	2.5 – 4.0
	5	Overloaded	18–20+	5.0+
Tractor-Trailer (6-axle)	6	Medium	16–18	3.0
	6	Fully Loaded	18–20	4.0 – 6.0
Heavy Haul Truck (7+ axles)	7+	Legal Load	20+	5.0
	7+	Overloaded	22–25+	8.0 – 12.0+

Key Insights from the Table

- **Passenger cars ≈ negligible** impact → engineers usually ignore them in ESAL calculations.
- **Axle load matters more than vehicle type** (a single overloaded truck can equal thousands of cars).
- **Buses can rival trucks** in ESAL impact, especially in urban corridors.
- **Overloaded trucks are ESAL monsters** → 1 pass can equal 5–10+ passes of a legal semi-truck.

Step-by-Step Conversion Example

Problem:

- Road AADT = 20,000
- 8% trucks (1,600 trucks/day)
- Design life = 20 years



- Assume truck mix avg. LEF = 2.0

Solution:

1. Total trucks over design life = $1,600 \times 365 \times 20 = 11.68 \text{ million}$
2. ESALs = $11.68 \times 10^6 \times 2.0 = 23.36 \text{ million}$

👉 Pavement must be designed for **23.4 million ESALs**.

Typical ESAL Ranges for Roads

Road Type	Design ESALs (lifetime)
Low-volume rural	$10^4 - 10^5$
Urban arterial	$10^6 - 10^7$
Expressway / Highway	10^8+

Quick Reference Notes

- Cars contribute **negligible ESALs** compared to trucks.
- Pavement **failure risk grows exponentially** with axle load (fourth power law).
- Always check **local design codes** (AASHTO 1993, MEPDG, IRC, etc.).