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Validation of the Performance of a 23.4m Log Truck

Version 1.1

Prepared for:

NZTA

July 2018

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INTRODUCTION

As part of the process of developing the New Zealand Performance Based Standards system for managing vehicle size and weight we have undertaken a validation exercise on a log truck currently operating under permit. This vehicle is expected to comply with the requirements for a new pro-forma log truck design. It has been found by computer simulation to meet all of the draft new PBS requirements.

This vehicle has been permitted to exceed the 23m length limit with a small amount additional load rear overhang. This enables 6.1m log lengths to be carried as two packets on the trailer which results in a much lower load and substantially improved rollover stability.

For the validation exercise, we monitored the vehicle's on-road performance by video-recording it on a trip of approximately 50km encompassing some urban routes, some higher speed rural routes and some hilly winding open road sections. The video recording was done on 29th May 2018.

We then undertook some low speed turning performance tests in the owner's yard to check the vehicle's measured performance against its computer-predicted performance. This testing was undertaken on the 30th May 2018.

The vehicle is one of a number of similar long vehicles operating to supply logs to the sawmill at Rainbow Mountain. We prepared a survey for the drivers of these vehicles to ask them to compare their experience of the vehicles' performance with that of 50MAX vehicles and standard legal 20m 44-tonne vehicles.

Finally we asked the drivers to record the trailer load heights and load rear overhangs for a number of trips. This is to verify the safety benefits achieved from the length concession that these vehicles have been granted.

THE TEST VEHICLE

The test vehicle, pictured in Figure 1 below, was provided by Williams & Wilshier Ltd. The steelwork on this vehicle is 22.4m long and the vehicle is permitted to operate at up 23.4m on approved routes. Thus the log load may overhang the rear of the vehicle by up to 1.0m. For the test the vehicle was loaded to 55.8 tonnes with 6.1m domestic saw logs.

Figure 1. Loaded test vehicle.

As can be seen from the photograph, the logs are carried in two packets on the trailer and the resulting load is relatively low giving a very stable vehicle. Without the length concession, the logs on the trailer would have to be carried as a single packet. Although some of the load could be moved to the truck, the load on the trailer would be much higher. The rollover stability of the vehicle would still meet the legal minimum requirements but the rollover risk would be increased.

The additional rear overhang and vehicle length required to achieve this improved rollover stability is quite small as shown in Figure 2 and the additional safety risks associated with this overhang are expected to be minimal.

Figure 2. Load overhang for test vehicle.

The load height at the back of the trailer was measured at 2.81m and the load overhang from the rear steelwork was measured at 0.6m.

ON-ROAD PERFORMANCE

The vehicle was followed by car on a trip from the Williams and Wilshier yard in Biak St, Rotorua, via SH5 to SH30A and then SH30 to the junction with SH34. The total trip distance was approximately 50km. The first few kilometres of the trip were on urban roads through the city of Rotorua. After about 10km this became open road (100km/h speed limit). For the first 20km or so this was relatively straight with the occasional bend warranting an advisory speed sign while the last 20km or so was quite winding with numerous curves with advisory speeds.

The vehicle was videoed throughout the trip using a Panasonic NV GS400 video camera. It tracked extremely well with no trailer sway at any time. On the curves, it was able to stay well within its lane and provided good clearance to the centreline. Figure 3 shows a still taken from the video of the vehicle in a 45 km/h curve while Figure 4 shows it on a 35 km/h curve. As can be seen the lanes are quite narrow but the vehicle had no difficulties in staying well within them and allowing adequate clearance for any similar oncoming vehicle.

Figure 3. Traversing a 45 km/h advisory speed curve.

Figure 4. Traversing a 35 km/h advisory speed curve.

LOW SPEED TURNING TESTS

The draft New Zealand PBS system includes two low speed turning manoeuvres. One is the standard 12.5m outside radius 90° turn used in the Australian PBS system where the path is followed by the outer face of the outside steer tyre (kerb-to-kerb turn). Three main performance measures are determined from this manoeuvre; low speed swept width, tail swing and frontal swing. The second manoeuvre is a 25m outside radius 360° turn where the path is followed by the outermost front corner of the truck (wall-to-wall turn). One performance measure, steady state low speed swept width, is evaluated during his manoeuvre.

The original intention was to conduct both these manoeuvres with the test vehicle and to measure the four performance measures. These could then be compared with the values obtained by computer simulation. However, it was found that the yard was not large enough to undertake the 25m radius turn. Thus the 25m radius turn was replaced by a 20m radius turn.

The desired tracks were marked out in the Williams and Wilshier yard using pavement chalk and spray paint.

The truck was fitted with pressurised water sprayer units on the right front corner and in line with the outside edge of the left rear trailer axle as shown in Figure 5. These sprayers were activated during each test and traced out the path followed by the respective points on the vehicle. In addition a wand was strapped to the outside right edge of the rear of the load (as shown in Figure 2) to indicate the tail swing. The location on the ground of the projection of the wand during the turn was marked manually with pavement chalk.

Figure 5. Sprayer units fitted to the test vehicle.

The driver had some difficulty in following the target path accurately particularly on the exit of the 90° turn. This mostly affected the frontal swing measurement which is measured relative to the target path. The swept width measurement records the distance between the inner and outer vehicle tracks and thus is less affected by small deviations from the target path. Like frontal swing, tail swing is measured relative to the target path but tail swing occurs at the start of the turn and the path following was better here.

In all six repeats of the 12.5m radius 90° turn were undertaken but inconsistent measurements due to poor path following were discarded. The results of these measurements are summarised in Table 1 below. The negative tail swing reflects the fact that the outside corner of the rear of the logs did not cross the target path at all. In terms of the PBS system this would be zero tail swing. The swept width values are all within 1% of the average and the frontal swing values are within 2% of the average, although, as noted, some frontal swing measurements were discarded because the path following for the test was clearly unsatisfactory by observation.

Table 1. Summary of measurement results for 12.5m outside radius 90° turn.

Performance Measure	Measurement 1	2	3	4	Average
Low Speed Swept Width (m)	6.32	6.23	6.30	6.26	6.28
Tail Swing (m) - Load	-0.09	-0.07	-0.06		-0.07
Frontal Swing (m)	0.62	0.61	0.60	0.62	0.61

For the 20m outside radius turn, the only measurement taken was swept width. Five readings were taken and these are summarised in Table 2. All readings are within 0.2% of the average.

Table 2. Summary of measurement results for 20m outside radius steady state turn.

Performance Measure	Measurement 1	2	3	4	5	Average
Steady State Swept Width (m)	5.22	5.24	5.22	5.23	5.22	5.23

COMPUTER SIMULATION MODELLING

In order to get its HPMV permit the test vehicle had already been modelled using the Yaw-Roll multibody simulation package and had been assessed using the proposed new NZ PBS system. The results of this performance assessment are shown in Table 3.

Table 3. Performance assessment of the test vehicle at full load using proposed new PBS.

Performance Measure	Acceptability Level	23.4m KW truck with 5-axle trailer
Low Speed Swept Width (m)	Less than 6.75	6.38
Tail Swing (m) - Load	Less than 0.3	0.10
Frontal Swing (m)	Less than 0.75	0.51
Steer-Tyre Friction Demand	Less than 0.50	39
Steady State Low Speed Swept Width (m)	Less than 5.20	4.77
High Speed Offtracking at 0.2g (m)	Less than 0.46	0.40
High Speed Offtracking at 0.25g (m)	Less than 0.68	0.57
Static Rollover Threshold (g)	Greater than 0.35	0.38
Dynamic Load Transfer Ratio	Less than 0.6 (0.7)	0.59
Rearward Amplification	Less than 2	1.92
High Speed Transient Offtracking (m)	Less than 0.6	0.41
Yaw Damping Ratio (%)	Greater than 15	31

The test conditions for this simulation were slightly different from those at trial. Specifically, for the original simulation the vehicle was loaded to 58 tonnes, the rear overhang of the log load was 1.0m from the steelwork and for the purpose of determining the tail swing the load was assumed to be 2.5m wide (this was known to be incorrect but is a conservative assumption). Furthermore the Steady State Load Speed Swept Width measure is based on a 25m radius turn while at the trial we could only undertake a 20m radius turn.

Thus, for validating the test, the model data was adjusted to match the test conditions and the relevant performance measures were evaluated. The results of this assessment are shown in Table 4.

Table 4. Performance assessment of the test vehicle as tested using proposed new PBS.

Performance Measure	KW truck with 5-axle trailer
Low Speed Swept Width (m)	6.38
Tail Swing (m) - Load	-0.06
Frontal Swing (m)	0.51
Steady State Low Speed Swept Width (m) - 20m radius turn	5.45

Referring back to Table 1 and Table 2, we can compare the simulated results with the measured results.

The simulated result for low speed swept with is 1.6% higher than the measured result. This is very close and the simulation result is conservative. This is consistent with other validation trials that we have conducted in the past where generally the vehicle’s measured performance has been slightly better than predicted by the simulation.

For tail swing the simulation and the measurements differ by only 10mm but the absolute value is very small. The measurement accuracy was probably no better than ±10mm so this is a reasonably good match.

For frontal swing the simulation result was 100mm or 16% less than the measured value. This difference is relatively large. As noted in the description of the measurement trials the driver had some difficulty following the prescribed path, particularly at the exit of the 90° turn. There was a tendency to overshoot and then to have to correct. It is likely that this additional steering input increased the measured value of frontal swing.

Like low speed swept width, the steady state low speed swept width is greater for the simulation than it was for the measurement. The difference is 230mm which is only about 4% so it is reasonably close.

Overall the match between the measurements and the simulations is quite good. For the key swept width measures, the simulation results are conservative which means that vehicles will perform at least as well as predicted.

I have tried to identify possible reasons for the differences even though they are small. Changing the trailer tyre data in the simulation model for that from a different tyre brand and size has a small effect. The computer simulations use a vehicle speed of 5 km/h. Changing this to 8 km/h reduced the steady speed swept width by 60mm. For the measurement test, although the driver was instructed to travel at 5 km/h, he was concentrating on following the required path and would not have been able to simultaneously monitor the speedometer. It is also unlikely that the speedometer would provide sufficient precision at these very low speeds. Thus, particularly for the steady speed turn, it is possible that the vehicle was travelling a little faster than 5km/h and it is also possible that the characteristics of the vehicles tyres were a little different from those implied by the data used in the model. However, there is no firm evidence for either of these hypotheses and no easy way of testing them.

DRIVER SURVEY

Vehicle Performance

The vehicles that have been permitted as trial vehicles for this log transport operation are being driven by some of the most experienced drivers in the two companies that are operating them. Therefore, it seemed logical to ask these drivers to provide feedback on their experience with them. A driver survey was developed and distributed to these drivers. The survey form is attached to this report as an appendix.

There were eight respondents to the survey; two from Williams and Wilshier and six from Rotorua Forest Haulage. There are only a very limited number of these vehicles in operation so this is actually a very high response rate.

Most of the drivers were very experienced with an average of 18.1 years (range 4-30 years) as a professional truck driver and 12.6 years (range 4-25 years) in log transport. All of them had had at least three years driving HPMV and/or 50MAX vehicles with an average of 4.6 years and all of them had prior experience on 20m 44-tonne log trucks.

The next set of questions asked them to compare the performance of their current 23.5m vehicle with a standard 20m 44-tonne vehicle. The response options for each aspect of performance were:

☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better

For analysis these responses were given a score of 1 to 5 with 1 being “lot worse” and 5 being “lot better”. One of the respondent’s answers for this series of questions were completely at odds with all the others and with his responses to the following set of questions. It is possible that he misinterpreted the question as asking about the performance of a 20m 44-tonne truck relative to his current vehicle. We will present the average response for each question both with and without this respondent.

The following set of questions asked them to compare the performance of their current 23.5m vehicle with other HPMV and 50MAX vehicles. The average scores for the responses both comparisons both with and without the outlier respondent are shown in Table 5. The effect of the outlier respondent on the averages is relatively small.

Table 5. Averaged responses to performance comparison questions.

Performance Characteristic	Performance of 23.5m log truck compared to			
	20m 44 tonne vehicle		Other HPMV/50MAX	
	All	w/o outlier	All	w/o outlier
Low speed turning	3.6	3.7	3.8	3.9
High speed tracking	3.9	4.1	3.9	3.7
Stability	4.4	4.9	4.3	4.1
General handling	4.4	4.7	4.1	4.0

Although the responses are generally in line with expectations based on the theoretical performance of these vehicles configurations, they appear to be a little biased in favour of the 23.5m vehicle. For example, the actual low speed turning performance of the 23.5m vehicle will be worse than that of a typical 20m vehicle and should be about the same as a 50MAX or HPMV vehicle yet the responses show it as being better for both comparisons. In part this discrepancy may be explained by one of the comments where the driver said “Newer vehicle better design”. These vehicles are all relatively new and thus the drivers are more likely to think positively of them compared to the older 20m 44-tonne vehicles.

There was one other specific question asking whether or not there had been any occasions where the additional load overhang allowed on these vehicles had caused any issues. They all responded “no” to this question.

There were also three open-ended questions – one for each of the two comparisons to other vehicle configurations asking them to comment on any other aspects of performance not covered by the specific questions and one asking for general comments.

Not all respondents replied to all of these open-ended questions and for the most part their comments were general comments rather that addressing specific performance differences between these vehicles and the other two configurations. All of the comments were positive.

There were a number of comments saying that being able to carry two packets of 6.1m logs on the trailer resulted in lower loads and a more stable vehicle. Apart from a generally positive attitude towards the vehicles and their handling, there were no other specific items of comment that were common to multiple respondents. One driver commented on reversing being easier which he attributed to the long drawbar. Another commented on the ABS braking on the trailer being helpful.

Loading Characteristics

In addition to the driver survey, we asked the two operators involved to arrange for the drivers to record the load overhang and the load height at the back of the trailer for a number of loads. We received data for six trucks. For two of the trucks, the data was for 28 loads each while for the other four it was for a total of 23 loads for all the trucks. Descriptive statistics of these measurements are shown in Table 6.

Table 6. Summary of load measurement data.

Quantity	Truck ID					
	1	2	3	4	5	6
No of loads	28	28	3	5	7	8
Average load height (m)	3.38	3.12	2.98	3.02	3.02	2.90
Std dev. load height (m)	0.18	0.10	0.08	0.10	0.09	0.08
Average load overhang (m)	0.69	0.66	0.96	0.89	0.59	0.86
Std dev. Load overhang (m)	0.24	0.24	0.02	0.12	0.05	0.08

All of the load heights on all of the vehicles are relatively low and will result in a good SRT particularly as the vehicles are fitted with high roll stiffness suspensions. Truck 1 has a significantly higher average load height than the others and also has greater variability in load height. It is not known whether this is due to the loading practices of the driver or whether there were differences in the types of logs being transported compared to the other vehicles. Truck 2 has a slightly higher average load height than the other four. Trucks 1 and 2 also have more variability in the load overhangs. Trucks 3 – 6 are all operating within a narrow range of load heights and load overhangs. Note that trucks 1 and 2 belong to one operator and trucks 3 -6 belong to another operator so there may well be differences in the freight tasks being undertaken when the data was recorded.

The largest load height recorded was 3.7m for truck 1 on two occasions. It is not known what these higher height loads consisted of. None of the other trucks recorded a load height above 3.3m. All of the load overhangs were less than or equal to 1m.

CONCLUSIONS

A small number of HPMV log trucks have been permitted to operate at overall lengths of up to 23.5m on a specified route. These vehicles are all under 23m on the steelwork but are allowed up to 1m of rear overhang for their log load. This enables them to transport 6.1m logs (an industry standard length) as a two-packet load on the trailer. This load configuration provides substantially improved rollover stability for negligible additional risk due the additional length.

The performance analysis undertaken on these vehicles prior to their permitting also tested them against the proposed new PBS requirements which they achieved. Thus this configuration is suitable as the basis for a log truck pro-forma design under the new PBS systems. For this reason it was decided to undertake a validation trial to compare the simulation results with real-world performance using one of these vehicles.

The validation trial had a number of elements:

- Video monitoring of the vehicle in real world driving conditions
- Low speed turning performance measurements in a yard
- Computer simulation of the vehicle and comparison with the measurement results
- Driver and loading survey

The key findings are:

- The video monitoring showed excellent on-road performance with very good tracking even on narrow winding roads.
- The computer simulation showed that the vehicle achieves all of the performance requirements in the draft proposed PBS system
- The match between the measured performance and the simulations was generally very good with the simulations being slightly conservative
- The driver survey showed a very positive view of the performance of these vehicles with no negative feedback at all.
- The loading survey showed that the ability to load the trailer with two packets of logs resulted in low average load heights and hence good rollover stability with all load overhangs within 1m. There were some differences between vehicles and it is not known whether this reflects differences in loading practice or differences in the type of load being transported.

DRIVER SURVEY

Why are we asking?

The NZTA wishes to understand how the 23.5m log trucks are performing in practice rather than just in theory. We are therefore seeking the opinions of the professional truck drivers who are operating these vehicles. Note that your individual response is confidential and will not be seen by your employer. Thank you your help.

How long have you been a professional truck driver?

How long have you been driving in the log transport industry?

How long have you been driving HPMV or 50MAX log trucks?

Have you previously driven standard 20m 44-tonne log trucks? ☐ Yes | ☐ No

Comparing your current 23.5m vehicle with **a standard 20m 44-tonne vehicle**, how do you find:?

Low speed turning[1]	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
High speed tracking[1]	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
Stability	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
General handling	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
Any other aspect of vehicle performance? (please specify)	

Comparing your current 23.5m vehicle with **other HPMV and 50MAX vehicles**, how do you find:?

Low speed turning	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
High speed tracking	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
Stability	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
General handling	☐ lot worse ☐ little worse ☐ same ☐ little better ☐ lot better
Any other aspect of vehicle performance? (please specify)	

Your 23.5m vehicle is longer than other HPMVs and has additional rear overhang of the load. Has there been any occasions where this length or overhang has caused issues?

☐ Yes | ☐ No If yes, can you describe the issue?

Do you have any other comments that you would like to add regarding the operation of the 23.5m vehicles?

[1] A description of this factor is on the back

Low speed turning effects

During a low speed turn, the trailing axles of the vehicle travel inboard of the steer axle as illustrated in *Figure 6*. The maximum swept width of this vehicle is shown by the line with the circles on the ends which, in this case, is 6.74m. This becomes a problem at intersections where the roads are narrow and when turning into narrow driveways and gateways.

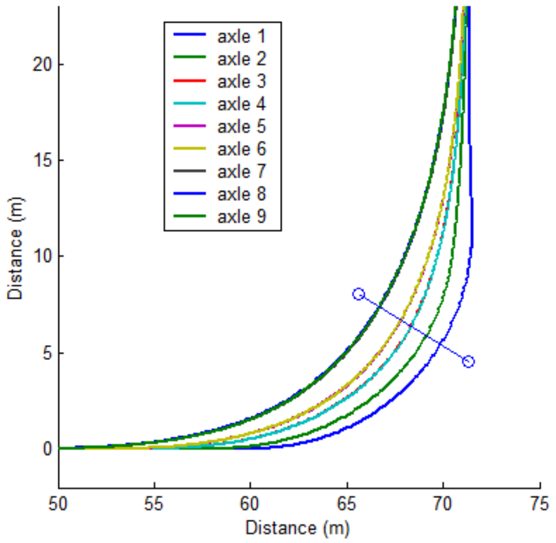

Figure 6. Path of the axles of a 9-axle truck and trailer during a low speed turn.

High Speed Tracking

At high speed the trailing axles travel outboard of the steer axle as shown in *Figure 7*. In the figure the vehicle is travelling from left to right through a sweeping left hand curve. The off-tracking value for this particular example is 396mm which means that the path of the last trailer axle is 396mm outside the path of the steer axle. This can be a problem on narrow winding roads with little or no shoulder.

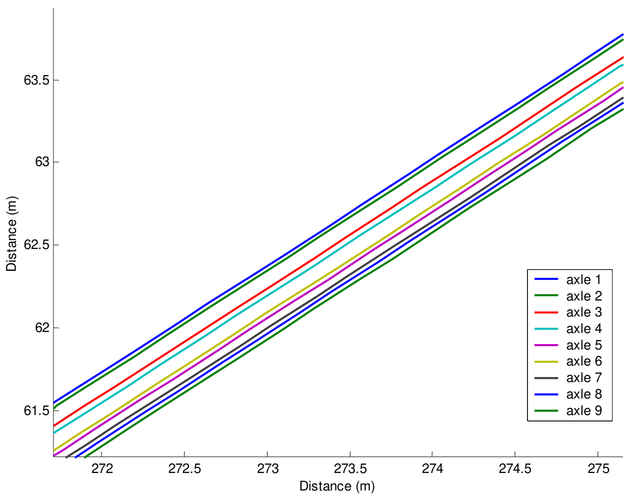

Figure 7. Path of the axles of a 9-axle truck and trailer during a high speed curve.