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EVALUATION OF WIDE-BASE SINGLE TIRES FOR A 9-AXLE B-TRAIN LOG TRUCK

PROJECT NUMBER: 301013563

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May 2020

Wide-base single tires are receiving renewed interest in the forest transport sector due to their inability to capture rock, as happens with dual tires, which can improve road user safety. Potential fuel efficiency gains are also attractive and, in support of this, the fuel consumption of a 9-axle tridem drive B-train truck was measured relative to a control truck under the following conditions: baseline, wide-base single tires on truck and trailer, and wide-base single tires on trailer only. The fuel consumption differences were insignificant, but the reductions in tare weight were significant. The tare reduction can be best used to carry more payload and increase revenue. Other potential benefits of wide-base tires are related to improvement of vehicle, operator, and public safety. Recommendations for implementation and economics of fitting wide-base single tires are discussed.

Project number: 301013563

Technical Report TR 2020 N23

ACKNOWLEDGEMENTS
This project was financially supported by Natural Resources Canada, Northern Development Initiative Trust, Canfor Corporation, and Wilson Bros Logging Ltd.

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1 INTRODUCTION

Almost all logging truck fleets use dual tires on their drive and trailer axles. Dual tires have been in use for decades and, while proven performers, they are also susceptible to having rocks being captured between the inner sidewalls, which can then get discharged with high-risk force. Log truck fleets are aware of this issue and are looking to improve public safety in the communities where they operate their trucks. There are policies in place to reduce the risk, which include visually checking dual tires for trapped rocks, outfitting the truck with tire guards or fenders, and employing other technical means, such as installing devices that sweep between the tires to clear trapped rocks. These measures may mitigate the risks of fly rock; however, near misses can still happen, such as rocks striking windshields, and can be inches from being fatal or life altering. Such accidents are preventable, and wide-base tires deserve further investigation from a safety standpoint.

As demonstrated in highway-based truck fleets, replacing dual-tire combinations with wide-base single tires (WBSTs) can provide some benefits: WBSTs cost less, weigh less, and have lower rolling resistance than the conventional dual tires they replace. These advantages were proven for on-highway applications through fuel consumption tests performed by FPInnovations, which showed up to 9.7% improvement in fuel economy for a tractor-trailer combination equipped with wide-base tires (Surcel & Michaelsen, 2010). Michelin has expanded its line of wide-base tires to include tires for on-/off-road applications. According to Michelin, its X One XZY3 on-/off-road wide-base tire is an all-position radial tire designed for weight and fuel savings in on-/off-road applications.

In previous FPInnovations studies with wide-base tires similar to the X One XZY3, traction for off-highway applications was poor, which limited their adoption (Jokai, 2014). Given the X One XZY3's limited traction in the challenging conditions encountered in the logging environment, alternative tire brands and models were considered. The Michelin XZL wide-base tire was identified as a high traction all-position tire capable of delivering the needed performance and was proposed for use on the truck's drive axles only, with the conventional X One XZY3 better suited for trailer use, proposed for application there.

2 OBJECTIVES

This project had the following objectives:

- Determine potential fuel savings from use of WBSTs;
- Evaluate the WBST handling characteristics through driver feedback;
- Reduce fly rock from dual tires with WBST use (an objective for WBST implementation, with no methodology for scientific evaluation);
- Calculate economic cost benefits for improved payload and fuel savings.

While not part of this study, the following future needs were identified:

- Evaluate durability, puncture resistance, and tire wear of WBSTs on a log truck;
- Evaluate the traction capabilities of WBSTs in various operating conditions or seasons.

3 METHODOLOGY

The test vehicles were 2019 Western Star 4900SF tractors powered by Detroit Diesel DD16 600 hp (447 kW) engines connected to 21 m (69.1 ft.) stretch super B-train trailers (Figure 1). Further details on the test vehicles are shown in Appendix A.

Figure 1. Test truck with wide-base tires on drive and trailer axles

The test and control vehicles had identical specifications and were loaded similarly with gross weights of 71 230 and 71 910 kg, respectively. The payload of the test vehicle was not adjusted after fitment of WBST. In the study, the vehicles usually transported saw logs from the woods to a sawmill in Houston, and sometimes to mills in the Prince George area. Both test and control vehicles in the baseline condition were fitted with dual 11R24.5 tires with full tread depth. The tire pressure for the 11R24.5 tires were set to 621 kPa (90 psi), which is 69 kPa (10 psi) below what this fleet would use during non-winter months, to provide a larger tire footprint and traction on snow- and ice-covered roads.

The test vehicle's first modified condition was fitting WBSTs to tractor and trailers as shown in Table 1.

Table 1. Test tires fitted to drive and trailer axles

Position	Brand and model	Size	Tire inflation pressure as tested/maximum (kPa)
Drive axles	Michelin XZL	445/65R22.5	758/830
Trailer axle	Michelin X One XZY3	455/55R22.5	793/900

The WBST pressures on both drive and trailer axles were set below the maximum recommended, but still in observance of the manufacturers' load and pressure recommendations. The drive tires were set 72 kPa (10.4 psi) lower and the trailer tires were set 107 kPa (15.5 psi) lower than the maximum recommended inflation pressures. The trailer tires had a greater pressure reduction because the supply of compressed air at the shop was regulated at a lower limit for worker safety compliance. The first test condition involved the truck and trailers fitted with WBSTs and the second condition was trailers only fitted with WBSTs.

The WBSTs on the drive axles were aggressive high-traction tires, whereas the trailer tires, while suitable for off-road use, were designed primarily for highway use, as shown in Figure 2.

Figure 2. Wide base tires—drive axles (left) and trailer axles (right)

The test route comprised equal sections of provincial highways and forest service roads with the average test cycle time of one hour and twenty minutes. The trucks went from the truck yard in Houston, travelled west on Highway 16, and turned around at a large wide turnout which was about 21 km from the starting point, returned to Houston, and proceeded south on the Morice River Forest Service Road where the trucks turned around at the 21 km marker and returned to the truck yard in Houston. The highway distance was approximately 42 km and, similarly, the Forest Service Road distance was 42 km, giving a total trip length of 84 km, as shown in Figure 3.

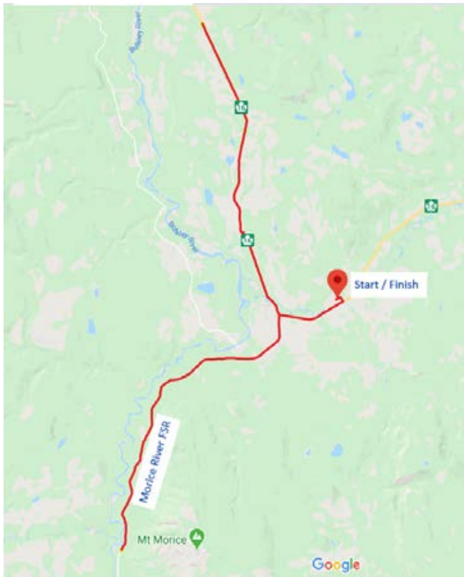

Figure 3. The test route from Houston, B.C.

The roads in Houston were generally covered with loose snow and ice, and the highway portion was mostly bare asphalt. The Morice River Forest Service Road section had compact snow and ice with low traction. The maximum speed on the road was 70 km/h with 60 km/h average speed. The maximum speed on the highway was 100 km/h with average cruising speed of 90 km/h. Both sections had steep grades that required the trucks to gear down, with the Forest Service Road requiring caution in some slippery sections. The weather conditions ranged from light snow to clear skies with daytime lows of -12 °C to highs of 1 °C. At no time during the study did the frozen Forest Service Road thaw and become soft.

The drivers assigned to each truck were instructed to drive as they would normally during their daily duties. The goal was to produce repeatable results and remove the variable that driver performance can have on fuel consumption. Each day before the start of testing, the drivers would travel the test route to warm their truck's engine and drivetrain to operating temperatures.

Controlled fuel consumption tests were performed based upon the principles set out in SAE J1321 Fuel Consumption Test Procedure – Type II (SAE International, 2012). The test compared the fuel consumption of the test vehicle under three different conditions—truck and trailers with dual tires, WBSTs on truck and trailers, and WBSTs on trailers only—to that of a control vehicle. A minimum of three test runs were conducted for each of the baseline and test conditions. Any differences in the fuel consumption ratios between the baseline and test phases were due to the changes made in the test vehicle, that is, from dual tires to WBSTs.

Fuel consumption was measured gravimetrically by installing external fuel tanks on each of the trucks. The trucks' fuel systems were modified by plumbing both the supply and return lines into the portable tanks, as shown in Figure 4.

Figure 4. Portable tank installed on a test truck

The tanks were weighed before and after each run to determine the mass of fuel consumed. Fuel temperature will increase as it is pumped from tank to engine, and then as a portion is returned to the tank. The increase in fuel temperature will cause the fuel to expand in volume, decreasing the fuel density. For this reason, the gravimetric method that determines fuel consumption by weight is preferred to a volumetric method because it does not require corrections for temperature.

4 RESULTS

4.1 Driver feedback on traction and stability

The driver had the opportunity to drive the truck on a warm-up cycle on the highway and on the road with the newly fitted WBSTs on drive and trailer axle positions. Traction was good in snow, compact ice, and bare pavement. Temperatures above freezing with snow melting were not encountered; such surfaces, when wet, would be considered the most extreme. During the test, there was no time that traction was limited, and fitting chains was never required. The stability of the vehicle with WBSTs was good compared to that of dual tires as characterized by the driver. With the 50.8 mm (2 in.) outset wide-base wheels, the wheel track width was 4.1 and 4.6 cm greater for the truck and trailer axles, respectively. For the WBSTs, the out-to-out width of the outer tire sidewalls measured approximately 2.5 cm narrower per side, as shown in Figure 5.

Figure 5. Outer tire sidewall difference with dual tire in background

After the WBSTs were tested on the drive and trailer axles, the tractor was refitted with dual tires and the driver had the opportunity to assess the handling of the vehicle with dual tires on the tractor and WBSTs on the trailers. Upon returning the dual tires to the drive axles, the driver could feel a slight improvement in response to directional changes, such as during lane change and cornering manoeuvres.

Instrumented testing was not performed on the WBST combinations to assess braking or acceleration. Acceleration or power may have improved slightly, as the driver reported having been able to negotiate a hill on the test route a half gear higher from what was possible when the truck was fitted with dual tires. Overall, the driver felt there was more power available as well, which is not surprising, as the tare reductions for both test conditions saw significant weight removal from the rotating mass of the wheel and tires.

4.2 Reduced tare weight

The trucks were loaded to full capacity and weighed at the sawmill in town. The gross weights for the test and control trucks were 71 230 and 71 910 kg, respectively. Since the WBSTs are lighter than the dual tires they replaced, the gross weight of the test truck was lower during the test phase with the WBSTs, as shown in Table 2. The log loads were not adjusted during the tests. The change in gross weight for the WBST-equipped trailer only and the truck and trailer decreased by

0.8 and 1.4%, respectively. This difference in mass would likely not have had a measurable impact on fuel consumption but adding more logs to the load may have an impact on fuel consumption due to a taller load increasing the truck's aerodynamic drag. This variable was not addressed during any of the fuel consumption tests.

The tire and wheel combinations were weighed, and the results are presented in Table 2.

Table 2. Weight of wheel and tire combinations used in tests and tare reduction.

Tire type and position	Weight of wheel and tire (kg)
Single 11R24.5, drive	97.6
Single 11R24.5, trailer	87.7
WBST 445/65R22.5 Michelin XZL, drive	131.1
WBST 455/55R22.5 Michelin X One XZY3, trailers	116.7
Tare reduction for WBSTs on trailers only	587
Tare reduction for WBSTs on truck and trailers	972

As shown in Table 2, there is a significant tare weight reduction when switching to WBSTs, which can be used to carry additional payload. Both options presented—replacing the dual tires with WBSTs on the entire combination or just the trailer—mean payloads can be increased accordingly. This gives a fleet two distinct options for implementation, which will be fully explored in the Implementation section of this report.

4.3 Fuel consumption

The baseline condition was measured on February 4 and 5, 2020. The first test, WBSTs on truck and trailers, was performed February 6, and the second test of WBSTs on the trailers was completed on February 7. Table 3 shows the fuel savings for both tests.

Table 3. Summary of fuel savings

Condition	Fuel savings	Confidence interval
WBSTs on truck and trailers	0.98%	± 2.9%
WBSTs on trailers	None	None

When the truck and trailers were equipped with wide-base tires, the result was a 0.98% decrease in fuel consumption. Given that the confidence interval is larger than the result, it could be said there was no significant change in fuel consumption found and the results are inconclusive. This result was not unanticipated, as the Michelin XZL is not designed for energy efficiency; rather, the tire's design priority is off-road traction, which is an operational necessity in forest transport.

Some of the characteristics of the Michelin XZL that distinguish it from the others in the test are as follows: greater mass, biased toward off-road traction with large tread blocks, larger loaded radius of 538 mm (versus 492 mm radius for X One XZY3), and 3 mm greater tread depth than the other tires in the test.

Given this first result for WBSTs on the truck and trailers, a second round of testing was conducted with dual tires refitted to the tractor and X One XZY3 tires on the trailers. This combination, although not using the same model of tires, has been explored in previous research work (Jokai, 2014), where a 6-axle chip truck used WBSTs on drive and trailer axles. In that experiment, it was found that WBSTs on the tridem trailer unit reduced fuel use 3.23%. Unfortunately for the present study, the tractor's fuel consumption was highly variable due to the emission systems undergoing frequent regeneration cycles to clean the diesel particulate filter, perhaps due to the short test cycles and an adaptive emissions strategy of the engine control unit. The regeneration cycles increased fuel consumption by up to 10% over the short duration tests, despite a preventive measure of forcing the regeneration cycle two days earlier at the local Detroit Diesel service facility. Clearly, forced regeneration of the diesel particulate filter is needed daily to ensure regeneration does not occur during the test cycle and to ensure consistent fuel consumption test results.

4.4 Energy intensity

Energy intensity is the energy required to move a unit of payload over a given distance, and the formula for this is given in Equation 1, where fuel consumption is expressed in litres per 100 km, and payload in tonnes (t), and the result is expressed in litres per 100 tonne-kilometres.

Equation 1: Energy intensity
Energy intensity = (litres / 100 km) / (tonnes)

In those cases where the tare weight of a combination is reduced, productivity gains can be made because payload capacity is increased. In instances where fuel consumption is constant or reduced, the energy intensity is reduced, to the benefit of the environment and productivity. Applying the 0.98% fuel reduction result from the first test gives an energy intensity improvement as shown in Table 4.

Table 4. Energy intensity comparison

Condition	Energy intensity (L/100 tkm)[a]	Improvement (%)
Baseline	1.947	n.a.
WBSTs on truck and trailers	1.857	4.6%

[a] tkm=tonne-kilometre

The results in Table 4 are based upon two assumptions: the tare reduction from using WBSTs is fully utilized to carry more payload, and carrying the increased payload (to the maximum 71 900 kg) would not increase fuel consumption, although in fact it may. Given that the tare reductions for the two test conditions were 587 and 972 kg (see Table 2), otherwise expressed as 0.82% and 1.36% of the test vehicle weight, the assumption that fuel consumption remained unchanged is reasonable. Nevertheless, with the fuel consumption tests being inconclusive, it would be best to characterize the energy intensity improvements as uncertain. One condition not measured was the empty truck cycle, where lighter tare could provide additional fuel economy benefits, even though the fuel economy improvement may be minor.

4.5 Economic considerations

The purchase of 18 new wheels and tires, including one spare for each of the unique drive and trailer combinations, along with chains for one drive axle, cost approximately $37 000, not including provincial and federal sales tax. If considering an upgrade of WBSTs to only five trailer axles, the cost would have been $20 000. Using FPInnovations' truck costing model and comparing the potential increased revenue (based on a payment rate of $3.75 per tonne-hour), the payback on this investment would be 3.6 years for the 9-axle truck equipped entirely with WBSTs and 4.5 years for the truck with WBSTs on the trailers only. For a complete list of inputs and assumptions for the truck costing model, see Appendix B. Government programs may provide funding assistance for those wanting to switch from dual tires to WBSTs. Funding to help offset the costs would provide a shorter payback and a higher return on investment.

Using the same cost model and the above-stated payment rate, it would be better to purchase a new truck and trailer equipped with WBSTs. New truck and trailer purchases or trailer-only purchases would be marginally cheaper than trucks with dual tires. New truck and trailer purchases can be made with axles optimized for WBSTs and feature wheels with zero offset, which could increase the service life of the wheel bearings when compared to 5 cm (2 in.) outset wheels. Doing so would improve annual profits by $10 535, an improvement of 9.1% for the truck with WBSTs on all positions. For the same truck with WBSTs only on the five trailer axles, annual profits would improve by $4 450, an increase of 3.9%.

5 CONCLUSIONS

This project investigated the fuel savings potential of WBSTs and found that the high-traction off-road biased Michelin XZL tires on the drive axles compromised the fuel-savings potential of the energy efficient Michelin XOne XZY3 tires that were on the trailers' axles. In all test cases, the tests were inconclusive. Based upon these results and past results (Jokai, 2014), the WBSTs on all axle positions as tested had an insignificant impact on fuel consumption and energy efficiency. However, the impact of WBSTs on the trailer only could be 3.23% or higher, according to past studies (Jokai, 2014).

WBSTs offer other benefits, such as safety and reduced tare weight, which offer a more compelling case for their adoption. WBSTs cannot capture large rocks, as do dual tires, and thus cannot launch larger rocks the same way that dual tires can. The substantial reduction in tare weights reduces the rotating mass of the driveline which should improve acceleration and braking. The reduced tare of 572 kg for WBST-equipped trailers and 972 kg for WBST-equipped truck and trailers is compelling. The tare reduction will increase the potential to carry more payload, get more wood to the mill in fewer trips, and increase revenues.

Failure in driver acceptance, while initially perceived as a potential barrier, did not occur. Admittedly, the duration of this observation period was short. Further study on the adoption of

WBSTs and their impact on maintenance costs, axle bearing life, tire wear characteristics, and puncture resistance in a logging environment is warranted. Stated improvements in profits, ranging from 4% to 9% depending on level of adoption, make a compelling economic case as well.

6 IMPLEMENTATION

As stated earlier, an investment of $40 000 to retrofit a 9-axle B-train truck may not be economically feasible when a fleet already has purchased equipment best suited for dual wheels and tires. There are negative consequences to axle bearing wear when using 50.8 mm (2 in.) outset wheels, such as increased maintenance requirements and possibly 58% shorter bearing service life (Allen et al., 2011). A better option is to specify wider axles at the time of the truck and trailer purchase and have the combination delivered with zero-offset wheels on the drive and trailer axles. Alternately, a fleet could consider only ordering trailers optimized and fitted with WBSTs, and fitting WBSTs to tractor units under conditions for which they may be best suited. Thus, the options for WBSTs can be considered separately. When considering switching from dual tires to WBSTs, governments may have incentive programs to help offset their purchase costs.

The following items should be considered for implementation:

- Specify axle widths that allow use of zero-offset wheels to maximize bearing life. Alternatively, specify standard track axles with outset wheels to protect potential truck and/or trailer resale value.
- Tire models selected for use in this test were higher-traction models, more fuel-efficient options exist.
- Purchase price can be lower for WBSTs at time of original purchase.
- Ensure out-to-out tire sidewall and track width dimensions comply with provincial regulations.
- Zero-offset wide-base wheels, and the required wider axles that are needed, will make the truck and/or trailer unsuitable for dual-wheel fitment on public roads.
- With WBSTs, checking tire pressure is easier; inflation pressure may get more attention from mechanics and drivers alike.
- An empty truck and trailer that experiences a punctured tire may be able to lift the affected axle and carry on towards a repair facility.
- A loaded truck and trailer with a tire puncture will need to stop and wait for a mobile mechanic if no spare is carried, as wide-base wheel and tire combinations may be too heavy for one person to manage.
- Mismatched spare wheel and tire combinations may not be suitable for use on public roads.
- Although 50.8 mm (2 inch) outset wheels may reduce bearing life by 58%, they provide better access to brake drums that have frozen to brake shoes in winter, thus making attempts to free the brake drum easier.
- The Michelin XZL 445/65R22.5 used in this test is optimized for off-road traction and has a 46 mm greater radius than the 11R24.5 it replaced, thus requiring uniquely sized traction chains.

- For extreme ice and mud, where traction is poorest, consider fitting tire chains to outside trailer tires to give better lateral traction and prevent sliding sideways off the road's crown, or when traversing in-sloped or out-sloped roads.
- Consider siping[1] your tires for improved snow and ice traction but realize this practice will increase friction and increase rate of tread wear.
- Although it would be expensive and require more wheels and tires, consider switching back to dual tires when traction is needed in winter or on soft roads.
- As with dual tires, worn traction WBSTs can be repositioned from drive to trailer positions to extend service life.

7 DISCLAIMER

The test results presented here are applicable to the truck configuration and the wide-base tire models as stated when fitted to a 9-axle B-train hauling saw logs. Individual results will vary given differences in conditions, such as truck and trailer configurations, weather, running surfaces, distances travelled, and speed. The wear characteristics and puncture resistance were not measured at the time of report writing.

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[1] Siping is a process where thin slits are cut into a tire's tread to improve traction in wet or icy conditions.

APPENDIX A – VEHICLE DATA

Parameters	Vehicles	
	Control	Test
Tractors		
Fleet test ID	758	757
Vehicle identification number	5KJRAED15KPKT6204	5KJRAED15KPKT6208
Make and model	Western Star 4900SF	
Build year (model year)	2018 (2019)	
Engine make and model/emission level	Detroit DD16/EPA 2017	
Rated power	447 kW (600 hp)/1800 rpm	
Peak torque	2779 Nm (2050 lb.-ft.)/1120 rpm	
Transmission	EATON FULLER RTLO 18-Speed	
Differential make and model	Meritor RZ-69-166	
Differential ratio	4.56	
Steer tires	Michelin XZY-3 385/65R22.5	
Drive tires	Bridgestone M775 11R24.5	Michelin XZL 445/65R22.5
Tire pressure (cold)	621 kPa (90 psi)	758 kPa (110 psi)
Test weight	13 294 kg (29 308 lb.)	12 876 kg (28 387 lb.)
Trailers		
Vehicle test ID	T1	T2
Vehicle fleet ID	595 & 596	593 & 594
Vehicle identification number	2F9FSS438K1101595 2F9FSS438K1101596	2F9FSS438K1101593 2F9FSS438K1101594
Make and model	FreFlyt Industries Ltd. Stretch Super B	
Build (model) year	2018 (2019)	
Type	13.35-m (43.8-ft.) & 9.10-m (29.9-ft.) with two log bunks each	
Tires	Firestone T819 11R24.5	Michelin XOne XZY3 455/55R22.5
Tire pressure (cold)	621 kPa (90 psi)	793 kPa (115 psi)
Tare weight	10 076 kg (22 214 lb.)	9 489 kg (20 920 lb.)
Test weight (with load)	61 834 kg (136 321 lb.)	61 741 kg (136 116 lb.)
Total test weight	71 910 kg (158 534 lb.)	71 230 kg (157 035 lb.)

APPENDIX B – TRUCK COSTING MODEL – INPUTS

FPINNOVATIONS TRUCK COSTING / RATE MODEL				
Values in green cells are calculated.				
		Trucks		
		1	**2**	**3**
Description	**Units**	**BC Tri-drive 9-axle**	**BC Tri-drive 9-axle WBST all**	**BC Tri-drive 9-axle WBST trailer only**
SCHEDULE				
Scheduled operator hours per shift	SMH	14	14	14
Hours per day - Contractor Management	SMH	0.5	0.5	0.5
Shift per day	shift/day	1	1	1
Scheduled days per week	days/week	5	5	5
Scheduled weeks (total)	weeks	38	38	38
Utilisation rate	%	90%	90%	90%
Paid stoppage time	min./trip	75	75	75
Days per year	days/year	190	190	190
Scheduled hours per year	SMH/year	2660	2660	2660
Productive hour per year	PMH/year	2394	2394	2394
LABOR				
Operator labor rate	$/PMH	$30.00	$30.00	$30.00
Contractor Rate	$/PMH	$0.00	$0.00	$0.00
Fringe Benefits	%	25%	25%	25%
Labor cost per PMH	$/PMH	$37.50	$37.50	$37.50
INTEREST RATE & PROFIT				
Interest Rate	%	6%	6%	6%
Profit Margin	%	0%	0%	0%
Profit per PMH	$/PMH	$0.00	$0.00	$0.00
VEHICLE AND EQUIPMENT COST				
Tractor & Trailer				
Tractor life	Years	5	5	5
Tractor purchase price	$	$210,000	$204,265	$210,000
Tractor salvage value	$	$31,500	$30,640	$31,500
Trailer life	Years	7	7	7
Trailer purchase price	$	$100,000	$100,000	$99,892
Trailer salvage value	$	$10,000	$10,000	$9,989

Tractor + trailer yearly fixed cost	$/year	$60,987	$59,778	$60,969
Onboard Loader (0$ if not present)				
Purchase price	$	$0	$0	$0
Salvage Value	$	$0	$0	$0
Life	Years	10	10	10
Tare weight	Tonnes	0	0	0
Loader yearly fixed cost	$/year	$0	$0	$0
Other Equipment (0$ if not present)				
Tire Pressure Control System (TPCS)	$	0	0	0
Onboard Weigh Scale	$	1500	1500	1500
Cab Protector	$	6000	6000	6000
Onboard Computer	$	1250	1250	1250
Miscellaneous Equipment (Radio, Cell, Chains etc.)	$	2000	2000	2000
Other equipment total purchase cost		$10,750	$10,750	$10,750
Other equipment yearly fixed cost	$/year	$2,150	$2,150	$2,150
Service Costs				
Insurance (% of purchase)	%	5%	5%	5%
Insurance	$/year	$15,500	$15,213	$15,495
Licensing + Safety Check (CMVI) Truck +Trailer	$/year	$6,700	$6,700	$6,700
Professional Services (accounting, legal, gov't reporting)	$/year	$3,000	$3,000	$3,000
Communications fees (cell, satellite, OBC)	$/year	$500	$500	$500
Total Service Costs	$/year	$25,700	$25,413	$25,695
Total yearly fixed cost	$/year	$88,837	$87,342	$88,814
Fixed Cost per PMH	$/PMH	$37.11	$36.48	$37.10
WEIGHTS				
Tractor +Trailer Tare Weight	Tonnes	23.14	22.168	22.553
Allowable Gross Vehicle Weight (GVW)	Tonnes	71.9	71.9	71.9
Payload buffer	Tonnes	0.8	0.8	0.8
Merchantable Wood Density	kg/m^3	850	850	850
Normal Period Payload	Tonnes	47.96	48.932	48.547
Normal Period Merchantable Volume	m^3	56.4	57.6	57.1
SEASONAL ALLOWANCES				
Winter period	weeks	0	0	0
Winter allowable GVW	Tonnes	71.9	71.9	71.9
Winter payload	Tonnes	47.96	48.932	48.547
Winter Period Merchantable Volume	m^3	56.4	57.6	57.1
Winter fuel consumption increase	%	5%	5%	5%
Spring load restriction period	weeks	0	0	0
Spring allowable GVW	Tonnes	71.9	71.9	71.9
Spring payload	Tonnes	47.96	48.932	48.547
Spring Period Merchantable Volume	m^3	56.4	57.6	57.1
Average payload for year	Tonnes	48.0	48.9	48.5

Average merchantable volume	m^3	56.5	57.5	57.1
DISTANCE BY ROAD TYPE				
Paved Road	km	75	75	75
Town or City	km	5	5	5
Class 1 Road	km	50	50	50
Class 2 Road	km	5	5	5
Class 3+ Roads	km	5	5	5
One Way Distance	km	140	140	140
SPEEDS				
LOADED				
Paved Road	km/h	90	90	90
Town or City	km/h	35	35	35
Class 1	km/h	55	55	55
Class 2	km/h	35	35	35
Class 3+	km/h	15	15	15
Average Speed Loaded (calculated)	km/h	59.3	59.3	59.3
UNLOADED				
Paved Road	km/h	95	95	95
Town or City	km/h	40	40	40
Class 1	km/h	60	60	60
Class 2	km/h	40	40	40
Class 3+	km/h	20	20	20
Average Speed Empty (calculated)	km/h	66.0	66.0	66.0
Overall Average Speed	km/h	62.4	62.4	62.4
FUEL CONSUMPTION				
Fuel Price	$/L	$1.00	$1.00	$1.00
Idle Fuel Consumption	L/hr	3	3	3
DEF Price	$/L	$1.00	$1.00	$1.00
DEF Consumption (% of Fuel Consumption)	%	3%	3%	3%
LOADED				
Paved Road - Loaded	L/100km	90.4	90.3	90.3
Town or City - Loaded	L/100km	105.4	105.3	105.3
Class 1 - Loaded	L/100km	99.3	99.2	99.2
Class 2 - Loaded	L/100km	127.3	127.2	127.1
Class 3+ - Loaded	L/100km	155.4	155.3	155.2
Average Consumption Loaded	L/100km	97.74	97.7	97.6
UNLOADED				
Paved Road - Unloaded	L/100km	39.5	38.5	38.9
Town or City	L/100km	54.5	53.5	53.9
Class 1 - Unloaded	L/100km	46.5	45.4	45.8
Class 2 - Unloaded	L/100km	52.9	51.4	52.0
Class 3+ - Unloaded	L/100km	58.0	56.0	56.8

Average Consumption Empty	L/100km	43.67	42.6	43.0
Total Rolling Fuel Consumption (FPInnovations)	L/100km	70.71	70.1	70.3
Overall Fuel Consumption including Idle	L/100km	72.05	71.5	71.7
Rolling Hourly Fuel Consumption (no Idle fuel or time)	L/hr	44.1	43.8	43.9
Overall Hourly Fuel Consumption including Idle	L/hr	35.2	34.9	35.0
Fuel & DEF Cost per PMH	$/PMH	$36.23	$35.94	$36.04
MAINTENANCE & REPAIR COSTS				
Scheduled maintenance (Oil, filters, lube, etc.)				
Interval between sessions	Weeks	2	2	2
Cost per sessions	$	$250	$250	$250
Scheduled maintenance yearly cost		$4,750	$4,750	$4,750
Repairs				
Drivetrain (Engine, transmission, axles)	$/year	$7,500	$7,500	$7,500
Suspension and brakes	$/year	$4,800	$4,800	$4,800
Electrics	$/year	$1,000	$1,000	$1,000
Truck Frame + Chassis	$/year	$2,000	$2,000	$2,000
Hydraulics (if so equipped)	$/year	$0	$0	$0
Trailer	$/year	$5,000	$5,000	$5,000
Others	$/year	$500	$500	$500
TPCS	$/year	$0	$0	$0
Total yearly repairs costs	$/year	$20,800	$20,800	$20,800
Tire cost				
Tire purchase cost	$/units	$715	$1,300	$1,040
Number of wheels	#	32	16	22
Tire life	Km	125000	125000	125000
# Blowouts per year	#	4	4	4
Yearly Tire Cost	$/year	$24,257	$24,652	$25,557
Total maintenance and repair cost	$/year	$49,807	$50,202	$51,107
Maintenance and repair per PMH	$/PMH	$20.80	$20.97	$21.35
TOTAL RATE PER PMH	$/PMH	$131.65	$130.89	$131.99
Labor	$/h	$37.50	$37.50	$37.50
Fixed	$/h	$37.11	$36.48	$37.10
Fuel	$/h	$36.23	$35.94	$36.04
Maintenance and repair	$/h	$20.80	$20.97	$21.35
Profit	$/h	$0.00	$0.00	$0.00
RATE PER TONNE	$/t	$15.73	$15.35	$15.61
Labor	$/t	$4.48	$4.40	$4.43372
Fixed	$/t	$4.43	$4.28	$4.39
Fuel	$/t	$4.33	$4.21	$4.26
Maintenance and repair	$/t	$2.49	$2.46	$2.52
Profit	$/t	$0.00	$0.00	$0.00

RATE PER m^3	\$/m^3	\$13.37	\$13.05	\$13.26
Labor	\$/m^3	\$3.81	\$3.74	\$3.77
Fixed	\$/m^3	\$3.77	\$3.64	\$3.73
Fuel	\$/m^3	\$3.68	\$3.58	\$3.62
Maintenance and repair	\$/m^3	\$2.11	\$2.09	\$2.15
Profit	\$/m^3	\$0.00	\$0.00	\$0.00

SUMMARY INFORMATION				
INFORMATION BY TRIP				
Rolling time (no stoppage time)	PMH/trip	4.48	4.48	4.48
Round trip time	PMH/trip	5.73	5.73	5.73
Lost time per trip	H/trip	0.64	0.64	0.64
Percent idle time	%	22%	22%	22%
Round trip distance	Km	280	280	280
Fuel consumed per trip	L/trip	201.73	200.1	200.7
Cost per trip	\$/trip	\$754.91	\$750.57	\$756.87
INFORMATION BY YEAR				
Trips per year	#	417	417	417
Tonnes per year	Tonnes	20023	20429	20268
Annual distance	km	116897	116897	116897
Yearly Fuel Consumption	L/year	84220	83533	83776
Costs per year		\$315,166	\$313,357	\$315,985
Labor		\$89,775	\$89,775	\$89,775
Fixed		\$88,837	\$87,342	\$88,814
Fuel		\$86,747	\$86,039	\$86,289
Maintenance and repair		\$49,807	\$50,202	\$51,107
Profit		\$0	\$0	\$0
LIFETIME INFORMATION				
Tractor life hours	PMH	11970	11970	11970
Trailer life hours	PMH	16758	16758	16758
Loader Life		NA	NA	NA
Tractor life km		584485	584485	584485
Trailer life km		818279	818279	818279
PERCENT COST BREAKDOWN				
Labor		28%	29%	28%
Fixed		28%	28%	28%
Fuel		28%	27%	27%
Maintenance and repair		16%	16%	16%
Profit		0%	0%	0%

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