Pavement Materials & Design

Pavement Structure Design

AASHTO 1993_ Traffic load calculations

1

Definition

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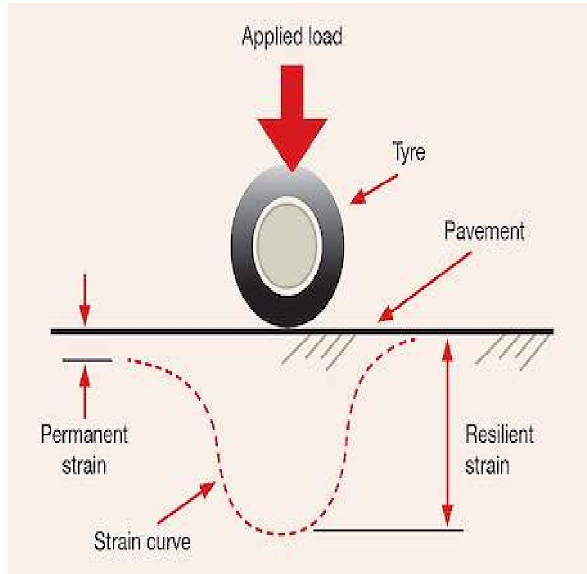
Introduction to Traffic Loads

Definition

- Traffic loads refer to the forces applied to pavement by vehicles in motion.



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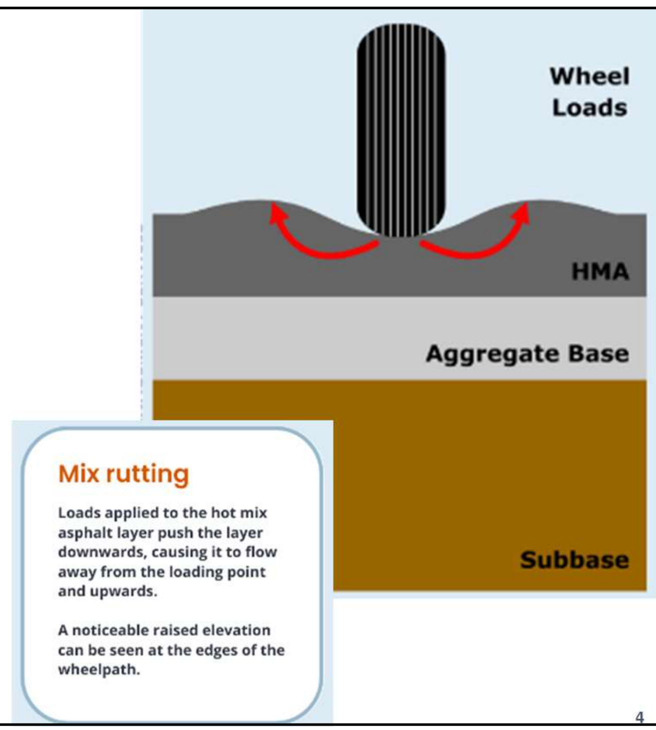
Traffic Loads

Impact

- Pavement deterioration is caused by the interacting damaging effects of traffic and the environment.
- Traffic loads, primarily those from heavy trucks, cause stresses/strains in pavement structures, whose effects **accumulate** over time, resulting in pavement deterioration,
- Such as rutting



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Rutting

Traffic Loads

Quantification criteria

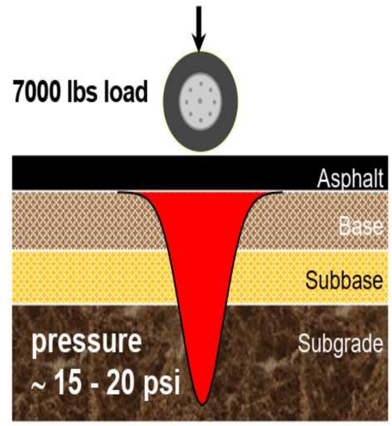
Traffic Loads

Quantification criteria

Pavement Damage depends on weight distribution

Truck traffic loads and their impact on pavements are Quantify using :

1. Vehicle/axle speed
2. Number of truck axles
3. Configuration of these axles
4. Their load magnitude
5. Tire inflation pressure



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Axle and Tire

Configuration

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Axle Configuration

- Axle configuration is defined by the number of
  - Axles sharing the same suspension system
  - the number of tires in each axle

Axle/truck	Example truck configurations	Axle configurations
Single		
Tandem		
Tridem		
Quad		
Five		
Six		
Seven		
Eight		

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Single Axle Configuration

13

Tandem Axle Configuration

14

Tridem Axle Configuration

15

Quad Axle Configuration

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Tire Configuration

Single Tire

- Typical Load per Tire: 20 - 50 kN

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Tire Configuration

Dual Tire

- Typical Load per Tire: 40 - 100 kN

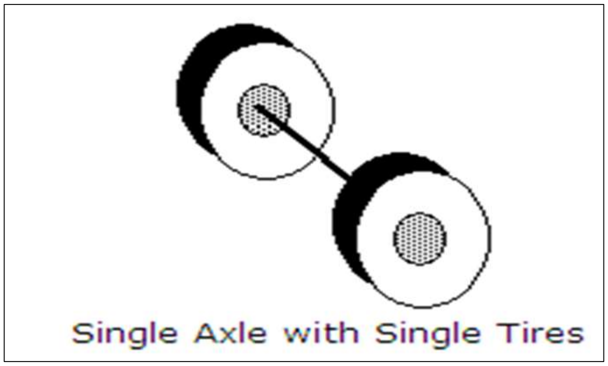
Tire Configuration

Wide Base Tire

- Description: Extra wide tire designed to replace duals for weight savings.
- Typical Load per Tire: 60 - 100 kN

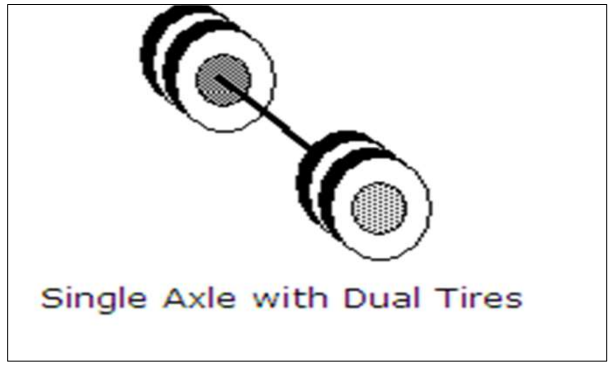
Traffic Load

Typical Axle and Tire Configuration



Single Axle Single Tires

Single Axle Dual Tires



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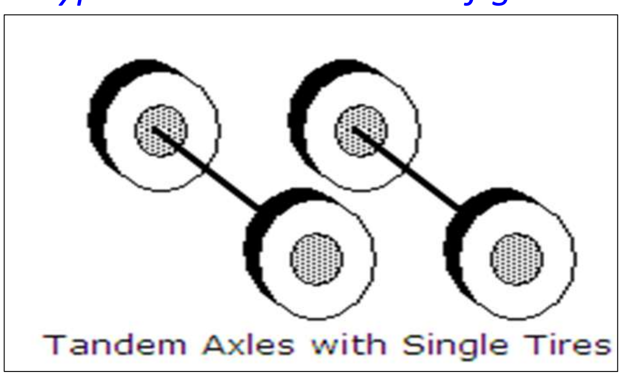
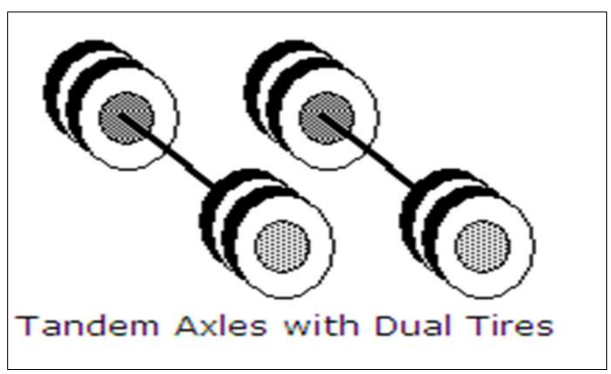
Traffic Load

Typical Axle and Tire Configuration



Tandem Axle Single Tires

Tandem Axle Dual Tires



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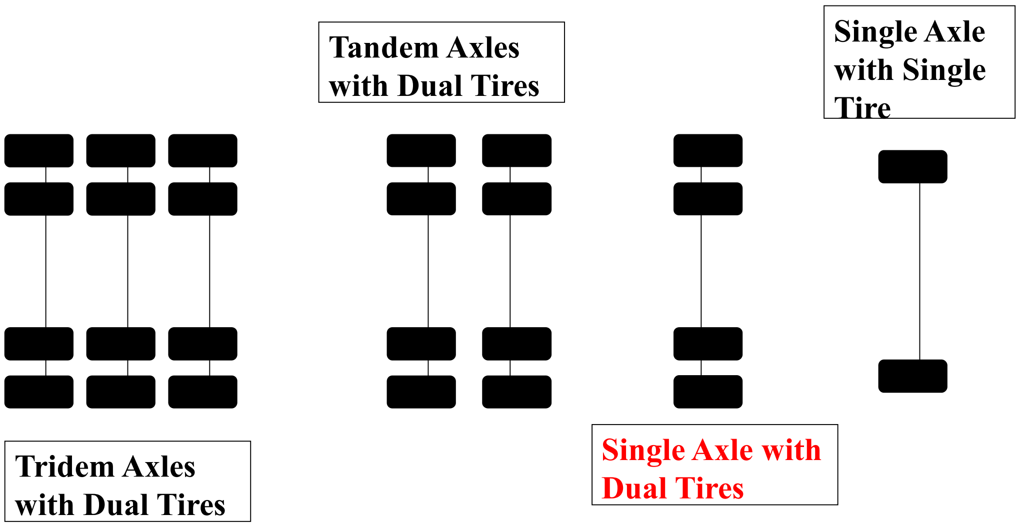
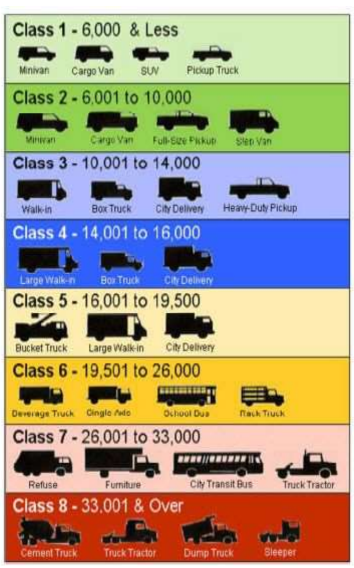
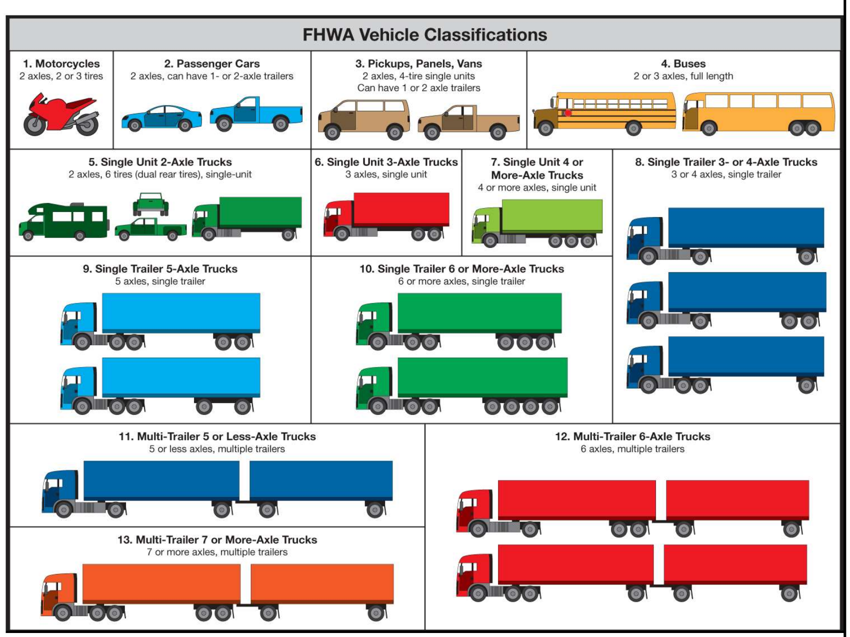
Axle Configuration

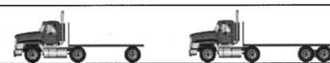
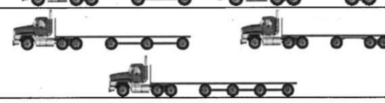
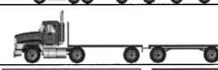
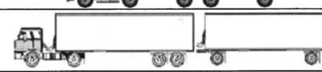
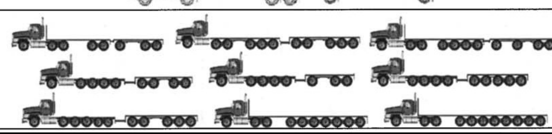


FHWA vehicle classification





FHWA vehicle Weigh class

FHWA Class Type	Class Definition	Axle Group	Example truck configurations
5	Two-axle, six-tire, single-unit trucks	1	
6	Three-axle single-unit trucks	1 and 2	
7	Four or more axle single-unit trucks	1, 3 and 4	
8	Four or fewer axle single-trailer trucks	1and 2	
9	Five-axle single-trailer trucks	1and 2	
10	Six or more axle single-trailer trucks	1, 2, 7 and 8	
11	Five or fewer axle multi-trailer trucks	1	
12	Six-axle multi-trailer trucks	1 and 2	
13	Seven or more axle multi-trailer trucks	1, 2, 3, 4, 5, 7and 8	

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Vehicle, Axle and Tire

Load distribution

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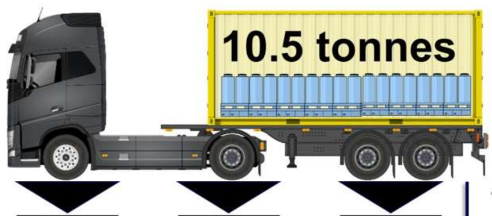
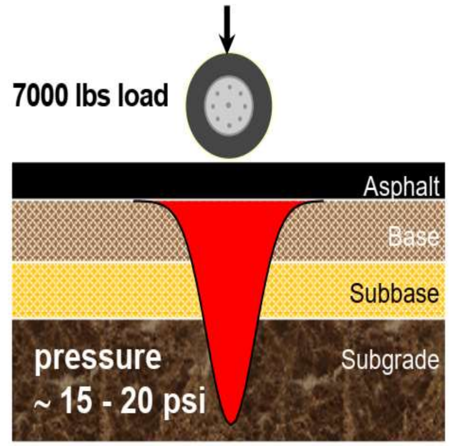
Vehicle, Axle and Tire weight

- The axle load distribution depends on the vehicle gross weight and spacing between axles.



				Truck weight
Truck & trailer	4.5 tonnes	3.0 tonnes	2.0 tonnes	9.5 tonnes
Container		4.0 tonnes	6.5 tonnes	10.5 tonnes
				20.0 tonnes



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Traffic Data for Pavement Design Input

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- The collected traffic data must be **summarized** in a format that is suitable for direct input into the pavement design process, ensuring accurate traffic loading estimates for long-term pavement performance analysis.
- Available Approaches:

➢ *ESALs appraoch (AASHTO 1986/1993 Pavement Design Approach)*

➢ *Load spectra (NCHRP 1-37A Pavement Design Approach)*

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AASHTO 1993 Method

Equivalent Single Axle Load (ESAL)

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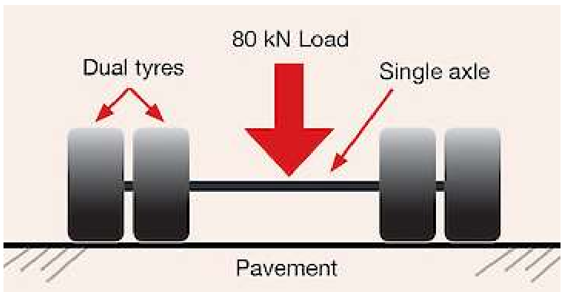
Equivalent Single Axle Load (ESAL)

Idea

- Traffic with different axle loads is simplified by converting them into an equivalent number of standard axles.
  - *Typically, this standard is a single axle with dual tires that has a weight of 18,000 lb (80 KN)*



Each repetition of this Standard Axle Load (SAL) will cause a specific damage to the pavement

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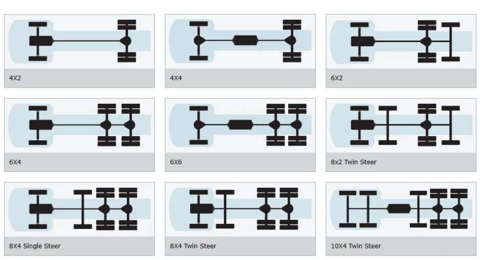
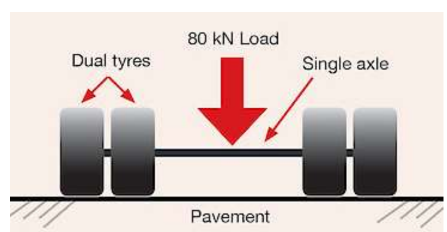
Equivalent Single Axle Loads (ESALs)

- Convert wheel loads of various **magnitudes** and **repetitions** ("mixed traffic") to an equivalent number of "standard" or "equivalent" loads **based on** the amount the damage they do to the pavement





Damage from Mixed Traffic [Different axles and tires combination

= X × [Damage from SAL]

1 ESAL = Damage caused by one SAL

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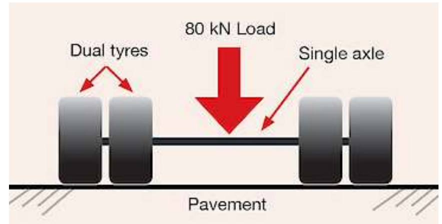
Equivalent Single Axle Loads (ESALs)

Damage by each axle alone



ESALs=0.23

ESALs by axle

=0.23 × [Damage from SAL]

https://www.penndot.pa.gov/ProjectAndPrograms/PostedBondedRoadway/Documents/ESAL-BASED%20COSTS.pdf

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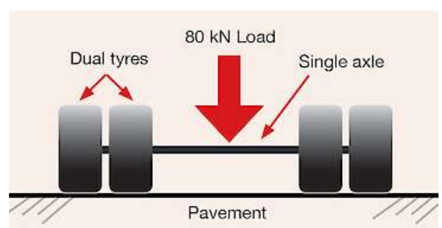
Equivalent Single Axle Loads (ESALs)

Damage by each axle alone



Damage from this vehicle [All axles\ tire combinations]

=1.179 × [Damage from SAL]

ESALs=1.179

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AASHTO 1993 Method

Equivalent Single Axle Load (ESAL)

(FE_i): load equivalency factor for axle category

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(F_{Ei}): load equivalency factor for axle category i

F_{Ei}

- Equivalent Axle Load Factor (EALF) (Or Load equivalency factors (LEFs))

➢ *A multiplier that quantifies the relative damage that defines the damage per pass to a pavement by the axle in question relative to the damage per pass of a standard axle load (18- kip axle load)*

- ***1 ESAL = Damage caused by one 18,000 lb single axle load***
- ***The load is convert using Load equivalency factors (LEFs)***

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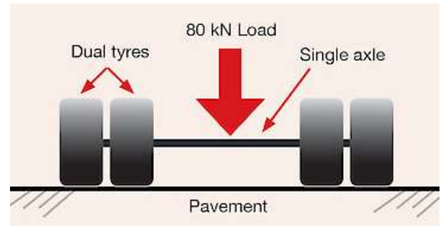
Equivalent Single Axle Loads (ESALs)

Damage by each axle alone



ESALs=0.23

ESALs by axle

=0.23 × [Damage from SAL]

https://www.penndot.pa.gov/ProjectAndPrograms/PostedBondedRoadway/Documents/ESAL-BASED%20COSTS.pdf

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Equivalent Single Axle Load (ESAL)

Determination for each axle category i

Axle/truck	Example truck configurations	Axle configurations
Single		
Tandem		
Tridem		
Quad		
Five		
Six		
Seven		
Eight		

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Factors Affecting LEF

- Axle Load:
  - Higher loads cause exponentially more damage.
- Axle Configuration:
  - Single axles concentrate more load, causing higher damage.
  - Tandem and tridem axles distribute load, reducing damage.
- Pavement Type:
  - Flexible and rigid pavements respond differently to axle loads.
- Pavement Strength:
  - *Thicker, stronger pavements can resist higher loads.*
  - *Pavement thickness or structural capacity (SN)*
  - *The terminal conditions at which the pavement is considered failed (P_t)*

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Determination of LEF

- LEFs can be determined using
  - *Design Equation*
  - *Table (Handouts)*

$$\log\left(\frac{W_{tx}}{W_{t18}}\right) = 4.79\log(18+1) - 4.79\log(L_x + L_2) + 4.33\log L_2 + \frac{G_t}{\beta_x} - \frac{G_t}{\beta_{18}}$$

$$G_t = \log\left(\frac{4.2 - p_t}{4.2 - 1.5}\right)$$

$$\beta_x = 0.40 + \frac{0.081(L_x + L_2)^{3.23}}{(\mathrm{SN}+1)^{5.19}L_2^{3.23}}$$

- W_{tx}: Number of load repetitions for axle load L_x during the design life.
- W_{t18}: Number of load repetitions for a standard 18,000-lb single axle load.
- L_x: Axle load under consideration (in kips).
- L_2: Standard axle load (commonly 18 kips).
- G_t: Terminal serviceability adjustment factor, accounting for pavement deterioration.
- β_x: Structural damage coefficient for axle load L_x.
- β_{18}: Structural damage coefficient for the standard 18,000-lb axle.
- p_t: Terminal serviceability index, representing pavement condition at the end of its design life.

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(FEi): load equivalency factor for axle category i

Tables

- Steps to Determine Load Equivalency Factor (LEF) from Table

1. Select the Pavement Type.
2. Check the Axle Type.
3. Identify the Terminal Serviceability Index (pt).
4. Determine the Structural Number (SN).
5. Determine the Axle Load (Lx).
6. Locate the Intersection in the Table.
7. Read the LEF Value.

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.0	102.0	79.0	60.0	53.0	55.0

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(F_{Ei}): load equivalency factor for axle category i

Tables

- Axle Load Equivalency Factors for
  - Flexible Pavements
  - Single Axles
  - P_t of 2.5
  - *Different SN*

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.0	102.0	79.0	60.0	53.0	55.0

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(F_{Ei}): load equivalency factor for axle category i (LEFs)

Tables

- Axle Load Equivalency Factors for
  - Flexible Pavements
  - Tandem Axles
  - P_t of 2.5
  - *Different SN*

Table 19.3b Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles, and p_t of 2.5

	Pavement Structural Number (SN)					
Axle Load (kips)	*1*	*2*	*3*	*4*	*5*	*6*
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470
30	.611	.648	.703	.695	.658	.633
32	.813	.843	.889	.887	.857	.834
34	1.06	1.08	1.11	1.11	1.09	1.08
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.73	1.69	1.68	1.70	1.73
40	2.21	2.16	2.06	2.03	2.08	2.14
42	2.76	2.67	2.49	2.43	2.51	2.61
44	3.41	3.27	2.99	2.88	3.00	3.16
46	4.18	3.98	3.58	3.40	3.55	3.79
48	5.08	4.80	4.25	3.98	4.17	4.49
50	6.12	5.76	5.03	4.64	4.86	5.28

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Example 5

Determination of LEFs for different axles

- Determine the LEFs for the following the following axle loads, assume SN = 5 and P_t = 2.5
  - One Single axle (10,000 lb/axle) (10 kips)
  - One Tandem Axle (10,000 lb/axle) (10 kips)

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Example 5

Determination of LEFs for different axles

- Determine the LEFs for the following the following axle loads,

➢ ***SN = 5*** *and* ***Pt = 2.5,*** **Single axle** (10,000 lb/axle)

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

	Pavement Structural Number (SN)					
Axle Load (kips)	1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606

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Example 5

Determination of LEFs for different axles

- Determine the LEFs for the following the following axle loads,

➢ ***SN = 5*** *and* ***Pt = 2.5,*** **Tandem axle** (10,000 lb/axle)

Table 19.3b Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles, and p_t of 2.5

	Pavement Structural Number (SN)					
Axle Load (kips)	1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013

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AASHTO 1993 Method

Equivalent Single Axle Load (ESAL)

T_f: Truck factor

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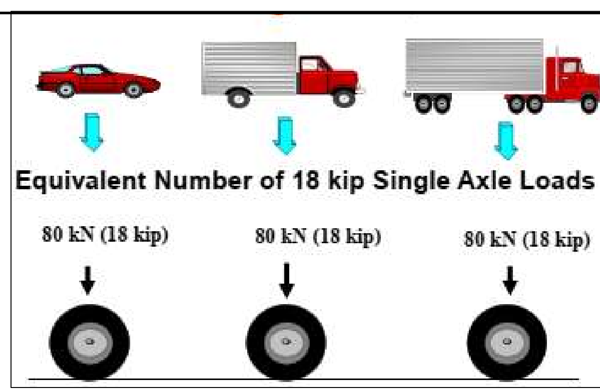
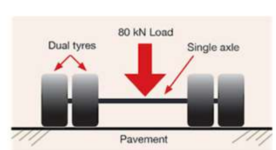
What is Truck Factor?

- Truck Factor (TF):
  - A multiplier representing the average pavement damage caused by a truck compared to a standard 18,000-lb single axle load.
- Purpose:
  - *To estimate the cumulative damage caused by truck traffic over the pavement design life.*





Damage from this vehicle [All axles\ tire combinations]

=1.179 × [Damage from SAL]

ESALs=1.179

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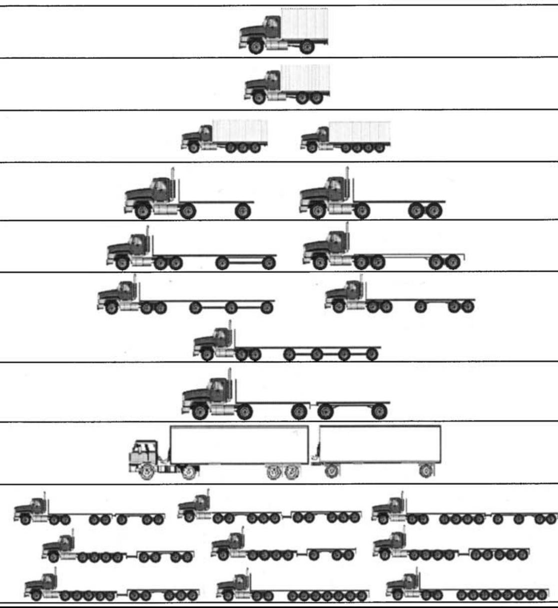
FHWA vehicle Weigh class

FHWA Class Type	Class Definition	Axle Group	Example truck configurations
5	Two-axle, six-tire, single-unit trucks	1	
6	Three-axle single-unit trucks	1 and 2	
7	Four or more axle single-unit trucks	1, 3 and 4	
8	Four or fewer axle single-trailer trucks	1and 2	
9	Five-axle single-trailer trucks	1and 2	
10	Six or more axle single-trailer trucks	1, 2, 7 and 8	
11	Five or fewer axle multi-trailer trucks	1	
12	Six-axle multi-trailer trucks	1 and 2	
13	Seven or more axle multi-trailer trucks	1, 2, 3, 4, 5, 7and 8	



74

Key Components for Truck Factor Determination

- Axle Load :
  - *Weight carried by each axle of the truck.*
- Axle Configuration:
  - *Single, tandem, or tridem axles distribute weight differently.*
- Load Equivalency Factor (LEF):
  - Relative pavement damage caused by axle loads compared to an 18,000-lb axle.
- Traffic Volume:
  - *Number of trucks passing over the design lane daily.*

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Steps to Determine Truck Factor

- Identify the truck's axle configuration and load distribution.
- Determine the Load Equivalency Factor (LEF) for each axle using tables or equations.
- Calculate the total ESAL contribution for the truck:
-
  - $\text{ESAL} = \sum(N_i \times F_{Ei})$, where:
    - N_i: Number of axles in axle group i.
    - F_{Ei}: Load Equivalency Factor for axle group i.
- Divide the total ESAL by the number of trucks to determine the **Truck Factor (TF)**.

$$Truck\ factor(T_f) = \frac{\sum(Number\ of\ axles\ \times LEFs\ for\ each\ axle\ )}{Number\ of\ vehicles}$$

76

Example

- Determine the Truck factor for the following vehicle mix and axle loads
  - ➢ Passenger cars (2000 lb/axle)
  - ➢ 2-axle single-unit trucks (6000 lb/axle)
  - ➢ 3-axle single-unit trucks (10,000 lb/axle)

Assume SN = 5 and P_t = 2.5

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Example

Passenger cars (2000 lb/axle)

Assume SN = 5 and Pt = 2.5

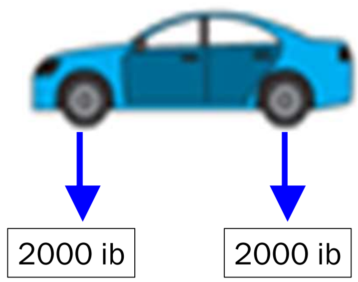

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98

LEF for single axle = 0.002

$$Truck\ factor\ (T_f) = \frac{\sum(Number\ of\ axles \times LEFs\ for\ each\ axle)}{Number\ of\ vehicles} = \frac{\sum(2\times0.002)}{1} = 0.004\ per\ vehicle$$

78

Example

2-axle single-unit trucks (6000 lb/axle)

Assume SN = 5 and Pt = 2.5

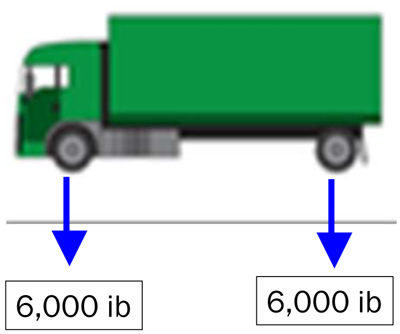

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606

$$Truck\ factor(T_f) = \frac{\sum(Number\ of\ axles \times LEFs\ for\ each\ axle)}{Number\ of\ vehicles} = \frac{\sum(2\times0.01)}{1} = 0.02\ per\ vehicle$$

79

Example

3-axle single-unit trucks (10,000 lb/axle)

Assume SN = 5 and Pt = 2.5

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	*Pavement Structural Number (SN)* 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080

Table 19.3b Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles, and p_t of 2.5

Axle Load (kips)	*Pavement Structural Number (SN)* 1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470

$$Truck\ factor(T_f) = = \frac{\sum(1\times0.088+1*0.18\ )}{1} = 0.264\ per\ vehicle$$

80

Example

Determine LEF for the truck below assume SN=6 and pt of 2.5

Assume SN = 5 and Pt = 2.5

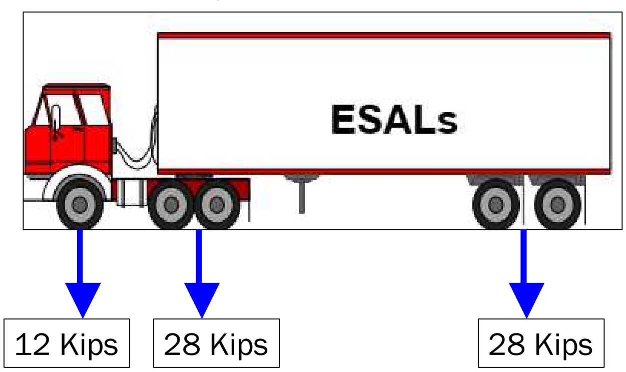

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	*Pavement Structural Number (SN)* 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176

Table 19.3b Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles, and p_t of 2.5

Axle Load (kips)	*Pavement Structural Number (SN)* 1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470

$$Truck\ factor(T_f) = = \frac{\sum(1\times0.189+2\times0.495)}{1} = 1.179\ per\ vehicle$$

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Vehicle Category, FHWA Classification	Class	Gross Weight	Axles loads and types (kips)										load equivalency factor axle					Tf (/ vehicle)
			Axle 1		Axle 2		Axle 3		Axle 4		Axle 5		Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	
			Type	Load	Type	Load	Type	Load	Type	Load	Type	Load	Load	Load	Load	Load	Load	
Passenger Cars and small trucks		4000	S	2000	S	2000							0.002	0.002				0.004
2axle, 4tire vans motorhomes, etc		12000	S	6000	S	6000							0.010	0.010				0.02
2-axle 6 tire single units																		
3 axle single unit		32000	S	10000	D	22000							0.088	0.180				0.264
4 axle single unit																		
4-or-less-axle multi unit																		
5 axle multi unit																		
6-or-more-axle double unit																		
5-axle or less, multi-unit																		
6-axle, multi-unit																		
7-or-more-axle, multi-unit																		

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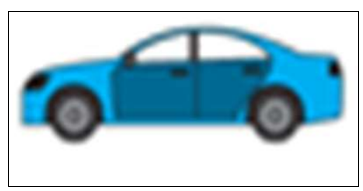
Traffic for pavement design

Why only truck traffic is important



$Truck\ factor(T_f) = \ 1.179\ per\ vehicle$

$Truck\ factor(T_f) = = 0.004\ per\ vehicle$

$$Damage\ from\ 1\ vehicle = \frac{1.179}{vehicle} \times 1\ vehicle = \mathbf{1.179}$$

$$Damage\ from\ 295\ vehicle = \frac{0.004}{vehicle} \times 295\ vehicle\ = \mathbf{1.179}$$

Therefore, we ignore the effects of passenger cars within pavement design

And specified maximum gross weight for trucks

83

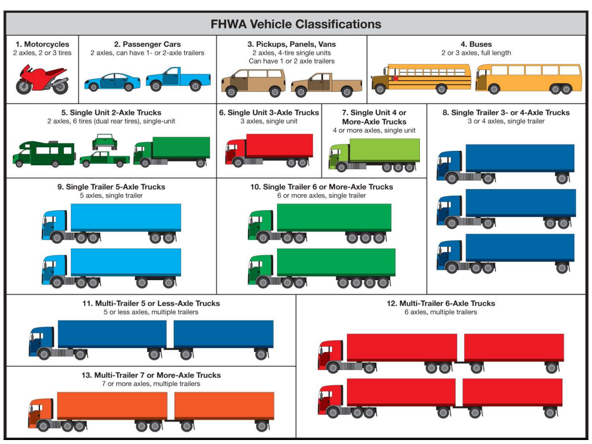
Specified Maximum Gross Weight For Trucks

نظام رقم (٣٠) لسنة ٢٠١٦
نظام الابعاد القصوى والاوزان الاجمالية وقوة المحرك للمركبات
صادر بمقتضى الفقرة (ب) من المادة (٥٢) من قانون السير رقم (٤٩)
لسنة٢٠٠٨

المادة ٤ـ تكون الأوزان الاجمالية للمركبات كما يلي:-

فئة المركبة	الوزن الاجمالى بالطن
سيارة شحن بمحورين	٢١
قاطرة بمحورين ومقطورة بمحورين	٣٨
قاطرة بمحورين ومقطورة بثلاثة محاور	٤٤
سيارة شحن بثلاثة محاور	٢٧
قاطرة بثلاثة محاور ومقطورة بمحورين	٤٥
قاطرة بثلاثة محاور ومقطورة بثلاثة محاور	٥١
سيارة شحن باربعة محاور	٣٢
قاطرة باربعة محاور ومقطورة بمحورين	٥٠

Truck Factors (ESALs/Truck) by FHWA Vehicle Classification



https://www.penndot.pa.gov/ProjectAndPrograms/PostedBondedRoadway/Documents/ESAL-BASED%20COSTS.pdf

TABLE 7.1 Average Initial Truck Factors (ESALs/Truck) by Vehicle Class

VEHICLE CLASSIFICATION			ESAL's	
Line # in DARWin® 3.01	FHWA Class	Corresponding Department Description	Rigid	Flexible
1	1	Motorcycle	0*	0*
2	2	Passenger Cars	0*	0*
3	3	SUV/Pick-up	0*	0*
4	4	BUS Factor	0.24	0.24
5	5	2-axle, 6-tire	0.24	0.24
6	6	3-axle, single unit	1.15	0.82
7	7	4-axle, single unit	7.00	4.50
8	8	3-axle, single trailer	0.60	0.44
9	9	3-axle, multiple axle trailer	1.59	1.00
10	10	6-axle, single trailer	1.42	0.75
11	11	5-axle, multiple trailer	2.40	2.33
12	12	6-axle, multiple trailer	1.42	1.28
13	13	7-axle, multiple trailer	1.42	1.28

*Note: Because motorcycles, passenger cars, and SUV/Pick-up trucks do not significantly contribute to the 18-kip ESALs they are considered negligible and an ESAL/truck factor of 0 is assigned. However, the percent of the ADT in this class must be input into DARWin because the Total Percentage must equal 100.00%. If there are any vehicles that are not large enough to be classified in any of the above classes, they should be grouped with the motorcycle percentage.

Cumulative ESALS determinations

Inputs

86

86

Cumulative ESALS determinations

inputs

- $ESAL_i$: ESAL for axle category i
- $AADT_i$: First year annual average daily traffic for axle category i.
- (T): The percentage of trucks in the ADT
- (G_{jt}): Growth rate factor for a given growth rate j and design period t.
- (F_d) = Design lane factor
- (FE_i): load equivalency factor for axle category
- (T_f): Truck factor

87

87

Cumulative ESALS determinations

Inputs

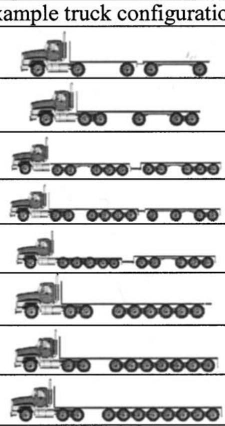
axle category (i)

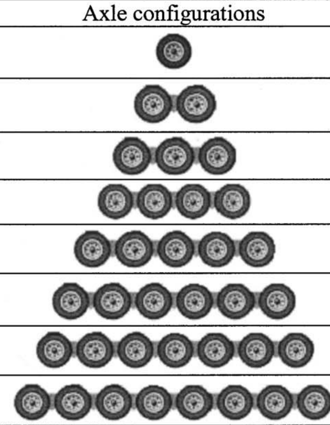
88

88

axle category (i)

Axle/truck	Example truck configurations	Axle configurations
Single		
Tandem		
Tridem		
Quad		
Five		
Six		
Seven		
Eight		





89

89

Cumulative ESALS determinations

Inputs

$AADT_i$ (i = for each axle category)

90

90

Average Annual Daily Traffic (AADT)

$AADT_i$ (i = for each axle category)

$$AADT = \frac{total\ traffic\ volume\ for\ 1\ year}{365\ days} \quad (4)$$

- AADT Defined as

➢ *The average number of vehicles passing a specific point on a road, calculated of 24-hour count day of the year.*

- Estimate the number of vehicles of different types (Passenger cars, single unit trucks, multi unit trucks of various sizes) expected to use the pavement over the design period.

➢ *Example Calculation:*

  ➢ Annual traffic = 5,475,000 vehicles/year
  ➢ Days = 365
  ➢ AADT = 5,475,000 / 365 = 15,000 vehicles/day

- $AADT_i$:

➢ *First year annual average daily traffic for axle category i.*

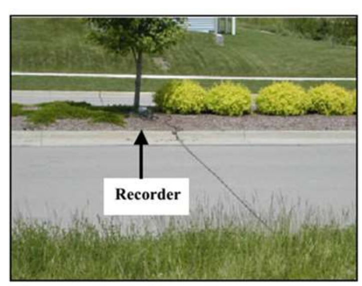


Figure 3.5. Pneumatic Road Tube and Recorder

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Cumulative ESALS determinations

Inputs

(T): The percentage of trucks in the AADT

92

92

(T): The percentage of trucks in the AADT

- Represents the proportion of truck traffic in the total vehicle count.
- A critical input for estimating the impact of heavy vehicles on pavement damage.

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Example Calculation of (T)

- Given Data:
  - ADT = 20,000 vehicles/day
  - Truck Count = 4,000 vehicles/day

- Solution:
  - T = (Truck Count / ADT) × 100
  - T = (4,000 / 20,000) × 100 = 20%
- Interpretation:
  - 20% of the total traffic is truck traffic.

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(T): The percentage of trucks in the AADT

If actual traffic data are not available,

Table 6 .9 can be used as a guide to determine the distribution of ADTT on different classes of highways in the United States .

TABLE 6.9 Distribution of Trucks on Different Classes of Highways in the United States[a]

Truck class	Percent trucks: Rural systems: Interstate	Rural: Other Principal	Rural: Minor Arterial	Rural: Collectors Major	Rural: Collectors Minor	Rural: Range	Urban systems: Interstate	Urban: Other Freeways	Urban: Other Principal	Urban: Minor Arterial	Urban: Collectors	Urban: Range
Single-unit trucks												
2-axle, 4 tire	43	60	71	73	80	43–80	52	66	67	84	86	52–86
2-axle, 6-tire	8	10	11	10	10	8–11	12	12	15	9	11	9–15
3-axle or more	2	3	4	4	2	2–4	2	4	3	2	<1	<1–4
All single units	53	73	86	87	92	53–92	66	82	85	95	97	66–97
Multiple-unit trucks												
4-axle or less	5	3	3	2	2	2–5	5	5	3	2	1	1–5
5-axle[b]	41	23	11	10	6	6–41	28	13	12	3	2	2–28
6-axle or more[b]	1	1	<1	1	<1	<1–1	1	<1	<1	<1	<1	<1–1
All multiple units	47	27	14	13	8	8–47	34	18	15	5	3	3–34
All trucks	100	100	100	100	100		100	100	100	100	100	

[a] Compiled from data supplied by the Highway Statistics Division, U.S. Federal Highway Administration.
[b] Including full-trailer combinations in some states.
Source. After AI (1991).

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Cumulative ESALS determinations

Inputs

(G_{jt}): Growth rate factor for a given growth rate j and design period t.

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Traffic Growth Factor (Gjt)

- The traffic to be used for design is the average traffic during the design period, so the initial traffic must be multiplied by a growth factor
- Traffic Growth Factor (Gjt)
  - It is a multiplier that accounts for the expected increase in traffic over the pavement design life
  - Reflects annual growth rates for traffic volume, particularly for trucks.
- Gjt: Growth rate factor for a given growth rate j and design period t.

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Traffic Growth Factor (Gjt)

Formula for Traffic Growth Factor

- The AASHTO design guide recommend the use of traffic over the entire design period
- To determine the total growth factor

➢ $(G_{jt}) = \dfrac{(1+j)^t - 1}{t}$

  - ➢ j is the annual growth rate
  - ➢ t is the design period (Usually 20 years)

Table 19.4 Growth Factors

Design Period, Years (n)	No Growth	*Annual Growth Rate, Percent (r)* 2	4	5	6	7	8	10
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

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Growth factor

Example

- For an annual growth rate of **4.0%** and a design period of **20 years**, compute the growth factors

Table 19.4 Growth Factors

Design Period, Years (n)	No Growth	*Annual Growth Rate, Percent (r)* 2	4	5	6	7	8	10
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	$\boxed{29.78}$	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

99

Cumulative ESALS determinations

Inputs

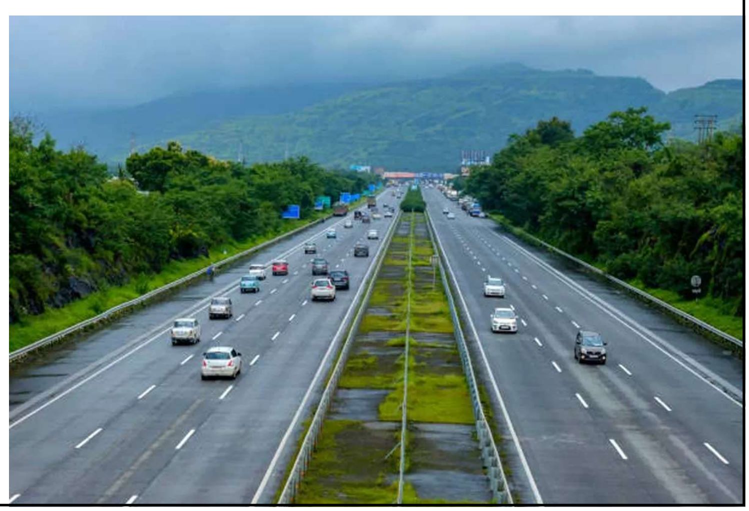
Design lane factor (F_d)

100

100

Design lane factor (Fd)

- The initial daily traffic is in two directions over all traffic lanes
- Design lane Factors:
  - *Adjustments made to traffic data to account for the uneven distribution of traffic:*
    - Between opposing directions of travel (**Directional Factor**).
    - Across multiple lanes in the same direction (**Lane Factor**).
- Why is it Needed?
  - *Accurate Load Distribution:*
  - *Cost-Efficient Design:*
    - Avoids overdesigning lanes that carry less traffic.



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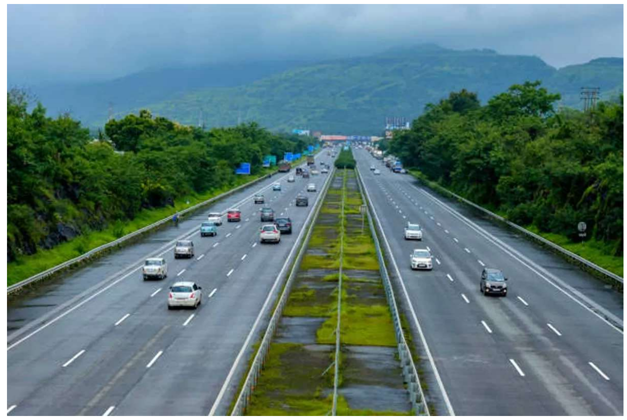
Design lane factor **(F_d)**

Why is it Needed?

- **Accurate Load Distribution:**
  - *Helps engineers focus on the* ***critical lane*** *with the heaviest traffic and load concentration.*
- **Cost-Efficient Design:**
  - *Avoids overdesigning lanes that carry less traffic.*



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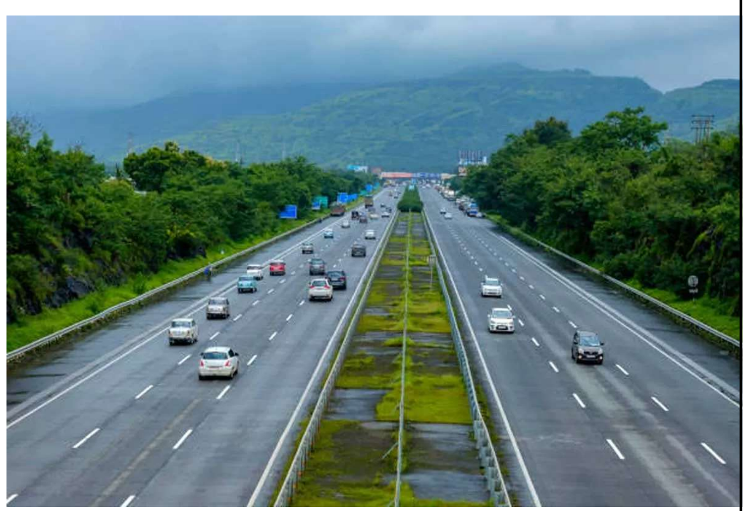
Design lane factor (Fd)

- The design lane adjustments is performed
  - Between opposing directions of travel (Directional Factor).
  - Across multiple lanes in the same direction (Lane Factor).
- Fd = D x L
  - *(D): D is the directional distribution factor*
  - *(L): L is the lane distribution factor*



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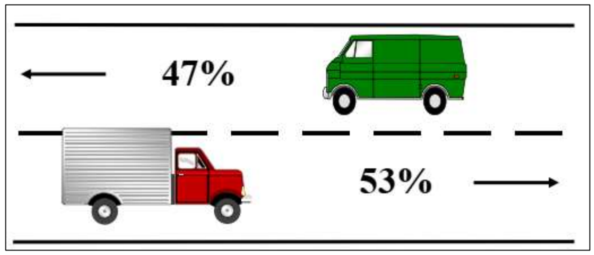
Directional Distribution Factor (D)

Traffic Distribution

- D represent percentage of trucks traffic traveling in one direction
- D usually assumed to be 0.5 unless the traffic in two directions is different



Design for worst case!!

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Lane Distribution Factor (L)

- Design lane:
  - *Lane expected to receive the severe service*
- For two-lane highways,
  - *The lane in each direction is the design lane, so the lane distribution factor is 100%*
- For multilane highways,
  - *The design lane is the outside lane*

TABLE 6.16 Lane Distribution Factor

No. of lanes in each direction	Percentage of 18-kip ESAL in design lane
1	100
2	80–100
3	60–80
4	50–75

Source. After AASHTO (1986).

Design for worst case!!

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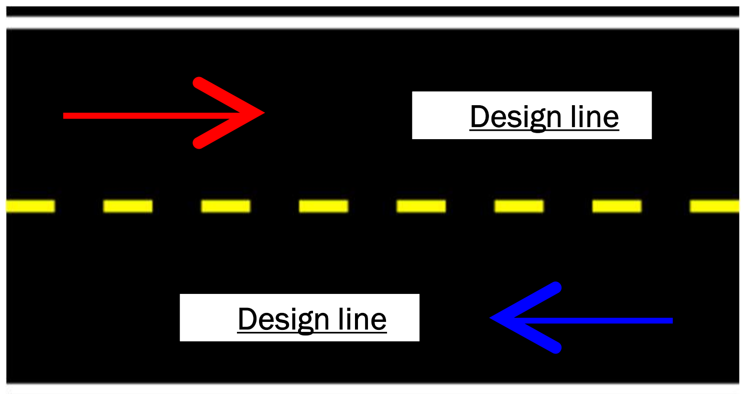
Lane Distribution Factor (L)

For two-lane highways,

- The lane in each direction is the design lane, so the lane distribution factor is 100%
- Design lane:
  - *Lane expected to receive the severe service*



https://english.stackexchange.com/questions/270607/what-is-meant-by-a-two-lane-road

Lane Distribution Factor (L)

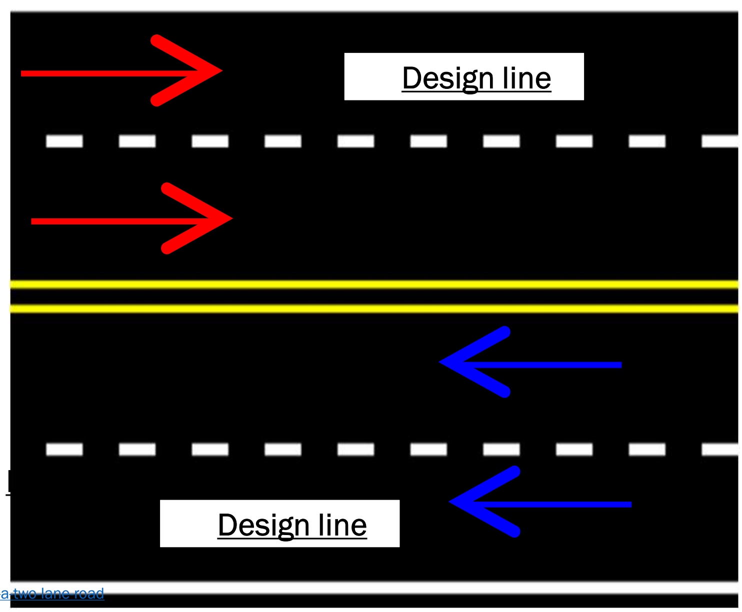
For Multilane highways,

- Design lane:
  - Lane expected to receive the severe service
  - The design lane is the outside lane

TABLE 6.16 Lane Distribution Factor

No. of lanes in each direction	Percentage of 18-kip ESAL in design lane
1	100
2	80–100
3	60–80
4	50–75

Source. After AASHTO (1986).



https://english.stackexchange.com/questions/270607/what-is-meant-by-a-two-lane-road

Example Calculation

- Given Data:
  - *Total AADT = 20,000 vehicles/day*
  - *Directional Factor (D) = 60%*
  - *Lane Factor (L) = 80%*

- Solution:
  - *Traffic in Design Direction = AADT × D = 20,000 × 0.60 = 12,000 vehicles/day*
  - *Traffic in Design Lane = Traffic in Design Direction × L = 12,000 × 0.80 = 9,600 vehicles/day*
- Interpretation:
  - The design lane carries 9,600 vehicles/day.

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Cumulative ESALS determinations

Process

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Equivalent Single Axle Loads (ESALs) for category i

*If the axle weight is **known***

■ $ESAL_i = (AADT)_0\ (T)\ (G_{rn})\ (F_d)\ (365)\ (N_i)\ (F_{Ei})$

- ➢ *$ESAL_i$: ESAL for axle category i*
- ➢ *$AADT_i$: First year annual average daily traffic for axle category i.*
- ➢ *(T): the percentage of trucks in the ADT*
- ➢ *(G_{jt}): growth rate factor for a given growth rate j and design period t.*
- ➢ *(F_d) = Design lane factor*
- ➢ *(N_i) = number of axles on each vehicle in category i*
- ➢ *(F_{Ei}) = load equivalency factor for axle category i*

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Equivalent Single Axle Loads (ESALs) for category i

*If the axle weight is **unknown** (Using truck factors)*

■ $ESAL_i = (AADT)_0\ (T)\ (G_{rn})\ (F_d)\ (365)\ (T_f)$

- ➢ *$ESAL_i$: ESAL for axle category i*
- ➢ *$AADT_i$: First year annual average daily traffic for axle category i.*
- ➢ *(T): the percentage of trucks in the ADT*
- ➢ *(G_{jt}): growth rate factor for a given growth rate j and design period t.*
- ➢ *(F_d) = Design lane factor*
- ➢ *(T_f): Truck factor*

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Total ESAL Calculation for mixed traffic

- ESAL = $\sum_{i=1}^{i=n} ESAL_i$
  - *ESAL : ESAL for **all vehicles** during the design period.*
  - *$ESAL_i$: ESAL for axle category i*
  - *n= number of truck categories*

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Total ESAL Calculation for mixed traffic

Vehicle Category, FHWA Classification	ESAL for Vehicle Category						
	AADT	T	G_{rn}	F_d	T_f (/ vehicle)		ESAL
Passenger Cars and small trucks						365	
2axle, 4tire vans motorhomes, etc							
2-axle 6 tire single units							
3 axle single unit							
4 axle single unit							
4-or-less-axle multi unit							
5 axle multi unit							
6-or-more-axle double unit							
5-axle or less, multi-unit							
6-axle, multi-unit							
7-or-more-axle, multi-unit							
Total ESAL							0.00E+00

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Cumulative ESALS determinations

Example 1

Example

- An eight-lane divided highway is to be constructed on a new alignment. Traffic volume forecasts indicate that the average annual daily traffic (AADT) in both directions during the first year of operation will be 12,000 with the following vehicle mix and axle loads
  - Passenger cars (1000 lb/axle) = 50% 
  - 2-axle single-unit trucks (6000 lb/axle) = 33% 
  - 3-axle single-unit trucks (6000 lb/axle) = 17% 
- The vehicle mix is expected to remain the same throughout the design life of the pavement. If the expected annual traffic growth rate is 4% for all vehicles, determine the design ESAL, given a design period of 20 years. The percent of traffic on the design lane is 45%, and the pavement has a terminal serviceability index (pt) of 2.5 and SN of 5

Step-1

- If the expected annual traffic growth rate is 4% for all vehicles, determine the design ESAL, given a design period of 20 years
- (G_{rn}) = 29.78

Table 19.4 Growth Factors

Design Period, Years (n)	No Growth	2	4	5	6	7	8	10
		Annual Growth Rate, Percent (r)						
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	$\boxed{29.78}$	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

Step-2

Determine design lane factor (F_d)

- The percent of traffic on the design lane is 45%,
  - *Thus, the design lane factor (F_d) = 45%*

Step-2

Determine the percentage of trucks in the ADT (T)

- Passenger cars (1000 lb/axle) = 50%

- 2-axle single-unit trucks (6000 lb/axle) = 33%

- 3-axle single-unit trucks (6000 lb/axle) = 17%

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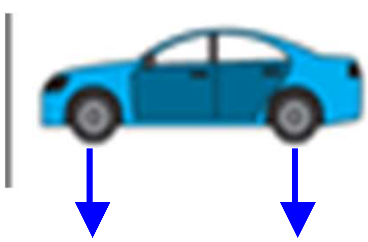
Example

Passenger cars (2000 lb/axle)

Assume SN = 5 and Pt = 2.5



2000 ib

2000 ib

LEF for single axle = 0.002

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98

$$Truck\ factor\ (T_f) = \frac{\sum(Number\ of\ axles \times LEFs\ for\ each\ axle)}{Number\ of\ vehicles} = \frac{\sum(2\times 0.002)}{1} = 0.004\ per\ vehicle$$

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Example

Assume SN = 5 and Pt = 2.5

2-axle single-unit trucks (6000 lb/axle)

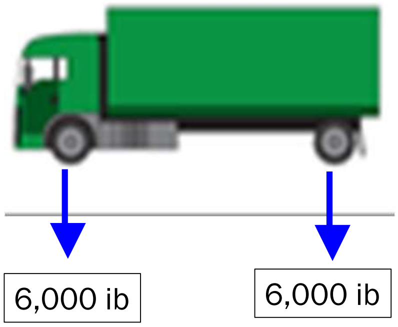

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

	Pavement Structural Number (SN)					
Axle Load (kips)	*1*	*2*	*3*	*4*	*5*	*6*
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606

$$Truck\ factor(T_f) = \frac{\sum(Number\ of\ axles \times LEFs\ for\ each\ axle)}{Number\ of\ vehicle} = \frac{\sum(2\times0.01)}{1} = 0.02\ per\ vehicle$$

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Example

3-axle single-unit trucks (10,000 lb/axle)

Assume SN = 5 and Pt = 2.5

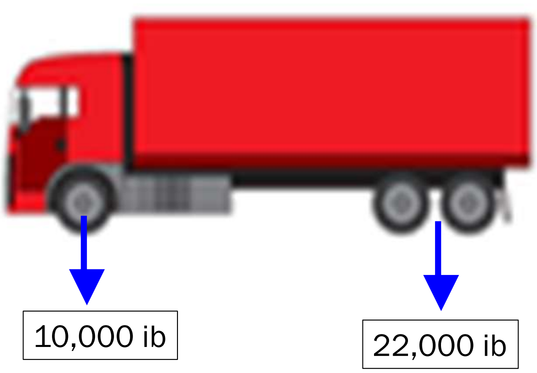

Table 19.3a Axle Load Equivalency Factors for Flexible Pavements, Single Axles, and p_t of 2.5

	Pavement Structural Number (SN)					
Axle Load (kips)	*1*	*2*	*3*	*4*	*5*	*6*
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080

Table 19.3b Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles, and p_t of 2.5

	Pavement Structural Number (SN)					
Axle Load (kips)	*1*	*2*	*3*	*4*	*5*	*6*
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470

$$Truck\ factor(T_f) = = \frac{\sum(1\times0.088+\ \ *0.18)}{1} = 0.264\ per\ vehicle$$

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Solution

Total ESAL Calculation for mixed traffic

- ESAL = $\sum_{i=1}^{i=3} ESAL_i$
- ESAL= $ESAL_{Passenger} + ESAL_{2\text{-axle single-unit trucks}} + ESAL_{3\text{-axle single-unit trucks}}$
- ESAL= 0 $+ ESAL_{2\text{-axle single-unit trucks}} + ESAL_{3\text{-axle single-unit trucks}}$

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Equivalent Single Axle Loads (ESALs) for category i

For 2-axle single-unit trucks (6000 lb/axle)

- $ESAL_{2\text{-axle single-unit trucks}} = (AADT)_0\ (T)\ (G_{rn})\ (F_d)\ (365)\ (T_f)$
- $ESAL_{2\text{-axle single-unit trucks}} = (12{,}000)_0\ (33\%)\ (29.78)\ (45\%)\ (365)\ (0.02) =$
- $ESAL_{2\text{-axle single-unit trucks}} = 0.3874 \times 10^6$
-

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Equivalent Single Axle Loads (ESALs) for category i

For 3-axle single-unit trucks (6000 lb/axle)

- $ESAL_{3\text{-axle single-unit trucks}} = (AADT)_0\ (T)\ (G_{rn})\ (F_d)\ (365)\ (T_f)$
- $ESAL_{3\text{-axle single-unit trucks}} = (12{,}000)_0\ (17\%)\ (29.78)\ (45\%)\ (365)\ (0.264) =$
- $ESAL_{3\text{-axle single-unit trucks}} = 2.6343 \times 10^6$
-

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Solution

Total ESAL Calculation for mixed traffic

Vehicle Category, FHWA Classification	ESAL for Vehicle Category						
	AADT	T	G_{rn}	F_d	T_f (/ vehicle)		ESAL
Passenger Cars and small trucks	12,000	50%	29.78	45%	0.004		1.17E+05
2axle, 4tire vans motorhomes, etc	12,000	33%	29.78	45%	0.02		3.87E+05
2-axle 6 tire single units							0.00E+00
3 axle single unit	12,000	17%	29.78	45%	0.264		2.63E+06
4 axle single unit							0.00E+00
4-or-less-axle multi unit						365	0.00E+00
5 axle multi unit							0.00E+00
6-or-more-axle double unit							0.00E+00
5-axle or less, multi-unit							0.00E+00
6-axle, multi-unit							0.00E+00
7-or-more-axle, multi-unit							0.00E+00
Total ESAL							3.14E+06

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and regulations

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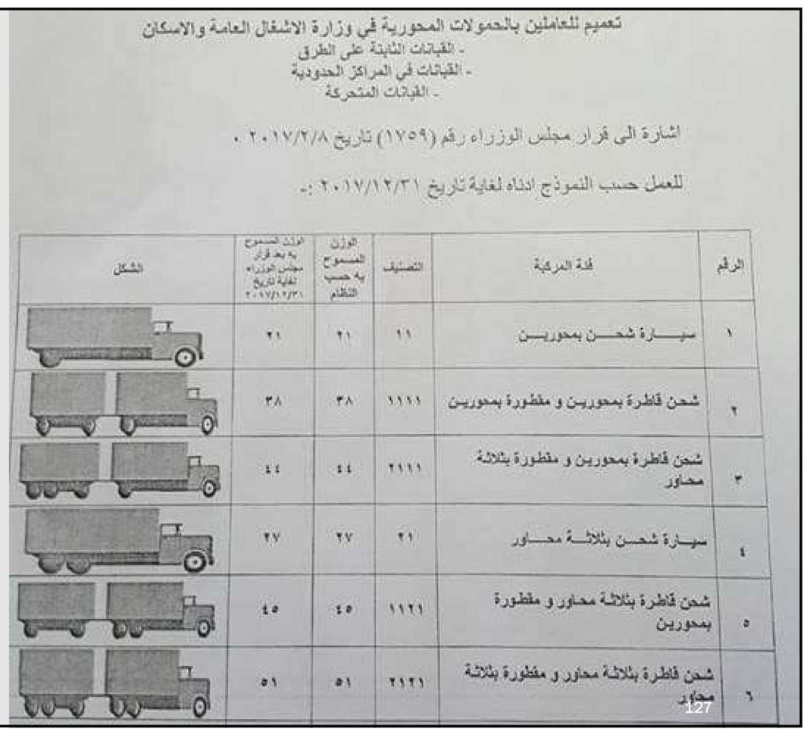

تعميم للعاملين بالحمولات المحورية في وزارة الاشغال العامة والاسكان

- القبانات الثابتة على الطرق
- القبانات في المراكز الحدودية
- القبانات المتحركة

اشارة الى قرار مجلس الوزراء رقم (١٧٥٩) تاريخ ٢٠١٧/٢/٨ .

للعمل حسب النموذج اداه لغاية تاريخ ٢٠١٧/١٢/٣١ :-

الرقم	فئة المركبة	التصنيف	الوزن المسموح به حسب النظام	الوزن المسموح به بعد قرار مجلس الوزراء لغاية تاريخ ٢٠١٧/١٢/٣١	الشكل
١	سيارة شحن بمحورين	١١	٢١	٢١	
٢	شحن قاطرة بمحورين و مقطورة بمحورين	١١١١	٣٨	٣٨	
٣	شحن قاطرة بمحورين و مقطورة بثلاثة محاور	٢١١١	٤٤	٤٤	
٤	سيارة شحن بثلاثة محاور	٢١	٢٧	٢٧	
٥	شحن قاطرة بثلاثة محاور و مقطورة بمحورين	١١٢١	٤٥	٤٥	
٦	شحن قاطرة بثلاثة محاور و مقطورة بثلاثة محاور	٢١٢١	٥١	٥١	

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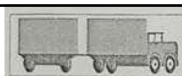
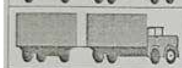
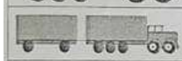
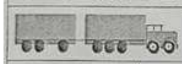
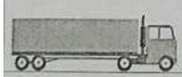
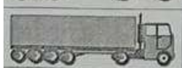
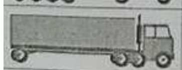
٨	شحن قاطرة باربعة محاور و مقطورة بمحورين محاور (المحاور الأمامية مزدوجة وقابلة للتوجيه)	١١٢٢	٥٠	٥٠	
٩	شحن قاطرة باربعة محاور و مقطورة بثلاثة محاور	٢١٢٢	٥٦	٥٦	
١٠	سيارة شحن بخمسة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيه)	٣٢	٣٦	٣٩	
١١	شحن قاطرة بخمسة محاور ومقطورة بمحورين (المحاور الأمامية مزدوجة وقابلة للتوجيه)	١١٣٢	٥٤	٥٧	
١٢	شحن قاطرة بخمسة محاور ومقطورة بثلاثة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيه)	٢١٣٢	٦٠	٦٣	
١٣	رأس قاطرة بمحورين ونصف مقطورة بمحور واحد	١١١	٣٣	٣٣	
١٤	رأس قاطرة بمحورين ونصف مقطورة بمحورين	٢١١	٤٠	٤٠	
١٥	رأس قاطرة بمحورين ونصف مقطورة بثلاثة محورين أو شاحنة كاملة قطعة واحدة	٣١١	٤٤	٤٨	
١٦	رأس قاطـرة بمحورين ونصف مقطورة باربعة محاور	٤١١	٤٨	٥٣	
١٧	رأس قاطرة بثلاثة محاور ونصف مقطورة بمحور واحد	١٢١	٤٠	٤٠	
١٨	رأس قاطرة بثلاثة محاور ونصف مقطورة بمحورين	٢٢١	٤٧	٥١	

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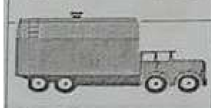
الرقم	فئة المركبة	التصنيف	الوزن المسموح به حسب النظام	الوزن المسموح به بعد قرار مجلس الوزراء لغاية تاريخ ٢٠١٧/١٢/٣١	الشكل
٢٥	سيارة شحن باربعة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيهوذات مسافة محورية أقل من ٢م)خلاطة - وجود نظام مكابح ABS/EBS على جميع المحاور	٢٢	٣٦	٣٦	
٢٦	سيارة شحن باربعة محاور (المحاور الامامية مزدوجة وقابلة للتوجيهوذات مسافة محورية أكثر من ٢م)خلاطة - وجود نظام مكابح ABS/EBS على جميع المحاور	٢٢	٣٨	٣٨	
٢٧	سيارة شحن باربعة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيهوذات مسافة محورية أقل من ٢م)سطحه بونش - وجود نظام مكابح ABS/EBS على جميع المحاور	٢٢	٣٦	٣٦	
٢٨	سيارة شحن باربعة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيهوذات مسافة محورية أكثر من ٢م)سطحه بونش - وجود نظام مكابح ABS/EBS على جميع المحاور	٢٢	٣٨	٣٨	
٢٩	سيارة شحن باربعة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيهوذات مسافة محورية أقل من ٢م)صهريج - وجود نظام مكابح ABS/EBS على جميع المحاور	٢٢	٣٦	٣٦	
٣٠	سيارة شحن باربعة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيهوذات مسافة محورية أكثر من ٢م)صهريج - وجود نظام مكابح ABS/EBS على جميع المحاور	٢٢	٣٨	٣٨	

محور عادي   محور توجيه   محور تعليق هوائي

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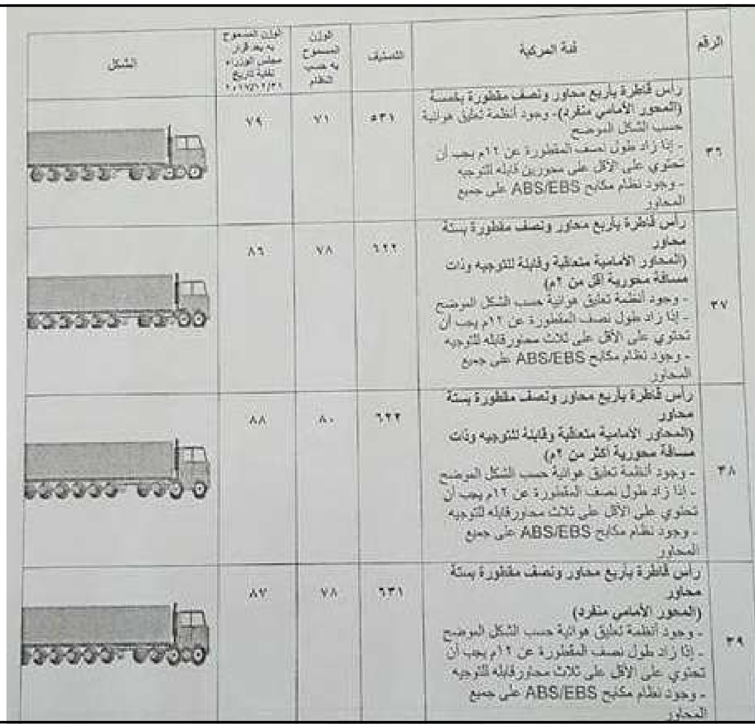

الشكل	الوزن المسموح به بعد قرار مجلس الوزراء لغاية تاريخ ٢٠١٧/٦/٣١	الوزن المسموح به حسب النظام	التصنيف	فئة المركبة	الرقم
	٧٩	٧١	٥٣١	رأس قاطرة بأربع محاور ونصف مقطورة بخمسة (المحور الأمامي منفرد)- وجود أنظمة تعليق هوائية حسب الشكل الموضح - إذا زاد طول نصف المقطورة عن ١٢م يجب أن تحتوي على الأقل على محورين قابلة للتوجيه - وجود نظام مكابح ABS/EBS على جميع المحاور	٣٦
	٨٦	٧٨	٦٢٢	رأس قاطرة بأربع محاور ونصف مقطورة بستة محاور (المحاور الأمامية متعاقبة وقابلة للتوجيه وذات مسافة محورية أقل من ٢م) - وجود أنظمة تعليق هوائية حسب الشكل الموضح - إذا زاد طول نصف المقطورة عن ١٢م يجب أن تحتوي على الأقل على ثلاث محور قابله للتوجيه - وجود نظام مكابح ABS/EBS على جميع المحاور	٣٧
	٨٨	٨٠	٦٢٢	رأس قاطرة بأربع محاور ونصف مقطورة بستة محاور (المحاور الأمامية متعاقبة وقابلة للتوجيه وذات مسافة محورية أكثر من ٢م) - وجود أنظمة تعليق هوائية حسب الشكل الموضح - إذا زاد طول نصف المقطورة عن ١٢م يجب أن تحتوي على الأقل على ثلاث محاور قابله للتوجيه - وجود نظام مكابح ABS/EBS على جميع المحاور	٣٨
	٨٧	٧٨	٦٣١	رأس قاطرة بأربع محاور ونصف مقطورة بستة محاور (المحور الأمامي منفرد) - وجود أنظمة تعليق هوائية حسب الشكل الموضح - إذا زاد طول نصف المقطورة عن ١٢م يجب أن تحتوي على الأقل على ثلاث محاور قابله للتوجيه - وجود نظام مكابح ABS/EBS على جميع المحاور	٣٩

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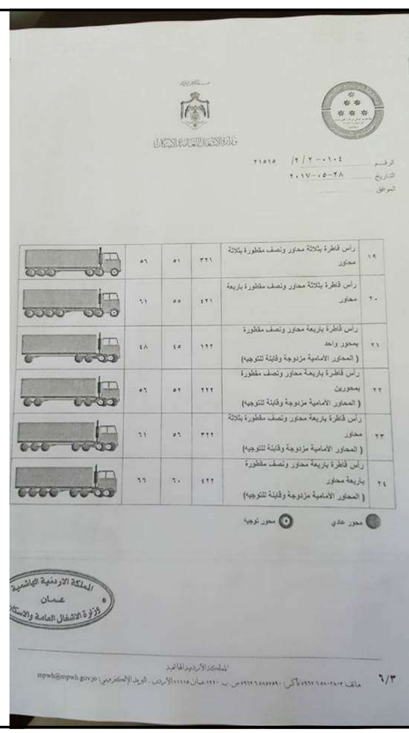

وزارة الأشغال العامة والإسكان

الرقم ٢/٢/٢-٠١٠٤ ٢١٥١٥
التاريخ ٢٠١٧-٠٥-٢٨
الموافق

	٥٦	٥١	٣٢١	رأس قاطرة بثلاثة محاور ونصف مقطورة بثلاثة محاور	١٩
	٦١	٥٥	٤٢١	رأس قاطرة بثلاثة محاور ونصف مقطورة بأربعة محاور	٢٠
	٤٨	٤٥	١٢٢	رأس قاطرة بأربعة محاور ونصف مقطورة بمحور واحد (المحاور الأمامية مزدوجة وقابلة للتوجيه)	٢١
	٥٦	٥٢	٢٢٢	رأس قاطرة بأربعة محاور ونصف مقطورة بمحورين (المحاور الأمامية مزدوجة وقابلة للتوجيه)	٢٢
	٦١	٥٦	٣٢٢	رأس قاطرة بأربعة محاور ونصف مقطورة بثلاثة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيه)	٢٣
	٦٦	٦٠	٤٢٢	رأس قاطرة بأربعة محاور ونصف مقطورة بأربعة محاور (المحاور الأمامية مزدوجة وقابلة للتوجيه)	٢٤

محور عادي   محور توجيه

المملكة الأردنية الهاشمية
عمان
وزارة الأشغال العامة والإسكان

المملكة الأردنية الهاشمية
هاتف ... فاكس ... ص.ب ١٢٢٠ عمان ١١١١٨ الأردن . البريد الإلكتروني: mpwh@mpwh.gov.jo   ٦/٣

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المـادة ١ ـ يسمى هذا النظـام (نظـام الابعـاد القصوى والاوزان الاجماليـة وقـوة المحـرك للمركبـات لسـنة ٢٠١٦) ويعمـل بـه مـن تـاريخ نشـره فـي الجريدة الرسمية.

المـادة ٢ ـ تكون الابعـاد القصـوى للمركبـات بمـا فـي ذلـك بـروز الحمولـة علـى النحو التالي :-

أ -العرض الاجمالي ٢٦٠ سنتيمترا

ب- الارتفاع الاجمالي ٤٢٠ سنتيمترا

ج- الطول الاجمالي كما يلي :-

فئة المركبة	سنتيمتر	متر
١.سيارة شحن ذات محورين او اكثر	-	١٢
٢. رأس قاطر مع نصف مقطورة	٥٠	١٦
٣. نصف المقطورة	٦٥	١٣
٤. سيارة شحن قاطرة مع مقطورة	٣٥	١٨
٥. المقطورة	٥٠	٨
٦. حافلة ذات محورين أو اكثر	-	١٢
٧. حافلة مفصلية	-	١٨
٨.رأس قاطرة مع نصف مقطورة باربعة محاور او اكثر	٥٠	٢٢
٩. نصف مقطورة باربعة محاور او اكثر	-	١٨
١٠. اذا كانت الشاحنة بتصميم تقليدي (المحرك امـام الكابينـة) يـزاد علـى الطول الاجمالي ما مقدراه (١,١) م		

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المـادة٣ـ تكون الاحمـال المحوريـة علـى كـل محـور مـن محـاور المركبـة كمـا يلـــي :-

أ ـ محاور قابلة للتوجيه :-

١ـ محور منفرد ٧ اطنان

٢ـ محاور متعاقبة ٦ اطنان لكل محور

ب- محاور غير قابلة للتوجيه :-

١ـ محور منفرد ١٣ طنا

٢ـ محور مزدوج كما يلي :-

ـ اذا كانت المسـافة المحوريـة اقل من متـرين ١٠ اطنـان لكل محور

ـ اذا كانت المسـافة المحوريـة لا تقل عن متـرين ١٣ طنـا لكل محور

يعامل معاملة المحور المنفرد

٣ ـ المحور الثلاثي ٨ اطنان لكل محور

٤ـ المحور الرباعي ٧ اطنان لكل محور

ج -علـى الـرغم ممـا ورد فـي الفقـرة (ب) مـن هـذه المـادة تكـون الاحمال المحورية للمقطورة على النحو التالي :-

١ـ محور منفرد ٩ اطنان لكل محور

٢ ـ محور مزدوج ٧ر٥ طن لكل محور

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المادة ٤ - تكون الأوزان الاجمالية للمركبات كما يلي:-

فئة المركبة	الوزن الاجمالي بالطن
سيارة شحن بمحورين	٢١
قاطرة بمحورين ومقطورة بمحورين	٣٨
قاطرة بمحورين ومقطورة بثلاثة محاور	٤٤
سيارة شحن بثلاثة محاور	٢٧
قاطرة بثلاثة محاور ومقطورة بمحورين	٤٥
قاطرة بثلاثة محاور ومقطورة بثلاثة محاور	٥١
سيارة شحن باربعة محاور	٣٢
قاطرة باربعة محاور ومقطورة بمحورين	٥٠
قاطرة باربعة محاور ومقطورة بثلاثة محاور	٥٦
سيارة شحن بخمسة محاور	٣٦
قاطرة بخمسة محاور ومقطورة بمحورين	٥٤
قاطرة بخمسة محاور ومقطورة بثلاثة محاور	٦٠
رأس قاطر بمحورين ونصف مقطورة بمحور واحد	٣٣
رأس قاطر بمحورين ونصف مقطورة بمحورين	٤٠
رأس قاطر بمحورين ونصف مقطورة بثلاثة محاور	٤٤
رأس قاطر بمحورين ونصف مقطورة باربعة محاور	٤٨
رأس قاطر بثلاثة محاور ونصف مقطورة بمحور واحد	٤٠
رأس قاطر بثلاثة محاور ونصف مقطورة بمحورين	٤٧
رأس قاطر بثلاثة محاور ونصف مقطورة بثلاثة محاور	٥١
رأس قاطر بثلاثة محاور ونصف مقطورة باربعة محاور	٥٥
رأس قاطر باربعة محاور ونصف مقطورة بمحور واحد	٤٥
رأس قاطر باربعة محاور ونصف مقطورة بمحورين	٥٢
رأس قاطر باربعة محاور ونصف مقطورة بثلاثة محاور	٥٦
رأس قاطر باربعة محاور ونصف مقطورة باربعة محاور	٦٠

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ب- الحمولات المحورية :-

١-تكون الاحمال المحورية على كل محور من محاور المركبات الواردة في الفقرة (أ) من هذه المادة ذات الاربعة محاور او اكثر كالتالي :-

أ- محاور قابلة للتوجيه منفردة (٩) اطنان

ب- محاور قابلة للتوجيه متعاقبة :-

-(اذا كانت المسافة المحورية اقل من ٢ م) (٧,٥) طن لكل محور

-(اذا كانت المسافة المحورية اكثر من ٢ م) (٨,٥) طن لكل محور

ج- محاور غير قابلة للتوجيه منفردة (١٣) طنا

د-محاور غير قابلة للتوجيه مزدوجة :-

- (اذا كانت المسافة المحورية اقل من ٢ م) (١٠,٥) طن لكل محور

- (اذا كانت المسافة المحورية اكثر من ٢ م) (١٣) طنا لكل محور

هـ- محاور غير قابلة للتوجيه ثلاثية (٩) اطنان لكل محور

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