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Contents

Evaluation of a long log B-train configuration for regulatory approval in Alberta

Abstract

B-trains have been found to exhibit superior dynamic performance compared to other heavy haul configurations, but are inherently inappropriate for transporting long commodities due to the mid-point articulation between the two trailers. Recently, an innovation employing a sliding kingpin on the pup trailer has been developed that makes it possible to carry long logs. The Forest Engineering Research Institute of Canada (FERIC) began a study of the long log B-train to facilitate regulatory approval in Alberta. This study was based on the B-train having a gross vehicle weight of 62 500 kg and included a cornering performance analysis, a vehicle dynamics evaluation and a review of the maintenance and operational history. This report documents the findings of this study and compares a B-train used for long log transportation to other existing configurations.

Keywords

Long log B-train, Vehicle dynamics, Cornering, Operating costs, Logging trucks.

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Introduction

B-trains have been shown to exhibit superior dynamic performance compared to other heavy haul configurations (Ervin and Guy 1986). As a result, many jurisdictions, including Alberta, have enacted regulations that allow B-trains a higher gross vehicle weight (GVW) to promote their use for heavy haul applications. Presently, the forest industry uses B-trains to haul short logs (i.e., cut-to-length). The B-train is unsuitable for hauling long logs (i.e., tree length) because the log load is supported by a single, rotating bunk on each trailer, and spans the articulation point between the trailers. As with the case of a pole trailer configuration, the bunk-to-bunk length is fixed (Figure 1). Therefore, length compensation is required when turning.

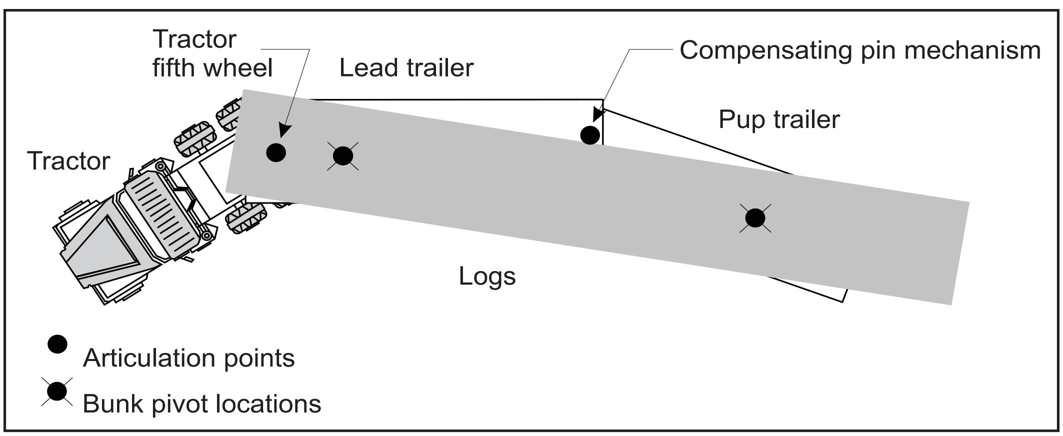

Figure 1. Plan view of long log B-train in a turn.

To provide this compensation, the B-train was modified by installing a sliding kingpin mechanism (Figure 2) into the pup trailer. The bolster plate on the pup trailer has a slot cut into it and the kingpin is able to slide within the slot. If desired, the kingpin can be locked into position and prevented from sliding. Through a special permit, a small number of these modified long log B-trains (Figure 3) have been in operation for Daishowa-Marubeni International Ltd. (DMI) in the Peace River area of northern Alberta. Before considering general approval for their use on the public road system, Alberta Transportation required a formal technical evaluation of the safety performance of this configuration. In particular, the sliding kingpin mechanism was of primary concern because its operational reliability directly influences the safe operation of this configuration.

In late 1998, FERIC undertook the evaluation on behalf of the forest industry with funding assistance provided by Alberta Economic Development. This report discusses the results of the evaluation and makes recommendations based on the observations.

Figure 2. Sliding kingpin mechanism and underside of trailer bolster plate.

Figure 3. B-train used for hauling long logs.

Objective

The objective of this study was to determine the suitability of the long log B-train configuration to operate on public roads in Alberta based on the weight and dimension regulations in place at the time. The following tasks were identified to achieve this objective:

- Compare the cornering performance of the long log B-train to existing configurations and intersection design standards.
- Determine the operational feasibility and maintenance requirements of the long log B-train configuration with particular attention to the sliding kingpin mechanism.
- Evaluate the dynamic performance of the long log B-train.
- Assess the overall ownership and operating costs of the long log B-train.

Study methods

Cornering performance

The cornering performance of a configuration is evaluated using the rear load sweep,[1] front load sweep,[2] and overall vehicle sweep.[3]

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[1] Rear load sweep is the maximum perpendicular distance between the paths travelled by the left, rear corner of the load and by the left, front tire (during a right turn) where the load travels outside the path of the tire.

[2] Front load sweep is the maximum perpendicular distance between the paths travelled by the left, front corner of the load and by the left, front tire (during a right turn) where the load travels outside the path of the tire.

[3] Vehicle sweep is the maximum perpendicular distance between the paths travelled by the left, front tire and by the right, rear corner of the vehicle (during a right turn) not including the load.

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The cornering performance of the long log B-train was compared to the cornering performance of two existing long log configurations—tandem tractor/tandem pole trailer and tandem tractor/tandem jeep/tandem pole trailer—and the Alberta intersection design standards as described by Jesualexander (1992).

A computer model called PathTracker®[4] was used to predict the cornering performance of the long log B-train. To validate PathTracker as an appropriate modelling tool for the long log B-train, FERIC first performed a field trial in Peace River. The turning paths (i.e., path of outer steering tire) used for this trial had radii of 12.5 m which represents an extremely tight turn such as on an in-block road, 15 m which represents a truck entering a highway from a local road, and 25 m which represents a turn at a highway intersection. The critical points for swept path determination were recorded as the configuration moved through the various turns. To measure these values, a path of the desired radius was marked on the ground, then the truck drove along the path until it reached a pre-determined critical point. Upon reaching a critical point, the truck was stopped and then measurements were taken from key locations, such as axle locations and front and rear corners of the load. These measured values were later compared to values predicted from PathTracker.

FERIC determined the appropriate dimensional limits for the load and trailers so that the configuration's cornering performance would be similar to that of existing long log configurations and compatible with Alberta's intersection design standards. Once validated, PathTracker was used to generate values for the critical cornering performance measures. The comparison used the three long log configurations (Figure 4) loaded to their respective Alberta legal axle weights, and used an overall load length of 21 m which is typical of Alberta loads. Then, the front[5] and rear[6] overhangs of the long log B-train were varied to determine acceptable limits based on the cornering performance of the other long log configurations and the intersection design standards. These simulations used a corner radius of 15 m.

Operation and maintenance

Field visits were made to review the in-service operation and performance of the long log B-train; to interview the owner and drivers to discuss the handling and maintenance of the configuration; and to inspect the equipment to review how age and wear affected the operation of the equipment. In addition, several trips were made with the long log B-trains to observe the in-service operation and in particular, the operation of the sliding mechanism.

The main concern regarding the sliding mechanism was the potential that the kingpin might bind during a turn. To fully understand this risk, the actual length of the sliding action was determined. Prior to negotiating a turn,

[4] PathTracker® (v1.2 1993) is a computer model for simulating vehicle tracking while cornering developed by the B.C. Ministry of Transportation.

[5] Front overhang is the distance that the load extends forward from the front bunk.

[6] Rear overhang is the distance that the load extends rearward from the centreline of the last axle in the configuration.

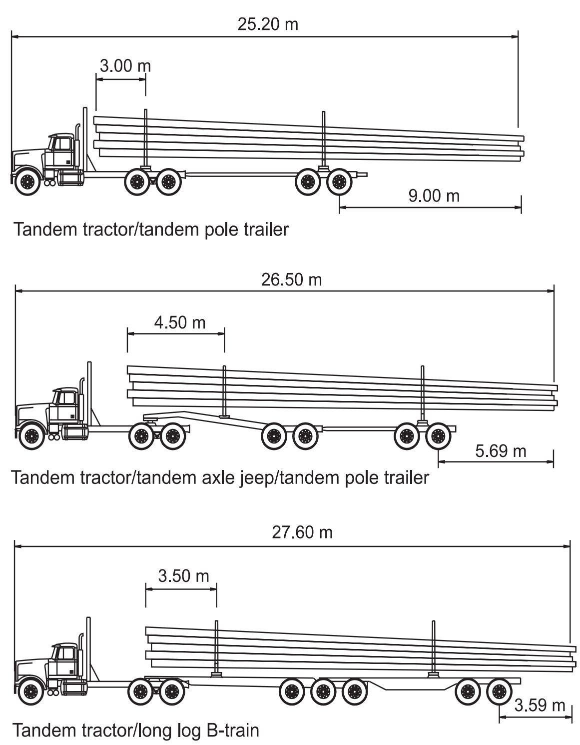


Figure 4. Alberta long log configurations with typical load length of 21 m.

and with the tractor and trailers aligned, a bead of grease was placed on the underside of the trailer bolster plate parallel to the kingpin slot and extending forward from the fifth wheel plate (Figure 5). After completing a turn and with the tractor and trailers once again aligned, the distance that the kingpin slid could be determined by measuring the distance from the fifth wheel plate to the furthest point of the grease bead that had been wiped away by the fifth wheel plate. Measurements were taken during cornering and after long stretches of road, including mainline and highway travel, to determine the kingpin movement during normal operation.

Ownership and operating cost

An estimate of the ownership and operating cost of the long log B-train configuration was made using the Foothill's Transportation Cost Model (Blair 1999). This cost was then compared to the ownership and operating cost of both the tandem tractor/tandem pole trailer and the tandem tractor/tandem jeep/tandem pole trailer configurations. The analysis compares these three long log configurations operating in a typical log haul that is 40% Alberta legal weights and 60% Alberta winter Green Route weights.

Vehicle dynamics

The University of Victoria/National Research Council of Canada (UVic/NRC) log truck yaw/roll model developed for the Western Log Truck Configurations Study (Parker and Amlin 1998) was reviewed to determine its ability to accurately predict the dynamic performance of the long log B-train. The NRC Centre for Surface Transportation Technology (CSTT) was contracted to review the yaw/roll model and to give its opinion regarding the dynamic performance of the long log B-train. The yaw/roll model predicts the dynamic performance of a configuration based on nine different performance measures (Appendix 1). As part of the review, NRC/CSTT personnel made field visits to Peace River to observe the configuration in operation.

Vehicle dynamic simulations were conducted according to the weight and dimension regulations of Alberta's Motor Transport Act (1998) for a long log B-train. For reference, three existing configurations were also evaluated: a short log B-train, a tandem tractor/tandem pole trailer, and a tandem tractor/tandem jeep/tandem pole trailer. These comparisons show the dynamic performance of the configurations loaded to both the Alberta legal weights and the Alberta winter Green Route weight allowances. The results are shown for a range of block load densities[7] (340 kg/m^3 to 555 kg/m^3) that is representative of the Alberta resource.

Using a tridem drive B-train may alleviate potential traction limitations and offer other operational improvements compared to a tandem drive B-train. Therefore, the NRC/CSTT assessment of the long log B-train included a vehicle dynamics evaluation using a tridem drive tractor.

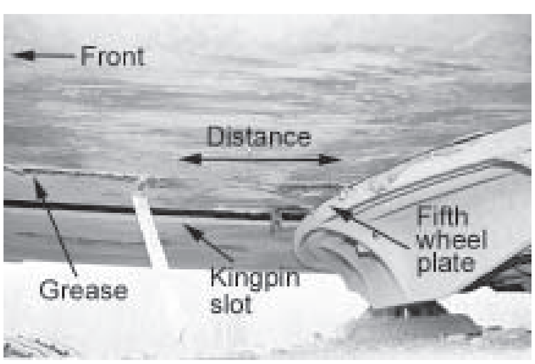


Figure 5. Underside of trailer bolster plate showing grease for determining slider movement.

Results and discussion

Cornering performance

The results of the field trials performed in Peace River and the corresponding PathTracker predictions are shown in Tables 1, 2 and 3 for vehicle sweep, rear load sweep and front load sweep, respectively. These tables illustrate that PathTracker is an acceptable tool for predicting the cornering performance of the long log B-train. Although PathTracker tended to underestimate the values, it has been shown by Jesualexander

[7] Block load density is calculated from payload weight and block volume (including air voids, which typically make up 40% of the volume).

Note:
PathTracker simulates the vehicles in an ideal situation where the vehicle starts from a perfectly aligned position and travels along the path without deviation. A slight misalignment between the tractor and its trailers, small steering corrections made while negotiating the path, and undulations in the test surface may explain some of the discrepancies between the predicted and measured values.

(1992) that the degree of variation (3–17%) between the measured and predicted values is acceptable.

Table 4 compares the cornering performance of the long log B-train, the tandem tractor/tandem pole trailer, and the tandem tractor/tandem jeep/tandem pole trailer with Alberta's intersection design standard based on the dimensions in Figure 4. The long log B-train compares favourably with the other long log configurations and would fit within the existing Alberta intersection design standards. The long log B-train is the longest of these configurations and therefore has the largest vehicle sweep. The front and rear load sweeps of the long log B-train are considerably less than the intersection design standard and are as good as, if not better than, those of the other configurations.

The front overhang limit is based on not exceeding the front load sweep of the tandem tractor/tandem jeep/tandem pole trailer. The rear overhang of the long log B-train is limited by the intersection design standard rear load sweep (3.4 m) and the overall length limit of 30.5 m. The PathTracker analysis showed that the front overhang should not exceed 4.0 m while the rear overhang should be limited to 6.5 m. The cornering performance of a long log B-train with the dimensions shown in Figure 6 would exhibit similar performance compared to existing long log configurations and would be within the Alberta intersection design standards. The inter-bunk spacing (shown to be 10.7 m) limits the actual log length that can be carried by the configuration. It is recommended that the log length be at least 2.0 m longer than the inter-bunk spacing, therefore, the minimum log length for this configuration would be 13 m. When carrying the minimum log length, loading becomes more complicated because it will be necessary to shift logs to obtain maximum axle weights.

Note:
This configuration can also haul short logs if additional bunks are added to each trailer and the sliding kingpin mechanism is locked.

Table 1. Predicted and measured vehicle sweep

Corner radius (m)	Predicted vehicle sweep (m)	Measured vehicle sweep (m)	Difference [a] (%)
12.5	7.94	7.75	+2.45
15.0	7.38	7.60	-2.89
25.0	5.78	6.20	-6.77

[a] + indicates that model overestimates relative to field measurement.
- indicates that model underestimates relative to field measurement.

Table 2. Predicted and measured rear load sweep

Corner radius (m)	Predicted rear load sweep (m)	Measured rear load sweep (m)	Difference (%)
12.5	2.14	2.39	-10.46
15.0	1.58	1.71	-7.60
25.0	1.11	1.33	-16.54

Table 3. Predicted and measured front load sweep

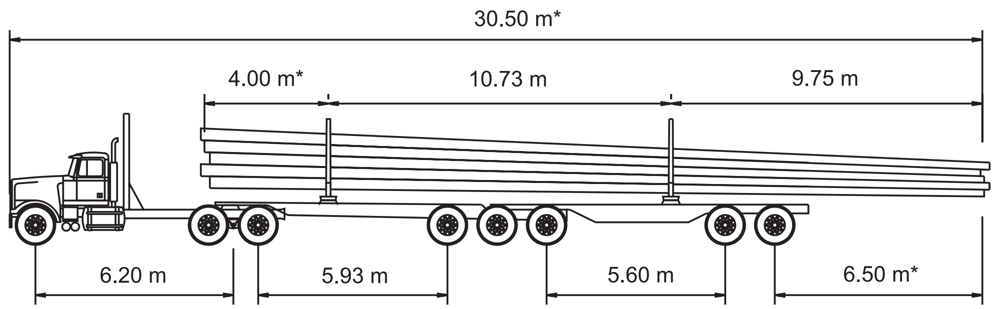
Corner radius (m)	Predicted front load sweep (m)	Measured front load sweep (m)	Difference (%)
12.5	0.54	0.53	+1.89
15.0	0.51	0.58	-12.07
25.0	0.42	0.44	-4.54

Table 4. Cornering performance of long log configurations

Configuration	Vehicle sweep (m)	Front load sweep (m)	Rear load sweep (m)
Design standard	8.78 [a]	1.35 [a]	3.44 [a]
Tandem tractor/tandem pole trailer	5.66	0.39	3.18
Tandem tractor/tandem jeep/tandem pole trailer	6.23	0.61	1.91
Long log B-train	7.59	0.45	1.46

[a] From Jesualexander (1992).

Figure 6. Long log B-train with critical dimensions identified.



Operation and maintenance

Nine long log B-train prototypes owned by Homestead Holdings are in trial operation for DMI in Peace River: one 1994 Lakewood trailer, six 1995 Superior trailers, one 1996 Advance trailer and one 1997 Superior trailer. As of June 1999, the oldest unit had accumulated over 1.6 million km of service, the next six oldest trailers had averaged over 1.2 million km each, the eighth trailer had accumulated over 900 000 km, and the newest trailer had accumulated just over 600 000 km. Only the oldest unit has had its fifth wheel assembly completely replaced (at approximately 1.4 million km) while the oldest seven have had their bolster plates (see Figure 2) replaced due to wear from sliding against the fifth wheel. None of the units have had their sliding kingpin mechanisms replaced.

During its operating cycle, the long log B-train returns to the loading site empty, with the lead trailer towed while carrying the pup trailer. At the loading site, the loader lifts the pup trailer off and couples it to the fifth wheel of the lead trailer. The driver makes sure that the trailers are aligned and that the sliding kingpin is fully to the rear of the slide before the logs are loaded. This is important for two reasons: enough free slide distance must be available to allow the kingpin to travel forward during turns; and if the kingpin is too far forward and there is articulation between the trailers, the trailers will not align themselves when the truck moves away. After the load is removed at the mill, the loader or a trailer re-load lifts the pup trailer back onto the lead trailer.

To gain insight into the length of travel of the sliding kingpin mechanism during the truck's duty cycle, FERIC took detailed measurements on three different trucks during regular operation (Table 5).

The variation in kingpin travel values between trials is small and likely a result of different lines of travel along the roadway or around a corner. For example, in trial 2 the driver maneuvered around potholes and ruts while travelling along the mainline. Trial 2 also had higher travel speeds along both the mainline and the highway. The slot in which the kingpin slides is over 90 cm long. The longest kingpin travel occurred on the block road corner and averaged 29 cm, therefore using about one-third of the available sliding room. The kingpin slid the most during low-speed maneuvers in tight-radius corners

Table 5. Measurements of kingpin travel during regular operation

Description	Direction of turn	Average speed (km/h)	Pin travel Trial 1 (cm)	Pin travel Trial 2 (cm)	Pin travel Trial 3 (cm)	Avg kingpin travel (cm)
Block road corner	Left	10	31	29	28	29
Block road onto mainline	Right	10	24	22	18	21
Travel mainline	Both	55	2	9	4	5
Mainline onto highway	Right	10	18	14	16	16
Travel highway	Both	70	2	2	1	2
Highway into mill	Right	10	4	3	3	3

where the potential for risk exposure to the public is minimal. In other words, if the kingpin bottoms at the front of its slide during a low-speed turn, the driver would feel the resistance and be able to take corrective action without causing a potential safety hazard. If the kingpin bottoms during a turn and the driver continues driving around the corner, the tires on the lead trailer will scuff or drag around the corner until the configuration straightens out.

Ownership and operating cost

The ownership and operating costs of the long log B-train were determined for a situation where the haul is comprised of 40% Alberta legal weights and 60% Alberta winter Green Route weights (Table 6). The calculations assume that each configuration operates 1800 hours per year, has an expected life of 5 years and a salvage value of 20%, and allows 10% for profit. It is recognized that as the utilization increases, the ownership costs will decrease. Operating cost index is calculated as the maximum payload divided by the total ownership and operating cost (including profit). This was 0.37 for the long log B-train which is comparable to the other configurations.

The long log B-train is allowed 62 500 kg[8] GVW compared to 39 600 kg and 56 600 kg GVW for the other two configurations under Alberta legal weight conditions. Under Alberta winter Green Route weights, the long log B-train and the tandem tractor/tandem jeep/tandem pole trailer are allowed 65 000 kg GVW while the tandem tractor/tandem pole trailer is allowed 55 600 kg GVW. Compared to the B-train, both of the other configurations experience a substantial gain in allowable GVW under Alberta winter Green Route weights. Although the higher tare weight of the long log B-train configuration limits its payload and therefore its productivity, the operating cost index of the long log B-train is similar to existing long log configurations. The long log B-train would be more effective in operations with a larger percentage of the haul in the summer or on winter Red Routes.

Vehicle dynamics

The NRC/CSTT found that the UVic/NRC yaw/roll computer model was appropriate for predicting the dynamics of the long log B-train (Billing and Preston-Thomas 2000). The NRC/CSTT also reviewed several options for longitudinal compensation for the long log B-train and found that the sliding kingpin on the second trailer is the preferred option, in terms of vehicle dynamics, to allow for longitudinal compensation.

The results of the dynamic analyses at maximum legal weights for the short log B-train, long log B-train, tandem tractor/tandem pole trailer, and tandem tractor/tandem jeep/tandem pole trailer can be seen in Table 7. The range given for the performance measures

[8] As of April 1, 2001 the GVW was increased to 63 500 kg. All references to the GVW in this report remain at 62 500 kg which was in effect at the time of this study. See Implementation for information on how the increase in GVW may affect the results.

Table 6. Estimated ownership and operating costs for Alberta long log configurations

	Long log B-train	Tandem tractor/tandem pole trailer	Tandem tractor/tandem jeep/tandem pole trailer
Ownership cost ($/h)	29.50	22.20	25.90
Operating cost ($/h)	75.00	65.10	72.00
Total including profit ($/h)	115.00	96.00	107.80
Tare weight (tonnes)	21.7	14.2	19.2
Maximum payload (tonnes) [a]	42.3	34.9	42.4
Operating cost index (tonnes/$/h) [b]	0.37	0.36	0.39

[a] Payload is based on 40% Alberta legal weights and 60% Alberta Green Route weights.
[b] The higher the operating cost index, the better the configuration.

Table 7. Dynamic performance of the long log B-train compared to other popular configurations (legal weights)

Performance measure	Pass criteria	Short log B-train	Long log B-train	Tandem tractor/tandem pole trailer	Tandem tractor/tandem jeep/tandem pole trailer
Gross vehicle weight (kg)		62 500	62 500	39 600	56 600
Understeer coefficient	>-4.51	-2.34–0.63	-1.22–0.57	1.91–2.50	2.78–2.94
Static rollover threshold (g)	>0.35	0.33*–0.40	0.38–0.46	0.40–0.45	0.32*–0.34*
Load transfer ratio	<0.60	0.44–0.62*	0.39–0.50	0.48–0.49	0.54–0.59
Rearward amplification	<2.20	1.77–1.84	1.70–1.74	1.73–1.77	2.24*–2.27*
Friction demand	<0.10	0.11*	0.14*	0.06–0.07	0.03–0.04
Lateral friction utilization	<0.80	0.56–0.57	0.60	0.50	0.56
Low-speed off-tracking (m)	<6.00	4.90–4.94	4.88-4.90	2.92–2.93	3.83–3.86
High-speed off-tracking (m)	<0.46	0.59*–0.64*	0.57*–0.62*	0.41–0.44	0.52*–0.54*
Transient off-tracking (m)	<0.80	0.57–0.68	0.52–0.59	0.43–0.50	0.57–0.58

* Indicates performance standard not met.

depends on the block load density. The lower density results in the higher end of the range for the load transfer ratio, rearward amplification, high speed off-tracking and transient off-tracking, and the lower end for the static rollover threshold. The measures from the low-speed maneuver are hardly affected by the payload density.

The long log B-train exhibited superior dynamic performance in key criteria—static rollover threshold and load transfer ratio—compared to the two existing long log configurations. Similar to the short log B-train, the long log B-train did not meet the less critical performance measures of friction demand and high-speed off-tracking. As friction demand is a low-speed maneuver, failing to meet this performance measure is not deemed to cause an increase in risk to public exposure. In addition, high-speed off-tracking generally occurs at higher speeds on large-radius corners and requires sufficiently large lateral accelerations to create substantive levels of tire slip angle to obtain an outboard deflection. Because these conditions for high-speed off-tracking are generally not common to log haul operations, the potential exposure to outboard deflections is also limited. The long log B-train exhibited better dynamic performance than the short log B-train in the static rollover threshold, load transfer ratio and rearward amplification criteria.

Table 8 shows that the long log B-train generally exhibits superior dynamic performance at winter Green Route weights. The GVW of both B-trains increases by only 4%, whereas the GVW of the tandem tractor/tandem pole trailer increases by 40% and the tandem tractor/tandem jeep/tandem pole trailer increases by 15%. Under maximum winter weight conditions, neither the tandem tractor/tandem jeep/tandem pole trailer configuration nor the tandem tractor/tandem pole trailer configuration meet the pass criteria for static rollover threshold, whereas the long log B-train exceeds the standard.

As traction limitations are often found in log hauling operations, the NRC/CSTT also undertook two computer evaluations using a tridem tractor in combination with this long log B-train. The first of these evaluations (LLB2) replaced the tandem tractor with a tridem tractor and eliminated the first axle of the tridem group on the lead trailer which resulted in a longer than necessary wheelbase on the lead trailer. The second evaluation (LLB3) used the minimum possible trailer dimensions for a tridem-tandem B-train. Both of the tridem drive B-trains exhibited similar dynamic performance (Table 9) compared to the tandem drive B-train, and have superior rollover resistance compared to a tandem tractor/tandem jeep/tandem pole trailer configuration.

Table 8. Dynamic performance of the long log B-train compared to other popular configurations (winter Green Route weights)

Performance measure	Pass criteria	Short log B-train	Long log B-train	Tandem tractor/tandem pole trailer	Tandem tractor/tandem jeep/tandem pole trailer
Gross vehicle weight (kg)		65 000	65 000	55 600	65 000
GVW increase (%)		4	4	40	15
Understeer coefficient	>-4.51	-3.30--2.65	-1.98--0.53	-1.75--0.26	0.45–1.09
Static rollover threshold (g)	>0.35	0.29*–0.37	0.35–0.44	0.28*–0.33*	0.27*–0.32*
Load transfer ratio	<0.60	0.42–0.59	0.41–0.55	0.65*–0.78*	0.59–0.73*
Rearward amplification	<2.20	1.71–1.79	1.73–1.77	2.00–2.60*	2.45*–2.65*
Friction demand	<0.10	0.11*	0.14*	0.05	0.04
Lateral friction utilization	<0.80	0.68–0.72	0.61–0.62	0.59–0.61	0.61
Low-speed off-tracking (m)	<6.00	4.92	4.89	2.92	3.93
High-speed off-tracking (m)	<0.46	0.62*	0.60*–0.67*	0.54*–0.56*	0.60*–0.65*
Transient off-tracking (m)	<0.80	0.51–0.63	0.55–0.64	0.66–0.73	0.69–0.81*

* Indicates performance standard not met.

Table 9. Dynamic performance of long log B-train configurations (legal weights)

Performance measure	Pass criteria	Tandem drive/ long log B-train	Tridem drive/ long log B-train (LLB2)	Tridem drive/ long log B-train (LLB3)
Gross vehicle weight (kg)		62 500	62 500	62 500
Understeer coefficient	>-4.51	-1.22–0.57	0.27–2.09	0.16–2.20
Static rollover threshold (g)	>0.35	0.38–0.46	0.35–0.42	0.35–0.42
Load transfer ratio	<0.60	0.39–0.50	0.37–0.48	0.39–0.51
Rearward amplification	<2.20	1.70–1.74	1.50–1.53	1.58–1.61
Friction demand	<0.10	0.14*	0.03–0.04	0.04
Lateral friction utilization	<0.80	0.60	0.82*–0.83*	0.82*
Low-speed off-tracking (m)	<6.00	4.88–4.90	5.22	4.79–4.80
High-speed off-tracking (m)	<0.46	0.57*–0.62	0.53*–0.56*	0.51*–0.55*
Transient off-tracking (m)	<0.80	0.52–0.59	0.45–0.52	0.49–0.57

* Indicates performance standard not met.

Alberta regulations

Alberta Transportation reviewed the findings of this evaluation and found the tandem tractor/long log B-train configuration acceptable for the Alberta log haul. This configuration is legal in Alberta under permitted conditions with a maximum overall length of 30.5 m, a front overhang measured from the pivot point of the front bunk of 4 m, and a rear overhang measured from the centre of the last axle of 6 m. This rear overhang dimension is consistent with Alberta Transportation's existing rear overhang dimensions (3, 6 and 9 m) for its log haul route maps. As well, a rear overhang of 6 m from the centre of the last axle is approximately 9 m from the last bunk. Alberta Transportation has limited the rear overhang of the long log B-train configuration to 6 m, which is 0.5 m shorter than that recommended by FERIC, but the reduction will not adversely affect the performance of the configuration. Limiting the rear overhang will result in a smaller rear load sweep for the configuration. In addition, the long log B-train is allowed the same GVW as the short log B-train, normally 62 500 kg and 65 000 kg under Alberta winter Green Route weights.

Conclusions

Based on the findings of this study, Alberta Transportation will allow the general operation of tandem tractor/long log B-trains on public roads in Alberta. Some of the regulatory conditions will be a maximum overall length of 30.5 m, a maximum front overhang of 4 m, a maximum rear overhang of 6 m, and a GVW limit of 62 500 kg (65 000 kg Alberta winter Green Route weights). With these dimensions, the cornering performance of the long log B-train will be similar to other long log configurations and within the limits of Alberta's intersection design standards.

The maintenance and operational experience did not yield any safety-related concerns. The maximum travel of the sliding kingpin was less than 30 cm and this was for a tight, low-speed corner within the cutblock. The available travel length of the slider is about 90 cm, so there is a considerable safety margin. However, since it is not evident where the kingpin is in the slide, the driver should always ensure that the kingpin is at the rear of the slide, and the vehicle is straight when being loaded.

The long log B-train had an operating cost index of 0.37 (tonnes/$/h) which is comparable to the other long log configurations (0.36 for the tandem tractor/tandem pole trailer and 0.39 for the tandem tractor/ tandem jeep/tandem pole trailer). The long log B-train is one of the more productive configurations under Alberta legal weight conditions but loses productivity under Alberta winter Green Route weights because it does not experience a substantial GVW gain compared to other configurations.

The long log B-train exhibited superior dynamic stability compared to both the tandem tractor/tandem jeep/tandem pole trailer and the tandem tractor/tandem pole trailer configurations under both Alberta legal weights and winter Green Route weight allowances. The long log B-train also exhibited similar dynamic performance to the short log B-train which is considered to be one of best dynamically performing heavy haul configurations for its GCW range.

The NRC/CSTT predicted the dynamic performance of tridem drive tractors with long log B-trains and found they exhibited similar performance to the tandem drive tractor and long log B-train configuration.

In general, the long log B-train clearly exhibits better dynamic performance than the two other long log configurations, whether loaded to maximum legal weights or maximum Green Route winter weights. It may be possible to improve the dynamic performance of the long log B-train by optimizing the trailer wheelbases and the axle spacings. However, caution is advised because changes may affect its cornering performance.

Implementation

- Now that Alberta Transportation has allowed these configurations, they may be incorporated into log haul fleets where appropriate. As the long log B-train was found to be as productive as other long log configurations under Alberta legal weights, operations that have a large portion of their haul during the summer months would be ideal candidates for this configuration. The proportion of winter and summer haul will directly affect how much advantage can be achieved by using the long log B-train. As well, this configuration can be easily modified with the addition of bunks to both trailers so that it can carry short logs. This flexibility to carry both long and short logs may be advantageous for some forest operations.
- It is recommended that the minimum log length be at least 2 m longer than the inter-bunk spacing; in this scenario, the inter-bunk spacing was 10.73 m and the minimum log length should be 13 m. When carrying the minimum log length, it will be necessary to shift logs to obtain sufficient front and rear overhangs for proper weight distribution.
- Although this study used the maximum B-train GVW allowance of 62 500 kg, the Alberta government increased this to 63 500 kg as of April 1, 2001. A benefit of this increase in GVW allowance is that the ownership costs decrease as productivity increases. The cornering performance of the configuration will not change because the length dimension regulations have not changed. The influence of the additional 1 000 kg of

payload can somewhat be interpolated as dynamic performance evaluation was undertaken at both 62 500 kg and 65 000 kg. The long log B-train loaded at Alberta winter Green Route weights (65 000 kg) only just failed to meet the criteria for high speed off-tracking and friction demand, and the configuration loaded to 63 500 kg would be expected to perform slightly better. The static rollover threshold would be expected to decrease and the load transfer ratio would be expected to increase, but neither should fail to meet the performance standard.

- The driver of a long log B-train configuration should ensure that the trailers are aligned prior to loading logs and that the kingpin is to the rear-most location within the sliding mechanism. These measures will prevent the sliding kingpin from bottoming during a turn and allow for the trailers to properly track behind the tractor and negotiate turns smoothly.
- The long log B-train is allowed the highest Alberta legal weight but tends to have a higher tare weight than other long log configurations. Therefore, methods of reducing tare weight should be explored to further improve its productivity. It may be possible to improve the trailer tare weight by using composite materials or aluminum bunks, and optimizing trailer design.
- As traction limitations are a serious concern for the log hauling industry, a field evaluation with a tridem drive tractor/long log B-train to determine its feasibility should be undertaken. It would be important to determine minimum log lengths and optimum trailer wheelbases for a tridem drive/long log B-train.
- Even though the long log B-train is a good dynamic performer, it may be possible to further optimize the dimensions of the configuration for improved dynamic performance. For example, the front bunk on the lead trailer is quite high (1.98 m). This results in a high centre of gravity, which in turn adversely affects the static rollover threshold and other performance measures. Developing a lower front bunk would be beneficial.

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Appendix I

Definition of Performance Measures [a]

Static rollover threshold (SRT): The static rollover threshold is the tractor lateral acceleration, measured by acceleration of gravity (g), at which the vehicle just rolls over in a steady turn. This measure is known to correlate well with the incidence of single truck rollover accidents in highway service.

High-speed off-tracking (HSOT): High-speed off-tracking is the lateral offset, in metres, between the path of the steer axle of the tractor and the path of the last axle of the vehicle in a steady turn of 0.2 g lateral acceleration. Since the driver guides the tractor along a desired path, there is a potential safety hazard if the trailer tires follow a more outboard path that might intersect a curb or other roadside obstacle, or intrude into an adjacent lane of traffic.

Understeer coefficient (USC): The understeer coefficient is a measure of vehicle lateral directional stability and handling. It is calculated at a lateral acceleration of 0.25 g in a steady turn.

Load transfer ratio (LTR): The load transfer ratio is the fractional change in load between left-hand and right-hand side tires of a vehicle in an obstacle avoidance maneuver. It indicates how close the vehicle came to lifting off all the tires on one side, a precursor to rollover.

Transient high-speed off-tracking (TOT): Transient high-speed off-tracking is the peak overshoot, in metres, in the lateral position of the rear-most trailer axle from the path of the tractor front axle in an obstacle avoidance maneuver. It is an indication of potential to sideswipe a vehicle in an adjacent lane, or for rollover due to the impact of a curb strike. This measure quantifies the "tail-wagging" response of a trailer to a rapid steer input in a manner related directly to highway safety.

Rearward amplification (RWA): Rearward amplification is the ratio of rearmost trailer peak lateral acceleration to tractor peak lateral acceleration in an obstacle avoidance maneuver. It is another way to quantify the tail-wagging response of a trailer to a rapid steer input.

Friction demand (FD): Friction demand is a measure of the resistance of multiple axles to travel around a tight-radius turn, such as at an intersection. It results in a "demand" for tire side force at the tractor drive axles. When the pavement friction level is low, a vehicle whose friction demand exceeds the friction available will produce a jackknife-type response of the tractor. Friction demand describes the minimum tire-pavement friction necessary for a vehicle to negotiate an intersection turn without suffering such loss of control.

Lateral friction utilization (LFU): Lateral friction utilization is the lateral friction at the front axle necessary for the vehicle to be able to make a right-hand turn at an intersection. It is particularly significant for tridem drive tractors.

Low-speed off-tracking (LSOT): Low-speed off-tracking is the extent to which the path of the rearmost axle of a vehicle tracks inside the path of the tractor front axle in a typical 90-degree right-hand turn at an intersection. This property is relevant to the "fit" of the vehicle on the road system, and has implications for safety as well as abuse of roadside appurtenances.

[a] From Billing and Preston-Thomas (2000).