USE OF A NEWLY DEVELOPED METHODOLOGY FOR ESTIMATING WIDEBASE STEERING TIRE ESALS TO PREDICT PAVEMENT DAMAGE FROM NEW 9 AXLE LOG TRUCKS

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Paper prepared for presentation at the Innovations in Pavement Management, Engineering and Technologies session

at the 2020 TAC Conference & Exhibition

Funding for this research was provided by the Canadian Forest Service, Natural Resources Canada

Abstract

British Columbia Ministry of Transportation and Infrastructure (TRAN), and other Canadian regulators, utilize the ESAL concept for vehicle impact evaluations and(or) pavement design. TAC's ESAL equations originally were developed in RTAC's Heavy Vehicle Weights and Dimensions Study (RTAC, 1986) and are widely accepted by the Canadian transportation industry. Unfortunately, TAC's ESAL equations do not account for tire size and, consequently, overestimate steering axle impacts when those axles are equipped with widebase steering tires. Most new vehicles proposed for use in B.C. (or in other Provinces) feature tridem drive tractors which, by regulation, must carry at least 25% - 27% of the drive group weight on the steering axle—these heavy loads necessitate the use of widebase steering tires. In order to optimize high efficiency truck configurations in Canada, therefore, accurate estimates of widebase steering tire ESALs are needed. This paper describes a methodology that was recently developed by FPInnovations, in consultation with TRAN, to estimate ESALs for widebase steering tires.

Using layered elastic pavement modeling, FPInnovations evaluated key strain responses to widebase steering tire traffic in the 14 RTAC-86 test pavement sections. The results were transformed to estimates of pavement life and then calibrated to RTAC-86's single-axle/single-tire ESAL model to develop ESAL relations for 8 popular North American steering tire sizes, including four widebase steering tires. The ESAL relations produced in this research extend the TAC ESAL equations to all popular North American widebase steering tire sizes and offer regulators, academics, and consultants a means to more accurately estimate steering tire pavement impacts.

The paper includes a practical example of the use of these widebase steering tire ESAL equations. In order that new truck configurations in B.C. evolve to create less road damage, TRAN requires that they meet certain safety and performance criteria. One performance criterion is that new truck configurations generate at least 5% less pavement damage (in terms of ESALs per tonne payload) than a specified reference vehicle. Using the widebase steering tire ESAL equations developed in this study, FPInnovations demonstrated that 9-axle tridem-drive log B-trains can have 7,300 kg steering loads and still meet this performance threshold. In May 2020, TRAN published a policy to incorporate this new methodology and, consequently, increased the steering axle loads of 9-axle tridem-drive log B-trains permitted in B.C.

Introduction

The equivalent single axle load (ESAL) concept is utilized by various regulators, researchers, and designers to evaluate relative vehicle impacts to pavements and(or) to design pavements. This concept estimates the theoretical pavement damage from a truck with any configuration of axles in terms of number of passes by a single axle equipped with dual tires and loaded to 8181 kg (18,000 lbs). ESAL equations have been created for single axles equipped with single tires or dual-tire assemblies, and for tandem- and tridem-axle groups equipped with dual-tire assemblies. The ESAL concept is by far the most widely accepted pavement concept in the world (TRB Circular E-C118, 2007).

The Transportation Association of Canada (TAC, formerly RTAC) and the American Association of Highway Transportation Officials (AASHTO, formerly AASHO) have produced generalized ESAL formulae based on average highway conditions (AASHTO, 1993; TAC, 1997). The Canadian ESAL equations were developed through field testing of 14 Canadian pavements in the Heavy Vehicle Weights and Dimensions Study (RTAC, 1986). A limitation of the TAC ESAL concept is that the field testing was conducted with trucks equipped with conventional-sized tires and, therefore, the data do not support evaluations of pavement damage for unconventional tire sizes. Recently, this has become an issue because of the widespread use of widebase steering tires on Canadian heavy trucks with steering axle loads in excess of 5,500 kg (e.g., trucks with tridem-drive axles which are required to carry 24%-27% of the drive group load on their steering axles). TAC's equations do not account for heavily loaded steering axles equipped with widebase tires and overestimates their pavement impacts and may result in unfair or inaccurate vehicle evaluations.

FPInnovations developed a methodology for accurately estimating ESALs for widebase steering tire sizes, and single-axle/single-tire ESAL equations for the most popular Canadian widebase steering tires.

Forest industry proponents of a new log hauling truck configuration in B.C. requested that FPInnovations' work with the BC Ministry of Transportation and Infrastructure (TRAN) to incorporate the new ESAL equations into the government's methodology for assessing new vehicle pavement damage rates. TRAN and Alberta Transportation [Juhasz and Anthony (2016)] have studied widebase single tires in the past; however, these studies have focused on the question of loading to create equivalent damage to current dual tire assemblies rather than single steering tire pavement impacts. The 9-axle tridem-drive log B-train was originally introduced in B.C. with a steering axle weight of 6,900 kg because the truck failed to meet the pavement damage performance criteria with full, legal (7,300 kg), steering axle weights. It was hoped that a more accurate assessment of steering axles equipped with widebase steering tires might result in a load increase to full steering axle weights. Apart from the increase in payload, it was expected that the use of full steering axle weights would result in improved steerability under low friction conditions and a reduction in out-of-compliance infractions due to steering axle overloads.

<u>Project Objectives</u>

- Conduct a literature review of widebase tire development and pavement impacts.
- Develop, in consultation with TRAN, a methodology to assess load equivalencies for widebase steering tires on flexible Canadian pavements.
- Develop equations to estimate ESALs for popular Canadian sizes and loads of widebase steering tires.
- Use the new equation(s) to assess the pavement impacts of B.C. 9-axle log B-trains.

FPInnovations methodology for estimating pavement damage

As stated earlier, TAC produced ESAL formulae based on average highway conditions and presented these in the Canadian Heavy Vehicle Weights and Dimensions Study (RTAC, 1986). A limitation of the TAC ESAL concept is that the field testing was conducted with trucks equipped only with conventional-sized tires and, therefore, does not account for steering axles equipped with larger tire sizes. For large (widebase) steering tires used on trucks with heavy steering axle loads the TAC single-axle/single-tire ESAL formula overestimates their pavement impacts and may result in unfair or inaccurate pavement impact evaluations. Recently, this has become an issue because of the widespread use of widebase steering tires on Canadian heavy trucks with steering axle loads in excess of 5,500 kg.

FPInnovations' ESAL equations were developed to bridge the gap in knowledge and to allow for accurately estimating ESALs for widebase steering tire sizes, and single-axle/single-tire ESAL equations for the most popular North American widebase steering tires.

Advanced pavement modeling was used to develop FPInnovations equations. The methodology of the advanced pavement modeling consisted of estimating the long-term impacts of steering tires on 14 representative Provincial pavements, and then calibrating these impacts to the TAC single-axle/single-tire ESAL equation. This analysis started with estimating the spontaneous strain responses to various steering axle loads and tire sizes. Strains were estimated at key depths in the highway structures using WinJULEA, a multi-layer, linear elastic software based on the Burmister theory, an extension to Boussinesq and Odemark linearity and elasticity of homogeneous structures theory. The input data needed to perform the analysis of steering axle impacts were:

- Pavement material mechanical properties (resilient modulus and Poisson's ratio).
- Pavement material layer thicknesses.
- Tire size, tire load, and the resulting tire contact area.

Two evaluation locations were specified for the analysis:

- Under the tire centre in the HMA mat near its interface with the granular base course.
- Under the tire centre at the top of the subgrade.

Two strain responses found in these locations in a flexible pavement can be used to predict long-term pavement performance. They are:

- Horizontal tensile strain at the bottom of the HMA mat.
- Vertical compressive strain at the top of the subgrade layer.

These two key strains were calculated for all 896 combinations of pavement structure, tire size, and tire load.

The long-term damage analysis was performed using the Asphalt Institute's strain-based transform equations (Huang, 2004), and focused on the two most common, traffic-related, failure modes for Canadian pavements: Asphalt Institute's surface rutting equation and Asphalt Institute's bottom-up fatigue cracking equation. The Asphalt Institute defines damage rate as (1/ no. of passes to create a failed condition); and, a failed condition in bottom-up fatigue cracking is when 10% of the wheel lanes is “alligator cracked” and a failed condition in rutting is when wheel lane rut depth has reached 12.5 mm (1/2 inch).

The cracking and rutting rates from each axle were accumulated using Miner’s law to estimate the damage rates from the entire truck. The governing mode of long-term pavement failure was taken to be that form of damage with the higher damage rate.

The long-term damage rates were calculated for the 14, representative, Provincial pavements and the test truck used in the RTAC-86 study, and then the governing failure mode and its associated damage rate were identified for each of the pavements. These governing damage rates then were normalized to general damage rates for a single, representative, Canadian flexible pavement. This approach is identical to that used in the RTAC-86 study.

Estimates of ESALs for each tire size were calibrated to the RTAC-86 ESAL estimate by multiplying its governing damage rate by the ratio of (RTAC-86 ESAL/RTAC-86 general damage rate). The RTAC-86 damage rate was based on the testing conditions (a 11R22.5 tire with a 2750 kg loading and 690 kPa cold inflation) and the corresponding load equivalency was 0.69 ESALs.

ESAL equations were developed for each size tire with a least-squares regression of ESAL values calculated for nine discrete tire loads ranging from 2,000 to 5,000 kg. The best fit was found to occur with a power form of equation.

This methodology was developed in consultation with TRAN and was favoured over other possible approaches because it built on the existing, accepted, TAC ESAL methodology. More detail about the methodology and about widebase tire research and development are provided in (Bradley and Thiam, 2020).

Steering tires investigated

Steering tires were evaluated over a range of loads corresponding to maximum legal axle limits used by various Provinces across Canada. Lighter tire loads also were evaluated in order to improve the accuracy of the least-squares regression equations for ESALs. All tires were evaluated at all loads regardless of whether the load exceeded the manufacturer’s maximum load rating.

Tire (gross) contact area is the total footprint area of a tire (including the spaces between tread blocks) and is an important consideration for modeling tire-pavement interaction. In practice, contact area varies with numerous factors, including tire size, load, inflation, carcass design, wheel width, tread pattern, and tread wear. Tire contact areas were estimated using a model published by Kettering University (formerly General Motors Institute) (BND 2020) and validated with formulae from Tire & Rim Association (2009).

Table 1 presents the truck steering tire sizes considered in the analysis and their key specifications. Tire specifications are listed with a mixture of metric and imperial units (as is common industry practice); the reader will note that these specifications are incorporated in the tire size nomenclature. These tire sizes were selected in consultation with TRAN and reflect the most popular steering tire sizes used in North America – as identified in FPInnovations’ extensive literature review of widebase single tires (Thiam, 2018). Figure 1 presents the estimated contact areas generated for each steering tire size over the range of tire loading at a cold inflation of 690 kPa (100 psi) because this reflects typical industry practice and was the standard used for the RTAC-86 study also.

Table 1: Popular North American truck steering tire sizes and specifications considered in the analysis

Tire size	Design section height (H) (inch)	Rim diameter code (D_r) (inch)	Design new tire section width on design rim width (S) (inch)	Maximum axle load capacity (kg)*	Comment
			Conventional steering tire sizes		
295/60R22.5	7.0	22.5	11.6	5,430	Not popular for forestry
11R22.5	9.49	22.5	11.0	5,400	Typical on eastern Canadian log trucks and on-highway trucks
11R24.5	9.49	24.5	11.0	6,520	Typical on western Canadian log trucks
315/80R22.5	9.9	22.5	12.4	5,780	Not popular for forestry
			Widebase steering tire sizes		
385/65R22.5	9.9	22.5	15.2	7,480	Common on tridem-drive log trucks
455/55R22.5	9.9	22.5	17.9	8,560	Not popular for forestry
425/65R22.5	10.9	22.5	16.7	8,880	Common on tridem-drive log trucks
445/65R22.5	11.4	22.5	17.5	9,640	Used on tridem-drive log hauling trucks

* at a cold inflation pressure of 690 kPa (100 psi)

The Tire & Rim Association formula estimates tire contact area as a function of tire inflation, tire load, and tire volume; the resulting linear relation for tire contact area is illustrated in Figure 1. The slopes of the tire contact lines are the same for all tire sizes because tire volume is the only variable to change with tire size (inflation pressure was held constant, as discussed). The tire volumes of the subject steering tires vary in the order shown in the legend of Figure 1, with 445/65R22.5 tires having the largest volume and 295/60R22.5 having the smallest volume. The height of metric tire sizes is calculated with the tire's aspect ratio (e.g., the height of a 455/55R22.5 tire = 455 mm x 55% = 250 mm). Although 455/55R22.5 tires have the largest width (455 mm), their height is smaller than that of the 425/65R22.5 and 445/65R22.5 tires, and this makes for a smaller tire volume. As can be seen, the widebase steering tires have considerably larger contact areas than the 11R22.5 tire. The difference in contact area varies from 1661 mm^2 (385/65R22.5 tires) to 5048 mm^2 (445/65R22.5 tires).

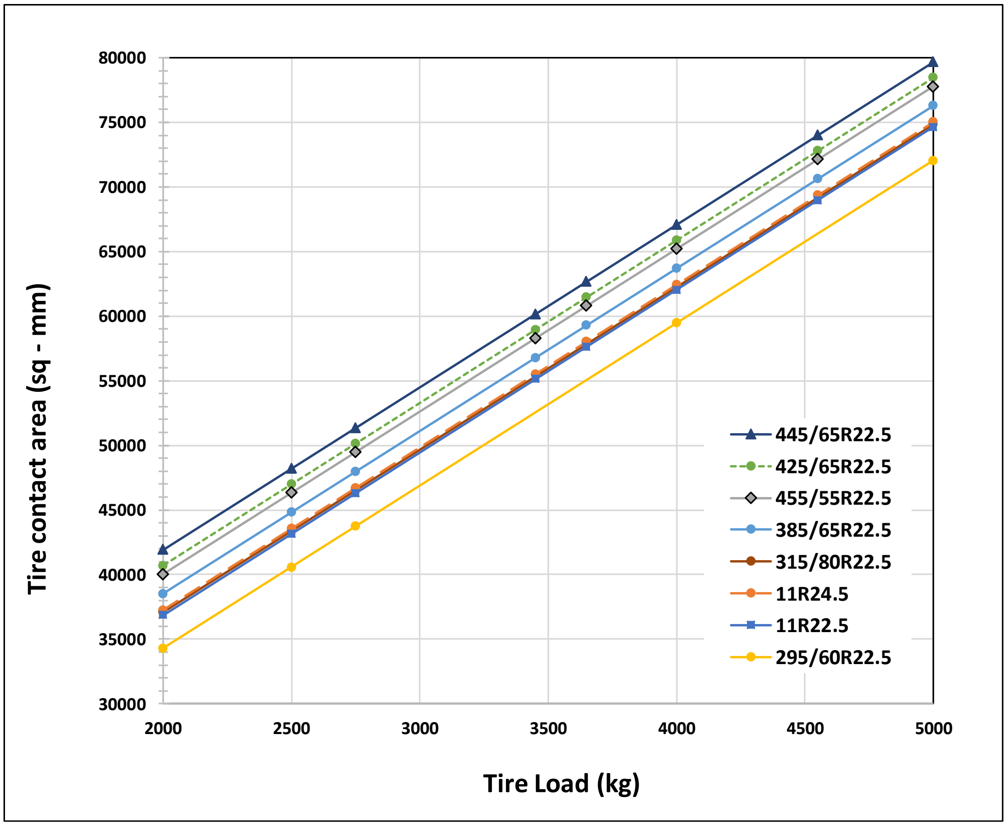

Figure 1. Tire contact area vs tire load for 8 truck steering tire sizes inflated to 690 kPa.

Validation of FPInnovations' proposed methodology

The proposed methodology for deriving ESAL values was validated by comparing results for conventionally sized tires (11R22.5) with ESALs derived using two well accepted methods: the TAC single-axle/single-tire ESAL equation and the generic ESAL equation from AASHTO (1993).

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

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

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

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

Close agreement with the TAC equation was anticipated because the TAC method was derived from field testing on Canadian pavements with steering axles equipped with single 11R22.5 tires. Conversely, poorer agreement with the AASHTO ESAL values was anticipated because the AASHTO values were derived from field testing on American pavements by trucks equipped with 10.00-22.5 bias ply tires (i.e., similar in size to 11R22.5 tires but less damaging than radial tires) and the ESAL values are applicable to single axles equipped with either single- or dual-tire assemblies (dual-tired assemblies are less damaging than single tires). Figure 2 illustrates the comparison of ESAL values derived by these three methods.

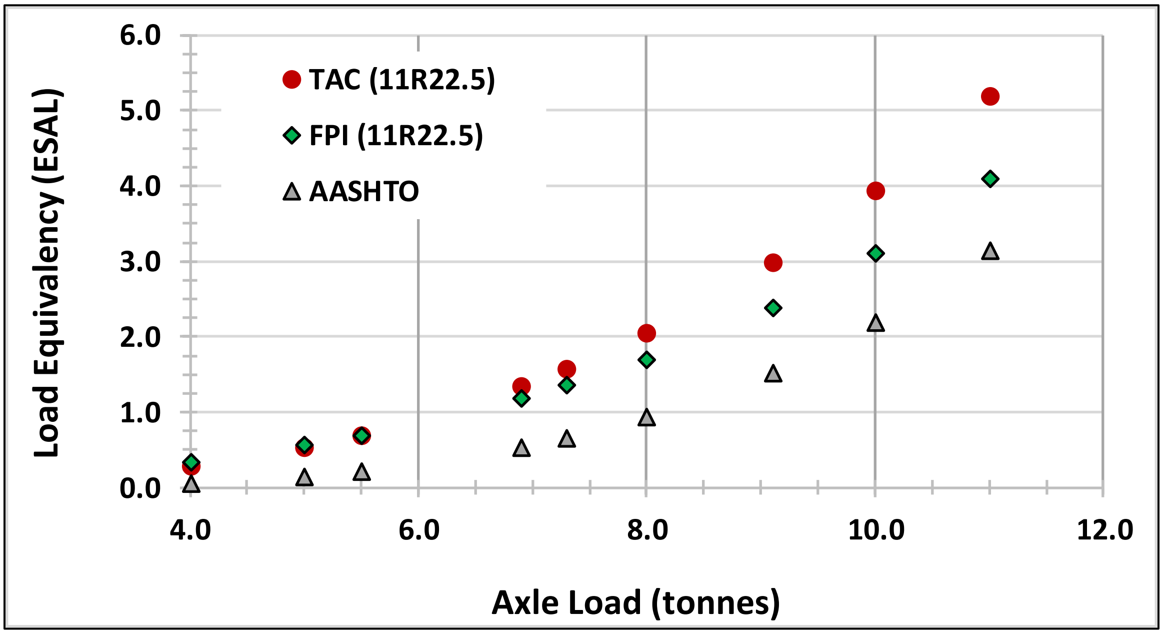

Figure 2. Comparison of three methods to estimate single-axle/single-tire ESALs.

In general, the FPInnovations ESAL values and curve shape agreed with both well accepted ESAL calculation methods. Very close agreement was observed between the TAC ESAL single-axle/single-tire equation, especially for the range of loads up to the manufacturer-specified load limit of these tires (5,400 kg axle load). As expected, beyond the steering tire load limit, the TAC methodology overestimates impact. Because pavement modeling software did not exist at the time RTAC researchers extrapolated single-axle/single-tire impacts for heavy axle loads by simply doubling ESAL estimates from single-axle/dual-tire impacts.

FPInnovations ESALs equations

A backwards stepwise multiple regression analysis resulted in a consistent form of power equation for predicting ESALs based on steering axle load. The equation took the form:

$$ESAL = a + b(axle\ load) + c(axle\ load)^2 + d(\frac{1}{axle\ load})$$

A regression analysis with this standard form of equation produced coefficient values for each size of tire. As can be seen in Table 2, the fit of these equations was excellent with coefficient of multiple determination (R^2) values of 0.9997 or better, and root mean square errors (RMSE) of 0.02 ESALs or better. The two metric-sized tires (295/60R22.5 and 315/80R22.5) were evaluated at only 5 discrete tire loads and, because of this, when they were regressed the resulting equations had very high R^2 values and very low RMSE values.

Figure 3 illustrates the ESAL equations for the conventional steering tire sizes (11R22.5 and 11R24.5) as compared to that of the widebase steering tire sizes (385/65R22.5, 445/55R22.5, 425/65R22.5, and 445/65R22.5).

Table 2: FPInnovations ESAL equations for 8 sizes of heavy truck steering tires

Tire size	Single-axle/single-tire ESAL equation	R^2	RMSE (ESAL)
	Conventional steering tire sizes		
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
	Widebase steering tire sizes		
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

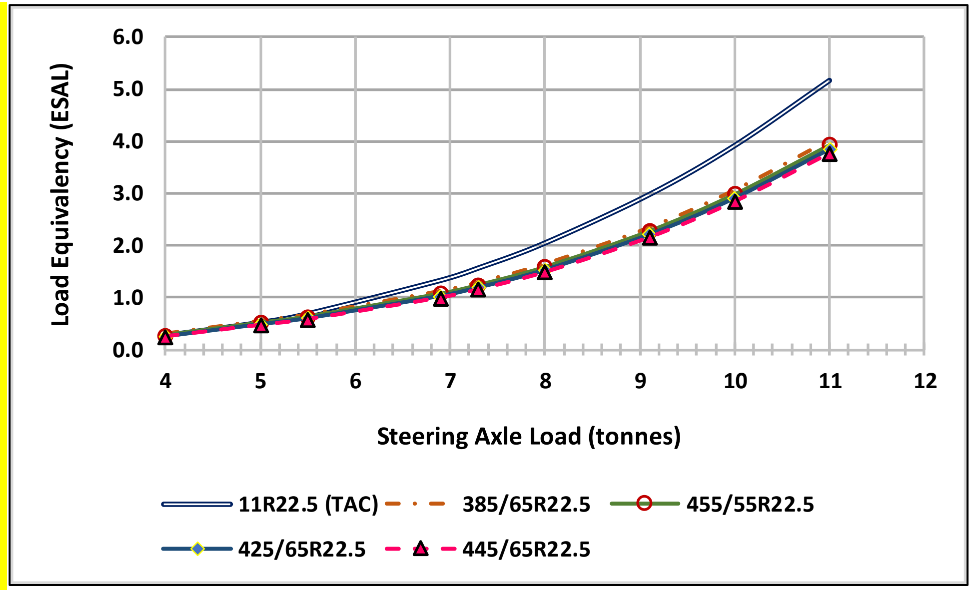

Figure 3. Steering axle ESALs estimated using TAC single-axle/ single-tire equation and new widebase tire equations.

Because they spread load over a larger contact area, widebase steering tires generate smaller pavement strains and damage rates than conventional sized tires. This is illustrated by the tires with larger contact areas having flatter ESAL curves. The ESAL equations have the same general shape as the TAC (11R22.5) ESAL equation. The difference in predicted ESAL values from these equations is relatively small for lighter axle loads but as much as 0.25 ESALs at the largest axle loads. Much greater differences arise, however, when comparing the new equations to TAC's single-axle/ single-tire ESAL equation. At a 10,000 kg axle load, widebase tires are predicted to generate 2.85 to 3.00 ESALs whereas the TAC equation predicts 3.90 (a difference of 0.9 to 1.05 ESALs). This seemingly modest reduction in steering axle ESALs can be large enough to noticeably reduce estimated truck load equivalency. For example, the estimated load equivalency for an 8-axle tridem drive B-train with a 7.3-tonne steering axle load would be reduced by about 5% when using the new 425/65R22.5 formulae (i.e., 7.23 ESAL vs 7.60 ESAL). As mentioned, TAC single-axle/single-tire ESALs were assumed to be double that of single-axle/dual-tire ESALs (for a given axle load). TAC steering axle ESALs were extrapolated to much higher steering axle loads than were used in testing or that the 11R22.5 tires are rated for. As a result, the TAC load equivalencies for steering loads in excess of about 5,500 kg are believed to overestimate actual pavement impacts, as predicted using pavement modeling. The load equivalencies for conventional tire sizes loaded up to their maximum load rating (e.g., 5.5 tonnes), however, closely agree with predictions using pavement modeling.

Use of FPInnovations' methodology for estimating ESALs to quantify new B.C. 9-axle log truck predicted pavement damage

Under the reducible load overweight policy of TRAN, non-regulation configurations can be permitted to use B.C. public highways. The authorization of overweight or over-dimension log truck configurations requires that they meet specific safety and performance criteria. In order that new B.C. truck configurations evolve to become less damaging to pavements, one of these criteria is that the damage from new truck configurations must be at least 5% less than from a reference vehicle. ESALs are estimated using TAC ESAL equations for each axle and the theoretical pavement damage, which is compared to that of a reference truck, is expressed as the total ESALs divided by payload (tonnes).

In B.C., trucks with tridem-drive axles are required by regulation to have a steering axle load of, at least, 27% of the drive load. Also, by regulation, log hauling truck's wheel loads must not exceed 110 kg per cm of tire width. These steering axle requirements for tridem-drive trucks exceed the carrying capacity of conventional-sized tires (see Table 1) and necessitate the use of widebase steering tires. Many new truck configurations feature tridem-drive axles.

Tandem- and tridem-drive variants of 9-axle log B-train configurations were authorized by TRAN for use in B.C. in 2017 after extensive theoretical and field evaluations. Figure 4 illustrates the new 9-axle tridem-drive B-train. When the pavement impacts of the tridem-drive variant were assessed it was found that it could not meet the 5% reduction criterion at full legal axle weights. To allow the configuration to meet the 5% threshold, therefore, the permitted maximum steering axle load was limited to 6,900 kg. Table 3 illustrates the original comparison of pavement impacts that led to a 400 kg reduction in steering axle load (from the legal maximum B.C. steering axle load of 7,300 kg). At the same time, FPInnovations undertook an evaluation of widebase tire ESALs to ascertain how the current method for new vehicle evaluations could be modified to account for widebase steering tires.

Figure 4. Tridem-drive 9-axle B-train.

Table 3. Original pavement impact calculations of the 9-axle tridem-drive B-train at 7.3 and 6.9 tonnes steering axle load, using TAC ESAL equations

Configuration		Steer axle	Drive axles	Lead trailer axles	Rear trailer axles	Total	Payload	ESALs/ payload	Difference from reference
8-axle tandem-drive B-train	Load (t)	5.5	17.0	24.0	17.0	63.5	43.89		
	ESALs	0.69	2.04	1.95	2.04	6.72		0.153	
9-axle tridem-drive B-train	Load (t)	**7.3**	24.0	24.0	17.0	72.3	50.47		
	ESALs	**1.57**	1.95	1.95	2.04	7.51		0.149	**- 2.8%**
9-axle tridem-drive B-train	Load (t)	**6.9**	24.0	24.0	17.0	71.9	50.07		
	ESALs	**1.33**	1.95	1.95	2.04	7.27		0.145	**- 5.1%**

Table 4 illustrates the same pavement performance evaluation using the FPInnovations-estimated 385/65R22.5 tire ESALs for the steering axle and the TAC ESAL equations for all other axles. Tridem-drive log hauling vehicles in Canada typically are equipped with 385/65R22.5, 425/65R22.5, or 445/65R22.5 steering tires; however, a 385/65R22.5 tire was conservatively used for this evaluation. The reference 8-axle B-train was assumed to be equipped with 11R22.5 steering tires, however, virtually the same ESAL outcome results if the reference truck were equipped with 11R24.5, 12R22.5, 12R24.5, or 315/80R22.5 size tires and their ESALs were estimated using the FPInnovations-generated ESAL equations.

Table 4. Theoretical pavement impact of a 9-axle tridem-drive B-train, accounting for steering tire size

Configuration		Steer axle	Drive axles	Lead trailer axles	Rear trailer axles	Total	Payload	ESALs/ payload	Difference from reference
8-axle tandem-drive B-train (reference)	Load (t)	5.5	17.0	24.0	17.0	63.5	43.89		
	ESALs	0.69	2.04	1.95	2.04	6.72		0.153	
9-axle tridem-drive B-train	Load (t)	7.3	24.0	24.0	17.0	72.3	50.47		
	ESALs	1.30	1.95	1.95	2.04	7.24		0.143	- 6.3%

The 385/65R22.5 steering tires were estimated to generate 1.30 ESALs at an axle load of 7,300 kg. The reduction in ESALs from the original TAC ESAL estimate, combined with the increase in payload, were enough for the fully loaded truck to meet the pavement performance criteria of a 5% reduction in ESALs per tonnes payload. Accordingly, this result substantiated increasing authorized steering axle loads for the B.C. 9-axle tridem-drive log B-trains by 400 kg. While this increase in payload is relatively small, the overall impact may become substantial if the projections for 9-axle truck numbers are reached (i.e., 20%-25% of all log hauling trucks in B.C.). Also, the additional load is expected to improve safety on icy roads and there should be less confusion (and fewer non-compliance incidents) because steering axle loads will now be in alignment with that used by other tridem-drive configurations.

Conclusions

FPInnovations' proposed methodology allows ESALs to be estimated for all popular North American steering tire sizes at typical Canadian regulated axle loadings. The methodology was validated by comparing ESAL values for conventional tire sizes (e.g., 11R22.5 and 11R24.5) with values estimated using ESAL equations published by the Transportation Association of Canada (TAC) and by the American Association of State Highway and Transportation Officials (AASHTO). This validation found relatively good agreement between ESAL estimates derived with these three methods at lighter steering axle weights; however, the TAC equation overpredicted ESALs for heavy steering axle loads while the AASHTO formula was relatively insensitive to load and underpredicted ESALs at heavy steering axle loads.

A backwards stepwise regression analysis produced tire-size-specific ESAL equations for 8 steering tires over the range of applicable axle loads. These equations took a consistent form of:

ESAL = a + b(axle load) + c(axle load)2 + d/(axle load)

The fit of these equations to the ESAL values estimated for discrete axle loads was excellent with coefficient of multiple determination (R^2) values of 0.9997 or better, and root mean square errors (RMSE) of 0.02 ESALs or better.

The ESAL concept is used by various regulators, academics, and consultants in Canada to evaluate relative pavement impacts from vehicles and(or) for designing pavements. These new tire-size-specific ESAL equations offer these stakeholders improved accuracy for long-term pavement impact comparisons.

Many new truck configurations in Canada feature tridem-drive groups and widebase steering tires. Having a method to accurately assess ESALs for these configurations will help to optimize their loading. An analysis of steering tire impacts for 9-axle tridem-drive log B-trains used in British Columbia found that use of widebase steering tires allowed these trucks to meet a pavement impact performance threshold for new configurations when their steering axles were fully loaded (to 7300 kg). Use of the new equation reduced steering axle ESALs by a relatively modest amount (0.27 ESALs); however, this generated enough change in pavement impact (from -2.8% to -6.3%) to meet the -5% performance threshold. Accordingly, the B.C. Ministry of Transportation and Infrastructure accepted the new equations and, in May 2020, increased the permitted steering axle weight for the new tridem-drive 9-axle log B-trains to reflect the new estimates of ESALs for widebase steering tire sizes.

This advance in pavement impact evaluation also will be used to optimize loading on high efficiency log hauling configurations currently under development in B.C. (i.e., tridem-drive 9-axle lumber B-train, tridem-drive truck with 5-axle full trailer, and 10-axle chip truck).

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