Streamlined pavement assessment for high-efficiency log truck implementation

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Abstract

FPInnovations, the Ontario Ministry of Transportation (MTO), and a local forest company, are collaborating on the introduction of a new high-efficiency truck configuration to a permitted haul corridor in north-west Ontario. Prior to permitting any new truck configuration the MTO requires a formal assessment to quantify truck impacts to corridor infrastructure and pavements. The impact assessment for this project was conducted in two phases – first for a network of highway sections west of Thunder Bay and second to expand this haul corridor to areas east of Thunder Bay. This paper describes the second assessment, and efficiencies made possible by general trends identified in the first analysis. The paper also describes a comparative analysis of pavement impacts assuming equal and unequal within-group axle loading.

This paper describes a 2023 pavement impact assessment from 9-axle B-trains operating in north-west Ontario. Building on a previous (2021) assessment of other highways, researchers utilized efficiencies and trends to streamline the assessment. The paper also describes a sensitivity analysis that modeled the impacts from within-group axle weight variation.

Key words: High efficiency; Truck configurations; Log trucks; Pavement performance.

Introduction

In January 2022, a new, high-efficiency, log hauling configuration was approved by the Ontario Ministry of Transportation (MTO) for use within a 753 km defined highway corridor north and west of Thunder Bay. The truck configuration was a tandem-drive 9-axle B-train with a 72.5-tonne allowable gross vehicle weight (AGVW) (Figure 1 and Figure 2). Prior to approval FPInnovations undertook a series of analyses to assess the feasibility, economics, and safety of the new truck configuration and to evaluate the impacts on pavements[1] and on infrastructure[2]. In early 2023, the expansion of the corridor was proposed by the forest company stakeholder to include an additional 424 km of highway to accelerate the pace of implementation of the 9-axle trucks and better capture the full benefits of this high-efficiency configuration (Figure 3). A second technical analysis was undertaken to evaluate the 9-axle B-trains' impacts to pavements and infrastructure in the corridor expansion[3]. Given the same configuration and axle loads were to be used, no additional examination of vehicle dynamics and economic feasibility were necessary. It was possible to streamline the pavement analysis process by building on learnings from the original corridor analysis. This paper summarizes the streamlined technical analysis and highlights the methodology, trends, and assumptions that support the revised approach.

Figure 1. 9-axle B-trains are the top performing high efficiency log truck in British Columbia and Ontario

Figure 2. 72.5-tonne tandem-drive 9-axle log hauling configuration

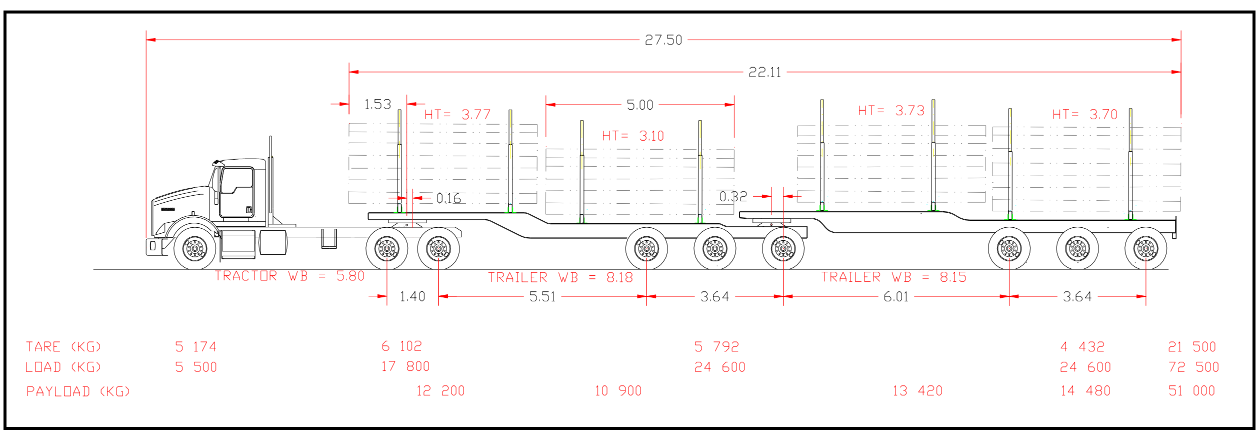
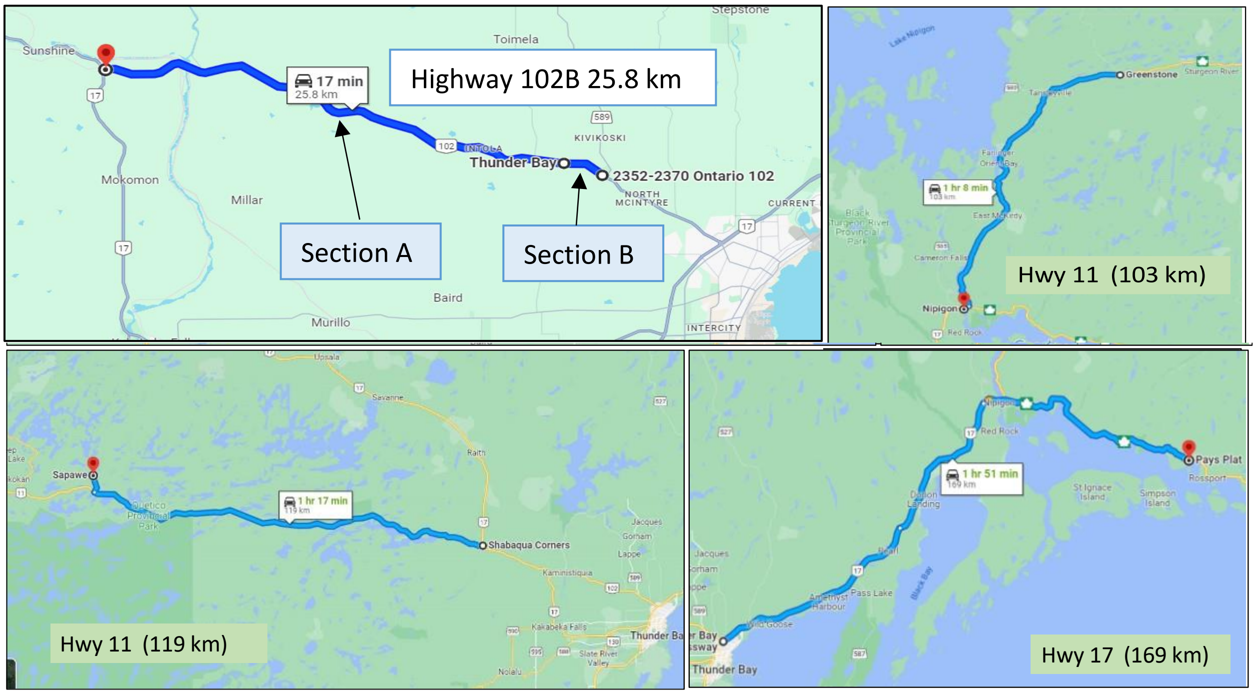


Figure 3. Corridor expansion routes west and east of Thunder Bay



Pavement analysis

The proposed and MTO-approved pavement analysis methodology included the following elements:

1. Estimate and compare the load equivalencies for the proposed configuration and the baseline reference truck configurations.
2. Estimate spontaneous and long-term pavement impacts from the subject trucks by route or stretch of route.

<u>Load Equivalency Factor Comparison</u>

To address these two requirements, the methodology for the original 2021 pavement impact analysis was structured in two parts. The first part consisted of a comparative analysis of the axle load equivalency factors (LEF) between the 9-axle B-train and representative baseline log trucks. The second part consisted of advanced pavement modeling to compare the short-term and long-term impacts from the same configurations as well as a sensitivity analysis with additional structures to assess the total impacts comprehensively and conservatively on the corridor.

The baseline trucks were representative of current log hauling trucks used in northwest Ontario. They were a 7-axle tandem-drive/ quad axle semitrailer and an 8-axle super B-train. These trucks were assessed at full Northwestern Ontario Log Transportation Association (NOLTA) Agreement weights (105% of legal axle weights). The project terms of reference specify the use of the American Association of State Highway and Transportation Officials (AASHTO) equations for making LEF comparisons[4]. In addition to the AASHTO LEF calculation method, FPInnovations included an analysis based upon the Transportation Association of Canada LEF equations[5] (to better account for Canadian pavement structures and the impacts from different axle configurations) and including the use of FPInnovations-developed modifications of the TAC equations to account for the use of widebase single tires[6]. Table 1 summarizes the loading and load equivalencies for the 9-axle B-train and the baseline reference log hauling trucks used for the analyses. *As a streamlining measure* (i.e., a means to simply the analysis approved for this analysis by the MTO) the LEF comparison was not included in the 2023 evaluation of the additional corridor routes because neither the trucks nor their loadings had been changed since 2021.

Table 1. Loading and load equivalencies of 9-axle B-train and baseline reference trucks

Configuration	Steer (t)	Drives (t)	Lead trailer (t)	Lift axle (t)	Rear trailer (t)	Payload (t)	LEF per tonne payload
9-axle B-train	5.5	17.8	24.6	n/a	24.6	50.90	0.139
8-axle super B-train (NOLTA Agmt. weights)	6.3	18.9 tandem axle	25.2 tridem axle	n/a	16.275 tandem axle	46.18	0.166
7-axle quad trailer (NOLTA Agmt. weights)	6.0	19.1 tandem axles	n/a	8.0 385/65R22.5 tires	26.0 tridem axles	43.55	0.184

Critical Strain and Long-Term Damage Estimates

The long-term damage analysis was performed using the popular and widely used layered linear elastic pavement analysis software, WinJULEA, to estimate the spontaneous critical strains in key locations of the pavement and the number of truck passes to cause the pavements to reach a failed condition. This analysis was conducted using the Asphalt Institute's strain-based transform equations[7] and focused on two performance parameters:

1. Horizontal tensile strain at the bottom of the asphaltic concrete mat (maximum bottom-up fatigue cracking criteria).
2. Vertical compressive strain at the top of the subgrade layer (maximum rutting criteria).

The Asphalt Institute surface rutting equation is:

$$N_R = 1.365 * 10^{-9} * \varepsilon_v^{-4.477} \quad (1)$$

N_R = number of passes to cause a 0.5 inch (12.5 mm) -deep surface rut
ε_V = vertical compressive strain at the top of the subgrade

The Asphalt Institute bottom-up fatigue cracking equation is:

$$N_F = 18.4 * 0.004325 * k_{F1} * |\varepsilon|^{-3.291} * E^{-0.854} \quad (2)$$

N_F = number of passes to cause alligator cracking over 10% of the wheel lanes
ε = horizontal tensile strain at the bottom of the HMA mat
E = resilient modulus of the asphaltic concrete (psi)

$$k_{F1} = 10^{\left(4.84*\left(\frac{Vbeff}{Vv+Vbeff}-0.69\right)\right)} = 1.0 \quad (3)$$

V_{beff} = effective bitumen content (estimated to be 11% for this analysis)

V_v = voids content (taken to be 5% for this analysis)[7]

For each axle group of a truck configuration, long-term rutting and cracking damage rates were calculated. Using Miner's Law, the axle group damage rates were accumulated to estimate the truck's damage rate and, from these truck damage rates, the governing failure mode was determined:

$$\sum_{i=1}^{k} \frac{n_i}{N_i} \tag{4}$$

k = number of different stresses
n_i = number of cycles accumulated at the i^{th} stress, S_i
N_i = numbers of cycle to failure at S_i

The governing failure mode was taken to be either rutting or bottom-up fatigue cracking – whichever failed condition was generated by the fewest number of truck passes (number of loading cycles) to failure.

Thiam and Bober[1] reported that the original 9-axle corridor comprised 57 segments equalling 753 km of King's highways 11 and 17 and collector highways 516, 599, 622, 623, and 642. The structural data and condition for these highway segments were detailed with MTO's AMS data. To simplify the analysis the segments were grouped according to highway type (secondary or King's), surface type (HMA or surface treatment), and granular base equivalency. Ultimately the pavement performance was modeled using four representative and worst-case structures (Figure 4, Table 2).

Granular base equivalency (GBE) = 2 x AC + GBC + 2/3 x GSB (5)

AC = asphalt layer thickness (mm)
GBC = granular base course thickness (mm)
GSB = granular subbase thickness (mm)

Figure 4. Representative pavement structures in the original 9-axle B-train corridor

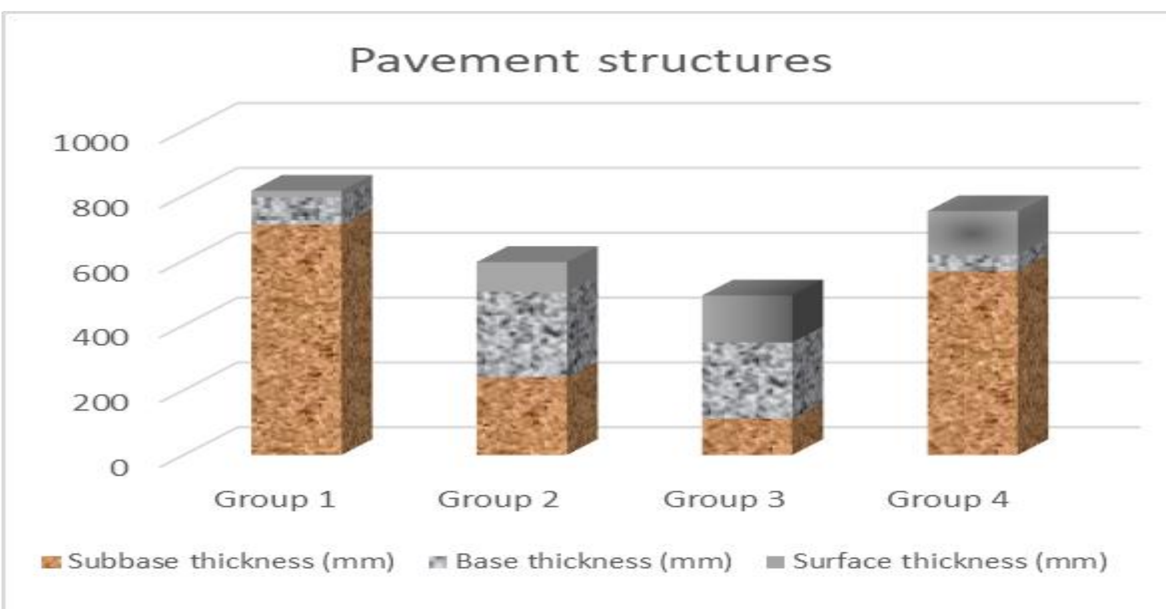


Table 2. Representative worst-case pavement structures for original 9-axle B-train corridor

Group	Highway type	Surface type	Surface (mm)	Granular base course (mm)	Granular subbase course (mm)	Granular base equivalency (mm)
1	Secondary	Surface treated	20 *	85	709	600
2	Secondary	Surface treated	92 *	240	263	600
3	King's	AC	145	235	112	600
4	King's	AC	135	50	567	700

** Modeled as an additional thickness of granular base course. Groups 1 and 2 evaluated for rutting only.*

Not surprisingly, the greatest vertical subgrade strain responses caused by the baseline trucks and the 9-axle B-train occurred in the thinner and(or) weaker structures (groups 1, 2, and 3). The governing failure mode was rutting in the surface treated highway structures (groups 1 and 2); these pavements failed considerably slower (20% to 27%) when subjected to 9-axle B-train traffic than when subjected to the reference truck configurations. The number of passes to reach a failed condition in the group 2 pavement was about 11% of the passes to failure for the group 1 pavement. The governing failure mode was bottom-up fatigue cracking in the HMA highway structures (groups 3 and 4); and these pavements failed slightly slower (2% to 4%) when subjected to 9-axle B-train traffic than when subjected to either of the reference truck configurations. Given these results *an important trend* was identified: the weakest surface-treated pavements are the most sensitive to performance differences caused by configuration. *As a streamlining measure* the 2023 analysis of the additional routes focused only on the <u>one</u> weakest pavement structure (highway 102B), and it was assumed that the other three King's highways were strong enough that they would be relatively insensitive to loading differences caused by the new truck configuration.

A 2011 investigation by TBT Engineering Limited [8] divided Highway 102B into three sections: eastwards 23.8 km from Sistonens Corner to 2 km west of Highway 589 (referred to in this paper as section A); a 2.0 km-long segment with weaker clay subgrade soils that extended from the east end of section A to Highway 589 (referred to in this paper as section B); and a third 6.7 km-long segment from Highway 589 to Highway 11 in Thunder Bay that was managed by the City of Thunder Bay and, therefore, was not part of the investigation. Per the recommendations of the 2011 investigation, the MTO upgraded the sections A and B of Highway 102B to a King's Highway structure (Table 3). The structures described in Table 3 were used as inputs for modelling pavement strain responses to the 9-axle B-train and the baseline reference configurations. The subgrade soil was modelled as a silty sand; however, as part of a sensitivity analysis, it was also evaluated as a low plasticity clayey soil [a CL soil per the United Soil Classification System].

Table 3. Structures of Highway 102B

Section	Length (km)	AC surface (mm)	Granular base course (mm)	Granular subbase course (mm)	Granular base equivalency (mm)	Subgrade
A	23.8	60	215	660	775	Predominantly SP with pockets of CL
B	2.0	130	300	580	947	

* *Per the unified soil classification system, SP is a poorly graded sand and CL is a low plasticity clay soil.*

Soil and material properties

Material properties that are needed for the advanced pavement modelling are the resilient modulus and the Poisson's ratio, which are both specific to each soil and material type, properties, and conditions. Thiam and Bober[1] specified resilient moduli values of 2000, 150, and 100 MPa to represent typical hot mix asphalt, granular A base course, and granular B subbase materials for the corridor pavements, respectively, per the MTO's AMS database and provincial studies.[9, 10] Despite the subgrade modulus values listed in the AMS being relatively conservative (low) these values were used for the 2011 pavement analyses.

As a streamlining measure the 2023 analysis of the proposed additional 9-axle B-train routes used the same properties for hot mix asphalt, granular base course, subbase course, and subgrade soils (Table 4).

Table 4. Soil and Material Properties for the Analysis of Highway 102B

Material layer	Resilient modulus (MPa)	Poisson's ratio
HMA surface	2000	0.35
Granular Base Course	150	0.35
Granular Subbase Course	100	0.35
SP Subgrade Soil	34.5	0.40
CL Subgrade Soil	20	0.45

Truck tire parameters

The log hauling fleet operating near Thunder Bay utilize a mixture of tire sizes depending on wheel configuration and loading. While only 11R22.5 size tires are used on drive and trailer axle dual wheel assemblies, widebase single 385/65R22.5 tires are frequently used in the steering position because NOLTA and winter weights slightly exceed the capacity of 11R22.5 tires. For the same reason widebase single 385/65R22.5 tires are used on the trailer's lift axle if it is equipped with single wheels.

To model strain responses in a pavement structure the tire contact load and footprint area for each wheel position must first be estimated. *As a streamlining measure* (in lieu of gathering field measurements) the following formulae from the Tire & Rim Association Yearbook[12] were used to estimate tire footprint areas, and contact load was assumed to be distributed equally over these footprints.

$$\text{Gross Contact Area (in}^2\text{)} = 39.8 - (\text{Cold Inflation (psi)} \times 0.315) + (\text{Tire Load (lb)} \times 0.00887) + (\text{Tire Volume} \times 0.000938) \quad (5)$$

$$\text{Tire Volume (in}^3\text{)} = \pi \times (H + Dr) \times S \times H \quad (6)$$

H = TRA Design Section Height (in.)
S = TRA Design New Tire Section Width on Design Rim Width (in.)
Dr = Rim Diameter Code (in.)

Also*, as a streamlining measure,* and per Thiam and Bober[1], the cold tire inflation pressures for 11R22.5 tires were assumed to be the maximum of either the TRA-recommended inflation for the given tire size and load at highway speed or a typical industry inflation of 100 psi. The inflation of 385/65R22.5 widebase single tires was taken to be as recommended by the Yearbook[12].

Axle Load variation

The 9-axle B-train and the two reference trucks were evaluated with both full NOLTA Agreement axle loads and with a worst-case loading condition of ±500 kg of within-group axle loading.[1] The within-group axle loading for the three modelled trucks was varied in a way that created the worst-case strain responses from each axle group without exceeding the AGVW for the trucks. The method was as follows:

- Tandem-axle groups +500 kg on the first axle and -500 kg on the second axle.
- Tridem-axle groups +500 kg on the middle axle and -500 kg on the third axle. No variation in axle load for the first axle.
- Quad-axle trailers with a single liftable axle and a tridem-axle group +500 kg on the lift axle and middle axle of the tridem group. -500 kg on the first and third axle of the tridem group.

Table 5 illustrates how these axle load variations, and tire arrangement, influenced modeling inputs.

Table 5. Tire contact load and footprint area modeling inputs for 3 truck configurations with ± 500 kg axle load variation

Axle group	Loading	Tire size	Axle group load (kg)	Tire load (kg)	Cold tire inflation (psi)	Contact load (kN) (± 500 kg axle load)	Footprint area (mm^2) (± 500 kg axle load)
9-axle tandem drive B-train							
Steering	Permit	11R22.5	5500	2750	103	26.98	45716
Tandem drive	Permit	11R22.5	17800 (±500 kg)	2225 (±125 kg)	100	21.83 (±5.4%)	39716 (±3.9%)
Tridem lead trailer	Permit	11R22.5	24600 (±500 kg)	2050 (±125 kg)	100	20.11 (±5.9%)	37512 (±4.1%)
Tandem rear trailer	Permit	11R22.5	24600 (±500 kg)	2050 (±125 kg)	100	20.11 (±5.9%)	37512 (±4.1%)
7-axle quad semitrailer (with dual tire assembly or with widebase single tire on lift axle)							
Steering	NOLTA load	385/65R22.5	6300	3150	80	30.90	58262
Tandem drive	NOLTA load	11R22.5	20055 (±500 kg)	2507 (±125 kg)	100	24.59 (±4.9%)	43264 (±3.5%)
Lift axle (dual assembly tire)	NOLTA load	11R22.5	8925 (+500 kg)	2231 (+125 kg)	100	21.89 (+10.1%)	39794 (+7.3%)

[1] Hendrickson, the manufacturer of the B-train trailer suspensions, designs its suspensions to share axle loads equally and, in the worst case, to allow no more than 500 kg within-group axle load variation per provincial regulations. Nov. 16, 2023, email correspondence. Patrick Jollette, Sales Representative, Temisko Inc. (manufacturer of the 9-axle B-train trailers used in this project).

Lift axle (single tire)	NOLTA load	385/65R22.5	8925 (+500 kg)	4463 (+250 kg)	100	43.78 (+5.3%)	66.66 (+4.5%)
Tridem axle group	NOLTA load	11R22.5	26775 (±500 kg)	2231 (±125 kg)	100	21.89 (±5.5%)	39794 (±3.5%)
8-axle super B-train							
Steering	NOLTA load	385/65R22.5	6300	3150	80	30.90	58262
Tandem drive	NOLTA load	11R22.5	18900 (±500 kg)	2363 (±125 kg)	100	23.18 (±5.2%)	41447 (±3.8%)
Tridem lead trailer	NOLTA load	11R22.5	25200 (±500 kg)	2100 (±125 kg)	100	20.60 (±5.8%)	38142 (±4.0%)
Tandem rear trailer	NOLTA load	11R22.5	26775 (±500 kg)	2231 (±125 kg)	100	19.96 (±6.0%)	37316 (±4.1%)

Results

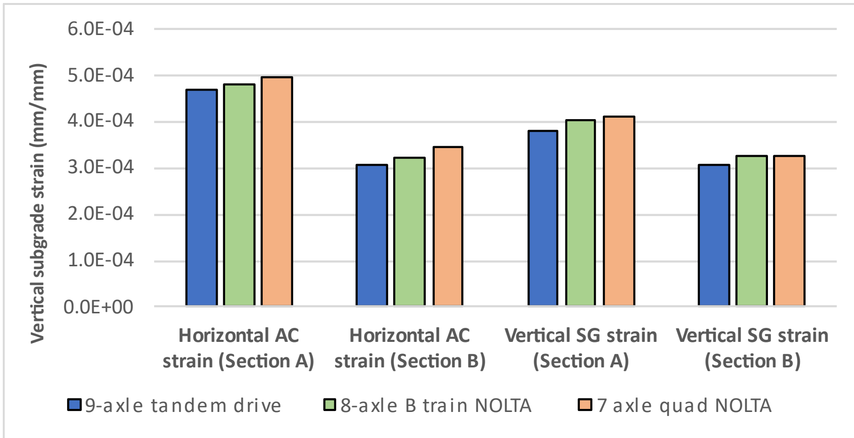
Peak strain locations

Spontaneous strains were evaluated at depths corresponding to the bottom of the asphalt layer and the top of the subgrade – these depths produce strain results that can then be transformed into estimates of truck passes for the pavement to reach a failed condition in surface rutting and bottom-up fatigue cracking[8]. Strains were checked at numerous XY locations corresponding to under and between axles and under and between tires. The greatest strains were found directly under the middle axle of tridem groups (either when axle loading was equal and when the middle axle carried 500 kg extra); and either directly under the centre of any of the tires or at the mid-point of dual tires. Similarly, the greatest strains for tandem axle groups were found directly under the heaviest axle (either axle if equally loaded) and directly under the centre of any of the tires or at the mid-point between dual tires.

Spontaneous Critical Strains

The comparative evaluations of spontaneous critical strains found that the 9-axle tandem-drive B-train generally created smaller strains in the Highway 102B pavement structures than either of the reference vehicles. Spontaneous strains were evaluated at the bottom of the asphalt layer and the top of the subgrade because these depths correspond with the long-term strain-based failure estimates discussed in the following section and Table 6. Figure 5 illustrates the critical strains results for tandem axle groups.

Figure 5. Comparison of maximum horizontal AC strains and maximum vertical subgrade strains in two Highway 102B pavement structures caused by tandem axles of three log hauling trucks



The comparative evaluations of long-term damage also found that the 9-axle tandem-drive B-train generally had less impact on the Highway 102B pavements than either of the reference vehicles. To account for differences in truck efficiency the number of passes to failure was expressed as a damage rate and normalized by truck payload. For example, the 9-axle B-train was predicted to cause a bottom-up fatigue failure condition in Section A after 18 359 trips and in Section B after 83 452 trips. The failure rates were 5.45E-05 and 1.20E-5, respectively. When divided by the 9-axleB-train's 51-tonne payload these failure rates became 1.07E-6 and 2.35E-07 per tonne payload. Table 6 summarizes the failure rates of the two sections of Highway 102B when subject to the 9-axle B-train and the two baseline vehicles.

Table 6. Estimated failure rate of two pavement structures on Highway 102B from 3 log hauling vehicles

Configuration	**Payload (t)**	**Failure rate per tonne payload**	
		Hwy 102B - Section A	**Hwy 102B - Section B**
72.5-t 9-axle B-train	51.000	1.07E-06	2.35E-07
66.675-t 8-axle B-train (385/65R22.5 steering tires)	46.175	1.04E-06	2.46E-07
62.055-t 7-axle quad trailer (385/65R22.5 steering tires and 11R22.5 dual tires on lift axle)	40.600	1.17E-06	3.07E-07
62.055-t 7-axle quad trailer (single 385/65R22.5 tires on steering and lift axle)	40.600	1.28E-06	3.47E-07

Pavement damage rates of the 9-axle B-train ranged from being up to 0.03E-06 (2%) more than the 8-axle B-train on Section A to 0.112E-6 (32%) less than the 7-axle quad trailer on Section B. It should be noted that approximately 90% of the existing log hauling fleet are 7-axle tractor/ quad semi-trailers and so the potential gains from the implementation of 9-axle B-trains in place of these trucks could be substantial.

Sensitivity Analysis: Weak Subgrade Soil

A sensitivity analysis was conducted to ensure that conclusions were based upon both conservative and comprehensive modelling results. This sensitivity analysis repeated the analysis assuming the same structures (shown in Table 3) but now with the subgrade of Highway 102B as a weak silty clay soil. The results were very similar to that observed for poorly graded sand subgrade except that small reductions in damage rate were found for all vehicles. This can be explained by the trend of the weaker subgrade conditions causing higher subgrade strains but smaller strains in the asphaltic concrete. As the governing failure mode for both of the Highway 102B sections was bottom-up fatigue cracking the net result was a reduction in damage rates across the board. Table 7 summarizes these results.

Table 7. Estimated failure rate of two pavement structures on Highway 102B from 3 log hauling vehicles assuming a weak CL subgrade

Truck configuration	**Payload (t)**	**Failure rate per tonne payload**	
		Section A structure	**Section B structure**
72.5-t 9-axle B-train	51.000	1.04E-06	2.33E-07
66.675-t 8-axle B-train (385/65R22.5 steering tires)	46.175	1.01E-06	2.44E-07
62.055-t 7-axle quad trailer (385/65R22.5 steering tires and 11R22.5 lift axle dual tires)	40.600	1.13E-06	3.06E-07
62.055-t 7-axle quad trailer (385/65R22.5 steering and lift axle tires)	40.600	1.24E-06	3.45E-07

In this worst-case scenario, pavement damage rates of the 9-axle B-train ranged from being up to 0.03E-06 (3%) more than the 8-axle B-train on Section A to 0.112E-6 (32%) less than the 7-axle quad trailer on Section B.

Sensitivity Analysis: 500 kg within-group axle load variation

This sensitivity analysis repeated the analysis assuming that up to 500 kg of load variation was present in all axle groups (excluding the steering axle) of the 9-axle B-train and the two baseline vehicles. As previously noted, the trucks were assumed to not be overloaded (their AGVW equaled their permitted limits).

Given the irregular shape of raw logs and accuracy limits of on-board weight scales it can be difficult to tightly control axle group loadings. Some highway agencies have concerns about the impact of axle load variation on pavement wear and tear – even if the trucks' overall weights respect AGVW limits. This analysis was intended to quantify the potential impact of axle load variation on pavement performance.

Axle weight variation is governed by provincial transport regulations and may differ between jurisdictions; however, MTO regulations specify a limit of 500 kg. The maximum variation for this analysis was taken to be 500 kg both because of Ontario regulations and because Hendrickson, a truck suspension manufacturer, advised FPInnovations that this is a typical design specification.

The influence of axle group had a substantial influence on the impact of varying axle load by 500 kg. Table 8 illustrates how axle load variation in tandem and tridem axle groups had negligible impact for both pavement structures. Conversely, the relative change was substantial for quad axle groups where the lift axle and the middle axle of the tridem group both had 500 kg extra loading. Table 9 summarizes the results of the sensitivity analysis.

Table 8. Estimated passes to fatigue failure of two pavement structures of Highway 102B assuming a 500-kg axle load variation

	Section A – Highway 102B			Section B – Highway 102B		
Axle group	**Equal axle loads**	**500-kg axle load variation**	**Difference**	**Equal axle loads**	**500-kg axle load variation**	**Difference**
Tandem axle (17.8 t)	1.55E+05	1.55E+05	-0.01%	6.3E+05	6.32E+05	0.0%
Tridem axle group (24.6 t)	1.73E+05	1.73E+05	+0.01%	7.9E+05	7.93E+05	0.0%
Quad axle group with dual-tired lift axle (34 t)	3.79E+04	3.72E+04	-2.0%	1.53E+05	1.45E+05	-5.1%
Quad axle group with single widebase tires on lift axle (34 t)	7.63E+04	5.61E+04	-26.5%	3.03E+05	1.92E+05	-36.4%

Table 9. Estimated failure rate of two pavement structures of Highway 102B from 3 log hauling vehicles assuming a 500-kg axle load variation within all axle groups (excluding the steering axle)

Truck configuration	**Payload (t)**	**Damage rate per tonne payload**	
		Hwy 102B - Section A	**Hwy 102B - Section B**
72.5-t 9-axle B-train	51.000	1.07E-06	2.33E-07
66.675-t 8-axle B-train (385/65R22.5 steering tires)	46.175	1.04E-06	2.44E-07
62.055-t 7-axle quad semi-trailer (385/65R22.5 steering tires & 11R22.5 lift axle with dual tires)	40.600	1.18E-06	3.14E-07
62.055-t 7-axle quad semi-trailer (385/65R22.5 steering & lift axle tires)	40.600	1.27E-06	3.48E-07

In this worst-case scenario, pavement damage rates of the 9-axle B-train ranged from being up to 0.03E-06 (2%) more than the 8-axle B-train on Section A to 0.115E-6 (33%) less than the 7-axle quad trailer on Section B. The 7-axle quad trailer had the largest increases in pavement impacts and this can be explained by the disproportionately large impacts that result when the lift axle equipped with widebase single 385/65R22.5 tires is overloaded by 500 kg. Again, it should be noted that a large majority of the existing log hauling fleet are 7-axle tractor/ quad semi-trailers and so, on the whole, these results favour the implementation of 9-axle B-trains.

These results indicate that, with the introduction of the new 9-axle B-trains in the additional corridor routes, pavement damage rates will be reduced, and this could result in reduced pavement maintenance requirements, increased safety, and associated reduced GHG emissions. In addition to the anticipated benefits on pavement service life and maintenance requirements, there are other important benefits that also can be expected with the implementation of the high efficiency 9-axle B-train configuration. These other benefits include fewer truck loads (less congestion) on public highways, less fuel use and reduced GHG emissions, reduced impacts to many of the corridor bridges and culverts, fewer drivers required (addressing ongoing driver shortages), and reduced transportation costs (improved competitiveness of local companies).

Conclusions

FPInnovations, the Ontario Ministry of Transportation (MTO), and a local forest company are collaborating on the introduction of a new high-efficiency truck configuration to a permitted haul corridor in north-west Ontario. Prior to permitting any new truck configuration the MTO requires a formal assessment to quantify truck impacts to corridor infrastructure and pavements. The impact assessment for this project was conducted in two phases – first for a network of highway sections west of Thunder Bay and second to expand the haul corridor to areas east of Thunder Bay.

In collaboration with MTO experts, four methodology changes were made possible for the second analysis given that the first analysis was of similar pavement structures and for the same vehicles. These changes streamlined and simplified the analysis without loss of scientific rigor. Streamlining measures for the second analysis included:

- A Load Equivalence Factor analysis and a dynamic performance assessment were not required.
- Strong low-risk pavements were excluded from the analysis.
- Modeling used conservative soil and material properties where data was missing or inconsistent.
- Tire and loading parameters were estimated instead of requiring field measurements to be gathered.

In addition, confidence in the modeling results was improved with a sensitivity analysis of two key assumptions (soil strength, axle loading).

Assuming equal within-group axle weights, the 9-axle B-trains will change Hwy 102B pavement damage rates by +2% to -32%, depending on pavement type and truck configuration. Approximately 90% of the log hauling fleet using the haul corridor routes are 7-axle quad semi-trailers. Replacement of these trucks with 9-axle B-trains has large potential benefits for pavement service life and maintenance budgets.

There was no significant difference in modeled damage rates between structures with the typical SP subgrade and those with a weaker CL subgrade. This indicates that the isolated pockets of weak CL soil on Highway 102B should not experience elevated damage with the use of 9-axle B-trains.

Assuming worst-case axle weight variation, the 9-axle B-trains would change Highway 102B pavement damage rates by +2% to -33% depending on pavement type and truck configuration. The similarity to damage estimates assuming equal within-group axle loading gives confidence to the predictions.

9-axle B-trains are more efficient than the 7- and 8-axle fleet trucks; they require 20% and 10% fewer trips, respectively, to move the same volume of logs. 9-axle B-trains are expected to reduce pavement impacts as well as reduce traffic congestion, infrastructure impacts, fuel consumption and GHG emissions, and transportation costs.

The practice of streamlining analyses and route approvals in Ontario may prove to be a cost effective and efficient means of expanding haul corridors for new high-efficiency truck configurations.

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