Performance Analysis of Revised Design for HPMV 23m B-train

Prepared for:

TNL

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INTRODUCTION

TNL in conjunction with MaxiTRANS have developed a design for an HPMV B-train combination. This is a variation on a design which was analysed and reported on in October 2012. The design does not conform to the dimensional envelope specified for the existing pro-forma 23m B-trains and thus is being submitted for approval as a one-off vehicle. In order for the design to be considered for a permit, a performance assessment has been undertaken to demonstrate that the vehicle will be able to operate safely on the approved routes.

METHODOLOGY

Performance Requirements

The critical performance aspect for over-dimension vehicles was expected to be low speed turning. For the pro-forma vehicle design development the NZTA specified a 120° wall-to-wall turn at 12.5m radius. The reason for the increased turn angle was to simulate a worst case situation which might typically be experienced during a right hand turn at a roundabout. In this situation the driver must initially turn to the left before then proceeding around the roundabout turning right. The total angle turned through by the vehicle is greater than 90°. Based on the worst-case standard vehicle (the 19m quad semitrailer) they determined that for satisfactory performance the vehicle should not cross a concentric inner circle with a radius of 4.9m while executing this manoeuvre.

For vehicles that achieve this critical performance level, a full range of performance measures is evaluated to ensure that the vehicles are not unsatisfactory in other respects.

Vehicle Configuration

The vehicle design submitted for analysis by TNL is as shown in Figure 1 below. This design is most directly comparable to the 23m long trailer pro-forma B-train design but it departs from the dimensional envelope in two key measures. The total trailing length is 17,700mm where the pro-forma design specifies a maximum of 17,500mm and the combined trailer wheelbase is 14825mm where the pro-forma design specifies a maximum of 14,540mm.   Both these changes will worsen low speed turning performance but the tractor is somewhat shorter than the maximum possible and the hitch offset on the first trailer is greater than the minimum required and both these differences will improve performance. A simulation analysis is needed to determine whether the trade-off is sufficient.

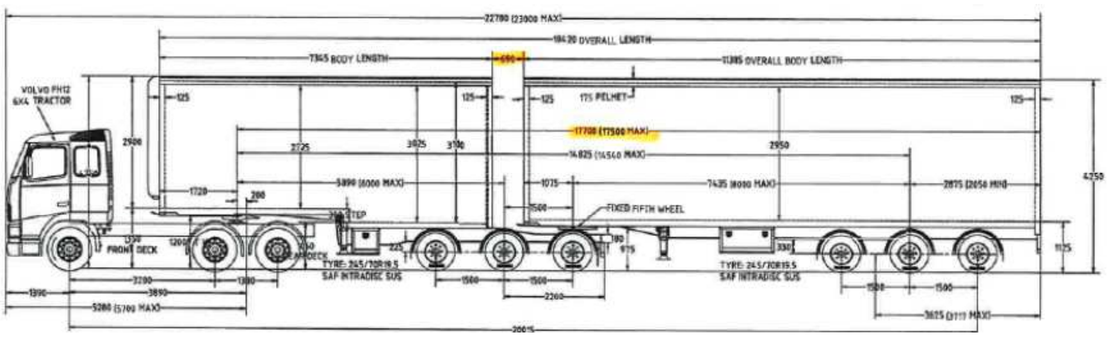

Figure 1. TNL's proposed HPMV design.

The drawing also shows that the inter-vehicle spacing between the trailers is 690mm. By drawing an arc centred on the kingpin of the second trailer it can be shown than the minimum inter-vehicle spacing that will occur for all articulation angles up to 90 degrees is 275mm. Thus the trailers will not clash during normal turning manoeuvres on flat ground.

The advice from TNL was that the vehicle has been designed to be fitted with a Wabco Optiturn axle on the third axle of the second trailer. The Optiturn axle has a mechanism where during low speed turns the air pressure in the suspension on the third axle is reduced. This has the effect of moving the rear axis of the axle group forward and thus reducing the effective wheelbase of the trailer which improves low speed turning performance. The system is configurable so that the extent to which the load on the rear axle is reduced can be limited. Under the current VDAM Rule, no axle in a tridem set is allowed to carry more than 6.6 tonnes and thus, if the axle group is loaded to the maximum weight, the extent to which the rear axle can be unloaded is quite modest. At high speeds no unloading occurs and so the vehicle's high speed performance is unaltered. This analysis was undertaken without including the effect of the Optiturn axle.

For the analysis the vehicle was loaded to 57 tonnes gross combination weight consisting of approximately 18 tonnes on each trailer axle group, 15 tonnes on the drive axles and 6 tonnes on the steer axle. To operate at these weights will require route specific permits while at 44 tonnes the vehicle could potentially be granted general access if it performs satisfactorily. The axle spacing is such that the vehicle also complies with the 50Max requirements and could operate at 50 tonnes where routes are approved for 50Max. The highest weights were used in the analysis because this is conservative. The performance at lower weights should be better.

Analysis Method

The main tool used in this analysis was multi-body computer simulation. The software package used was Yaw-Roll (Gillespie 1982) which was developed by the University of Michigan Transportation Research Institute (UMTRI).

The first step was to model the proposed alternative design to determine whether or not it meets the low speed turning criterion. Once it was established that it passed the low speed turning requirement a full set of performance measures was evaluated to ensure that the overall performance of the vehicle is satisfactory.

RESULTS AND DISCUSSION

The performance of this vehicle compared to that of the long trailer 23m B-train pro-forma design is shown in Table 1. It should be noted that the pro-forma designs were modelled with relatively poor performing suspensions to ensure that all vehicles built to the design would perform adequately and this HPMV vehicle has been modelled with the same suspension data so that a direct comparison can be made. The vehicle is likely to be fitted with better performing suspension than this and should perform better than shown.

As noted previously the analysis was undertaken without considering the effects of fitting an Optiturn axle on the second trailer. The vehicle achieves the required level of low speed turning performance without it. Fitting an Optiturn axle would improve low speed performance. At high speeds the Optiturn system is inactive and thus high speed performance is unaffected. Thus fitting an Optiturn axle would not have a negative impact on the vehicle's ability to achieve satisfactory performance. However, there are some of aspects of the Optiturn system that do require the NZTA to grant exemptions from some Rules before the vehicle can operate.

Overall the performance of the design is satisfactory in that it meets the required levels for all the performance measures that have been assessed. Its performance differs only a little from that of the pro-forma design. From a PBS performance point-of-view there is no reason that this vehicle should not be permitted to operate on the same routes that 23m pro-forma B-trains operate.

Table 1. Overall performance assessment of the TNL design compared to the comparable pro-forma design.

Performance Measure	Acceptability Level	23m Long Trailer Pro-forma B-train	TNL 23m B-train
120° turn – inner radius (m)	Greater than 4.9	4.90	5.12
Low Speed Offtracking (m)	Less than 4.2	3.82	4.00
Tail Swing (m)	Less than 0.3	0.06	0.06
Static Rollover Threshold (g)	Greater than 0.35	0.36	0.36
Rearward Amplification	Less than 2	1.69	1.66
High Speed Transient Offtracking (m)	Less than 0.6	0.55	0.58
Dynamic Load Transfer Ratio	Less than 0.6	0.47	0.43
Yaw Damping Ratio (%)	Greater than 15	>30	>30
High Speed Offtracking (m)	Less than 0.8[1]	0.47	0.50

[1] There is no formal limit for HSO in New Zealand. A maximum level of 0.8m has been used in the past but there is some debate as to whether this is too liberal. It has been suggested that a maximum of 0.5m is more appropriate.