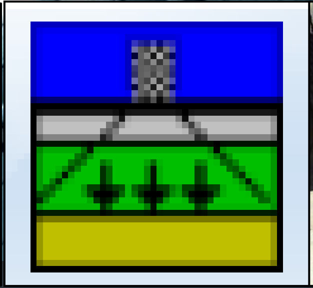



New Load Equivalency Equations Account for Steering Axle Tire Size

Allan Bradley (speaker) & Papa-Masseck Thiam

Vehicle Weights & Dimensions Task Force Meeting _ Dec. 1, 2020

B.C. 9-axle tridem-drive log B-train

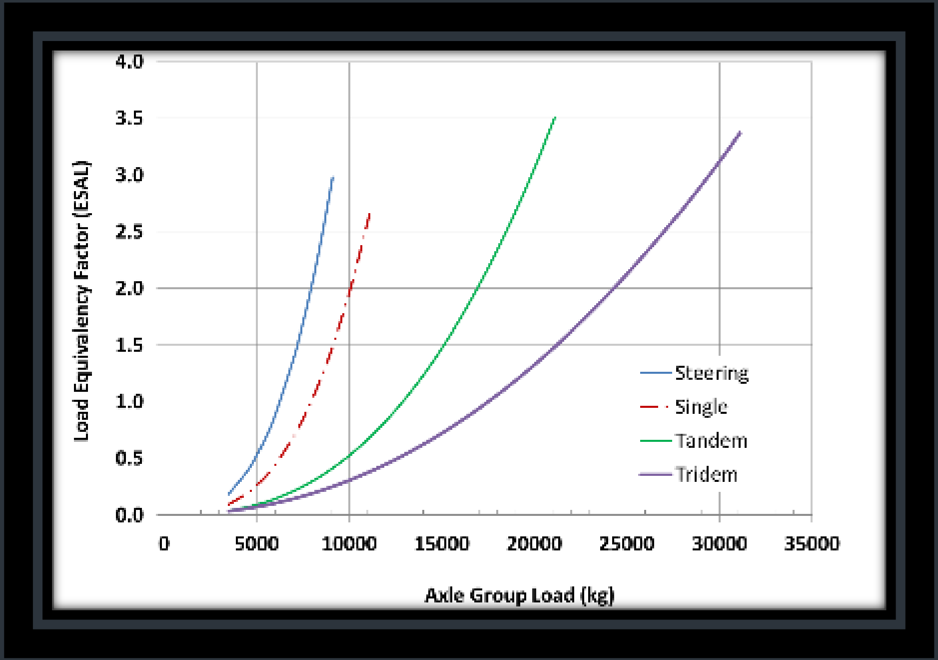
27.5 m long, 2.6 m-wide axles, 2.9 m-wide bunks

71.9 tonnes GVW (permit max), 50 tonne payload

PROBLEM STATEMENT

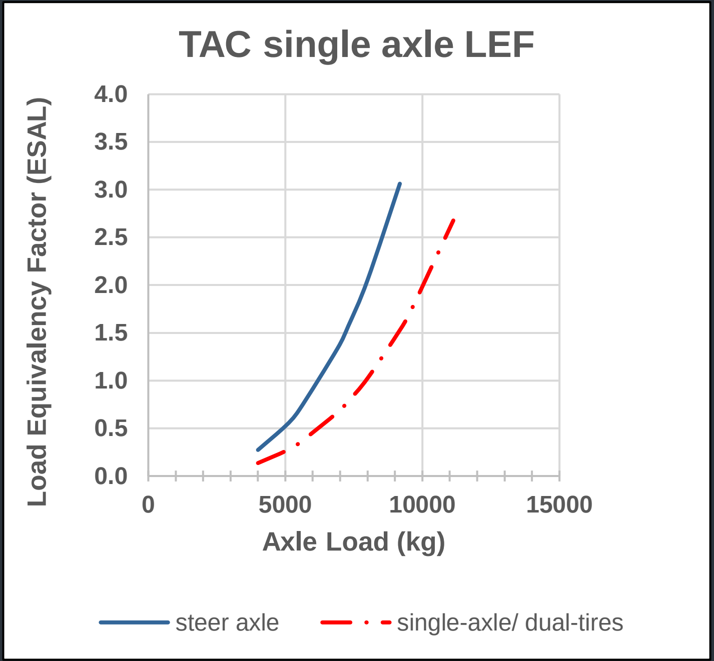
- Proposed new B.C. configurations must have ≥5% reduction in pavement impacts.
- TAC ESAL formulae don't account for tire size and over-estimate impacts from heavily loaded steering axles.
- Tridem-drive configurations are erroneously assessed and even may be unfairly rejected.
- 9-axle B-trains steer axle load was reduced to 6.9 t.
- Industry concerned that this impacts steerability, compliance, and productivity – *possibly without technical justification*.

RTAC-86 PAVEMENT IMPACT STUDY



- Most important Canadian pavement design study.
- $32M cost.
- 14 instrumented test pavements from across Canada, representing 5 main geologic/ geographic regions.
- Highway truck loadings.
- Load equivalency factors are basis of many Canadian highway policies.
- LEF relations for single-axle single tire “steering” axles & for single/tandem/tridem axles with dual tires

CRITIQUE OF RTAC-86



Only tire size : 11R22.5

Measured steer load: ≤ 5500 kg

(5500 kg steer axle = 0.69 ESALs)

Steer LEF = 2x single-axle/ dual-tire LEF

single-axle/ dual-tire LEF = $0.002418 \times \text{Load}^{2.9093}$

single-axle/ single-tire LEF = $0.004836 \times \text{Load}^{2.9093}$

BUILDING ON RTAC-86

Using LE modeling to extend RTAC-86 results to different tire sizes.

1. Contact areas for tire sizes and loads (100 psi)
2. Build LEM of 14 RTAC-86 pavements & apply static loads
3. Calculate strains at key locations in the pavements
4. Estimate passes to rutting and cracking failure (mode of fewest passes governs (P_{TL})) for each tire & load combo
5. ESAL = (P_{TL}) x 0.69 ESAL / $P_{11R22.5\ @\ 5500\ kg}$

T&RA

WinJULEA

AI

RTAC-86

Modeled: 8 North American steering tire sizes

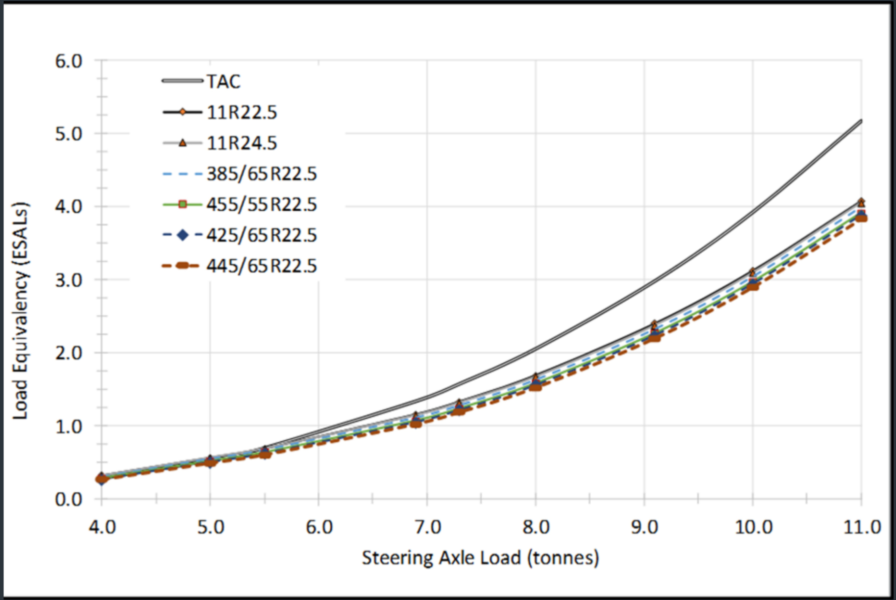
Tire size	Maximum axle load capacity (kg) *	Comment
295/60R22.5	5,430	Not popular for forestry
11R22.5	5,400	Typical on eastern Canadian log trucks and on-highway trucks
11R24.5	6,520	Typical on western Canadian log trucks
315/80R22.5	5,780	Not popular for forestry
WIDEBASE TIRE SIZES		
385/65R22.5	7,480	Common on tridem-drive log trucks
455/55R22.5	8,560	Not popular for forestry
425/65R22.5	8,880	Common on tridem-drive log trucks
445/65R22.5	9,640	Used on tridem-drive log hauling trucks

**Inflated to 690 kPa (100 psi) cold inflation*

Modeled: 14 RTAC-86 Highway Test Pavements

Test site	Province	14 provincial structures for RTAC study (1986)						
		AC		Base		Subbase		Subgrade
		Thickness (mm)	Description	Thickness (mm)	Description	Thickness (mm)	Description	Description
1	NB	225	HMA	76	Crushed rock	460	Crushed stone	Silty-Sand
2	NS	160	HMA	275	Granular	200	Granular	Gravelly Clay
3	Qc	135	HMA	200	Crushed limestone	625	Granitic sand	Granitic gravel
4	Qc	130	HMA	375	Crushed limestone	450	Granitic sand	Granitic gravel
5	Qc	56	HMA	150	Granitic Gneiss	450	Granitic sand	Clay
6	Qc	56	HMA	200	Granitic Gneiss	550	Granitic sand	Clay
7	ON	110	HMA	150	Granular A	350	Granular C	Silty-Sand
8	ON	170	HMA	200	Granular A	250	Granular B	Sand
9	ON	190	HMA	300	Granular A	90	Old road	Clay
10	AB	136	HMA	170	2-20 Gravel	-	-	Clay
11	AB	136	HMA	250	2-20 Gravel	-	-	Clay
12	BC	75	HMA	200	Granular	610	Granular crushed rock	Silty-Sand
13	BC	85	HMA	210	Granular	610	Silty gravel	Silty-Sand
14	BC	100	HMA	454	Granular	50	Mixed clay and sand	Clay

Steering axle ESALs by tire size and axle load



8 steering tire sizes
4 t < axle load < 11 t

TRENDS:

1) Higher load = Higher LEF
2) Larger tire footprint = Lower LEF
3) Higher load = Greater LEF spread
4) Higher load = Greater TAC error

Steering axle load equivalency equations

The **TAC LEF** equation for a single axle with single tires is:

$$\text{ESAL} = 0.004836 \times [\text{ axle load (t) }]^{2.9093}$$

The **AASHTO LEF** equation for any axle type or axle spacing is:

$$\text{ESAL} = [\, 0.01169 \times (\text{axle load (kN)}) + 0.064 \,]^{[\, 4 + 8.9/(\text{axle load (kN)} \,]}$$

Steering axle load equivalency equations

Tire size	Single-axle/single-tire ESAL equation	R^2	RMSE (ESAL)
295/60R22.5	$ESAL = 4.05-0.82(Load)+0.081(Load)^2-6.76/Load$	1.0000	0.003
11R22.5	$ESAL = 5.31-1.03(Load)+0.091(Load)^2-9.23/Load$	0.9997	0.021
11R24.5	$ESAL = 5.77-1.10(Load)+0.094(Load)^2-10.16/Load$	0.9998	0.018
315/80R22.5	$ESAL = 4.24-0.86(Load)+0.082(Load)^2-7.08/Load$	0.9999	0.009
385/65R22.5	$ESAL = 6.03-1.15(Load)+0.096(Load)^2-10.66/Load$	0.9998	0.019
455/55R22.5	$ESAL = 5.81-1.12(Load)+0.094(Load)^2-10.20/Load$	0.9997	0.021
425/65R22.5	$ESAL = 5.98-1.15(Load)+0.095(Load)^2-10.57/Load$	0.9997	0.022
445/65R22.5	$ESAL = 5.88-1.14(Load)+0.094(Load)^2-10.30/Load$	0.9997	0.020

9-axle log B-train pavement impact re-evaluation (2020)

NEW single-axle/ single-tire load equivalency

		Steer WBST	Drives	Lead	Rear	Total	Payload (t)	ESALs/tonne payload	Difference from baseline
9-axle tridem drive B-train	Load (t)	7.3	24	24	17	72.3	50.47	**0.143**	-6.4%
	ESALs	**1.29**	**1.95**	**1.95**	**2.04**	**7.23**			
		385/65R22.5							

		Steer	Drives	Lead	Rear	Total	Payload (t)	ESALs/tonne payload
8-axle tandem drive B-train	Load (t)	5.5	17	24	17	63.5	43.89	**0.153**
	ESALs	**0.69**	**2.04**	**1.95**	**2.04**	**6.72**		
		11R22.5						

Implications of research

BC MOTI has new steering axle LEF equations with which to more accurately evaluate truck pavement impacts.

These 8 tire-specific load equivalency equations are now available for use by other regulators.

Some jurisdictions use provincially-specific ESAL equations. This methodology could be used to build tire size-specific equations based on these provincial formulae.

At full axle weights, BC industry has a competitive advantage created by a new, highly efficient, safe, and environmentally friendly truck configuration.

References

Bradley, A; Thiam P.-T. 2020. *A methodology to estimate widebase steering tire load equivalency. Technical Report 12(2020).* FPInnovations. Vancouver. BC. March 2020.

Bradley, A; Thiam P.-T. 2020. *New load equivalency equations account for steering axle tire size*. In proceedings of TAC 2020 Conference. Vancouver. BC. September 2020.

Thiam P.-T.; Bradley, A. 2021. *Development of a methodology to estimate widebase steering tire load equivalency in Canada*. Accepted for presentation at TRB 2021 Conference. January 2021.

QUESTIONS?

Allan Bradley, P.Eng., RPF

allan.bradley@fpinnovations.ca

(604) 831-3248

www.fpinnovations.ca