CAN POPULAR PBS TRUCKS ENTER MAINSTREAM REGULATIONS?

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Abstract

When Australia's Performance Based Standards (PBS) Scheme commenced it was envisaged that new and improved truck and trailer configurations would emerge and that some of these would be so popular that they would become common under the Scheme. If these popular PBS configurations could somehow be added back into the mainstream mass and dimension regulations, their level of adoption by the industry and their consequent impact on the broader economy would both increase significantly. This paper examines the rise of the PBS 'truck and dog' combination, and presents a proposal for how this combination may be treated under mainstream regulations without undue compromise on the safety checks and balances that have hitherto applied to it under the PBS Scheme.

Keywords: Truck, dog, PBS, regulation, mass, dimensions, productivity, safety

HVTT13
San Luis, Argentina
October 2014

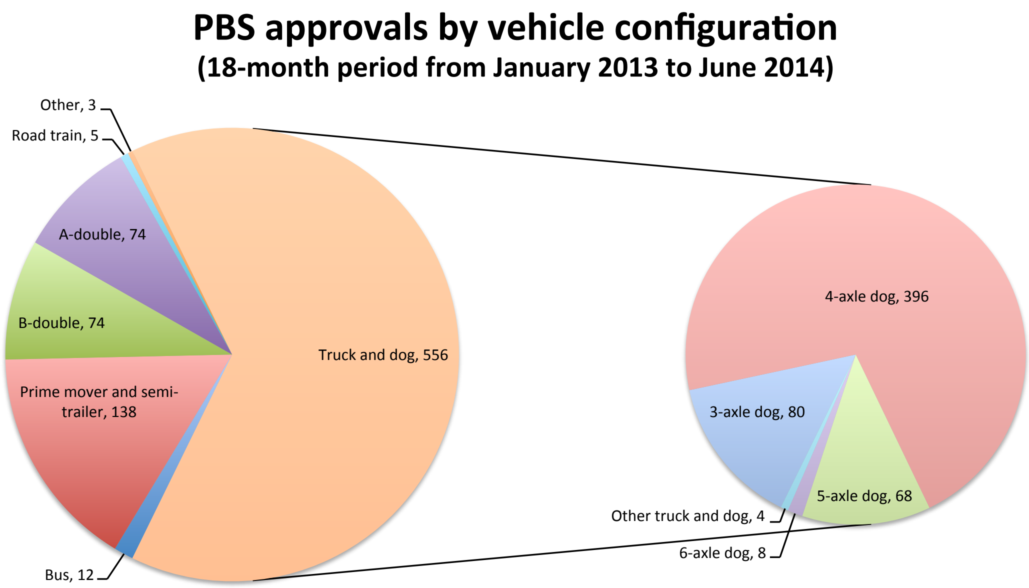
1. Introduction

The vast majority of heavy vehicle approvals granted under the Australian Performance Based Standards (PBS) Scheme during its seven years of operation are for 'truck and dog' combinations. These combinations, which comprise a rigid truck towing a full trailer, are commonly built with tipper bodies for transporting sand and gravel and other high-density quarried materials typically used in civil construction. They are also popular for the transport of grain and other bulk commodities with high-sided bodies. By far the most popular truck and dog configuration in the PBS Scheme is the 7-axle configuration featuring a 3-axle truck and 4-axle dog. This combination has unrestricted road access and can achieve a substantially higher payload on a restricted road network. An example is shown in Figure 1.

Photo courtesy of Prime Creative Media ('Trailer' magazine)

Figure 1 – Typical PBS 3-axle truck and 4-axle dog (7-axle configuration)

Figure 2 shows the breakdown of approvals by vehicle configuration for the 18-month period from January 2013 to June 2014. Truck and dog combinations in general make up 65 per cent of approvals, of which 71 per cent are the popular 7-axle configuration ('4-axle dog').



Source: National Heavy Vehicle Regulator

Figure 2 – Breakdown of PBS approvals by vehicle configuration

The reason for the immense popularity of the PBS 7-axle truck and dog is its unrestricted road access up to a certain mass (more than a conventional semi-trailer configuration), and its substantial increase in mass when operating on a restricted road network.

Emerging patterns in the design of this combination indicate that simple prescriptive rules may be sufficient to continue regulating it outside of the PBS Scheme while maintaining the acceptable safety outcomes that are presently controlled by the PBS Scheme safety standards. This approach would do away with the costly and time-consuming PBS Assessment and PBS Certification processes that some say have become unduly burdensome for this otherwise rather ordinary and predictable vehicle type. Design parameters such as maximum body height and longitudinal dimension ranges that allow the combination to meet PBS safety standards have become well known to those involved in the PBS process for this combination.

The objective of this research was to propose simple prescriptive rules for 7-axle truck and dog combinations based on experience gained in the PBS Scheme, supported by industry consultation and a study of PBS performance for the range of design parameters possible under the proposal. If these rules were written into the mainstream mass and dimension regulations, vehicle designs like those operating under PBS would be able to operate at the same mass and dimensions outside of PBS, while maintaining a reasonable level of confidence that a design satisfying the prescriptive rules also aligns sufficiently with PBS safety standards.

2. The 7-axle truck and dog: Then and now

To understand the rise of the PBS 7-axle truck and dog one must first understand how the rules changed for those combinations when PBS commenced.

In Australia there is a general gross combination mass limit of 50.0 tonnes for all trucks that have unrestricted road access. The limit rises to 50.5 tonnes if the vehicle is eligible for an additional 0.5 tonnes on the steer axle under the existing 6.5-tonne steer axle policy. The 50.0/50.5-tonne limit sometimes restricts a combination vehicle's gross mass to less than the sum of its individual axle group mass limits. Typical combinations affected by this include B-doubles, road trains and truck and dogs.

For B-doubles and road trains on restricted road networks, legislation permits the gross combination mass limit to be up to the sum of individual axle group mass limits. Some B-doubles are short enough to operate without road access restrictions if they do not exceed 50.0/50.5 tonnes; they can be loaded to the sum of axle group mass limits when on a restricted network. As it happened, until PBS commenced, the truck and dog combination was never given the same flexibility due to safety concerns relating to its potentially unfavourable dynamic performance at higher mass. Therefore a truck and dog combination was limited to 50.0/50.5 tonnes regardless of which roads it was using.

When PBS commenced in 2007, it could be used as a means of checking the safety of the truck and dog at higher mass. This meant that PBS-certified truck and dog combinations could achieve the kind of mass flexibility that was already available for short B-doubles. That is, up to 57.5 tonnes on the restricted PBS Level 2 road network (effectively the B-double road network) and up to 50.5 tonnes on other roads (PBS Level 1). An additional 1.0 metre in overall length is also allowed for Level 1 PBS vehicles (compared with non-PBS general access vehicles), which is necessary for some designs to achieve the maximum masses and still satisfy the bridge formula. Figure 3 illustrates the differences.

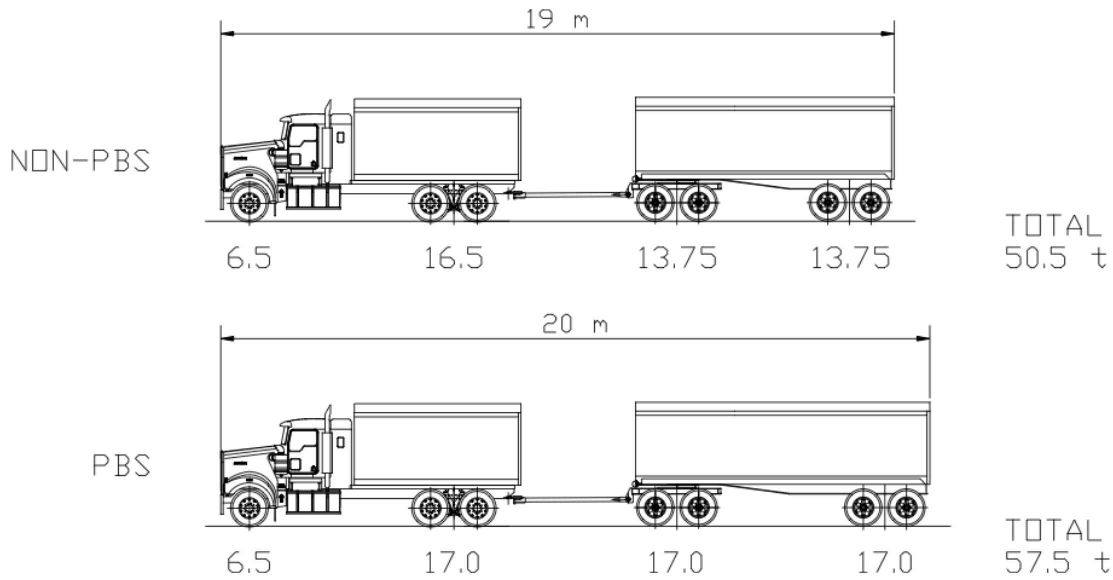


Figure 3 – Difference between non-PBS and PBS truck and dog

3. Critical PBS standards

There are typically two critical high-speed dynamic performance standards for truck and dog configurations, depending on the PBS Level being assessed. Each of these is discussed in the following sections, along with some discussion of other standards.

3.1. Level 1: High Speed Transient Offtracking (HSTO)

In Level 1 assessment for general access at up to 50.5 tonnes the critical standard is normally High Speed Transient Offtracking (HSTO). Level 1 HSTO performance is typically controlled to be at or below the acceptable upper limit through height limitation and, if necessary, suspension and tyre selection. Longitudinal vehicle dimensions such as truck and trailer wheelbases, coupling positions and drawbar lengths do also play a part, as does gross mass, but performance is preferably controlled through the other methods so the applicant does not need to compromise on longitudinal dimensions or gross mass, which are more operationally important.

3.2. Level 2: Rearward Amplification (RA)

HSTO ceases to be critical when moving from Level 1 assessment to Level 2 assessment for restricted access at up to 57.5 tonnes. This is because the vehicle's HSTO performance degrades by less than 0.1 metres due to the additional mass while the HSTO performance target relaxes by 0.2 metres. The vehicle's Rearward Amplification (RA) performance also degrades, but in the case of RA the performance target actually becomes more stringent as the trailer's Static Rollover Threshold (SRT) degrades with the additional mass. Therefore, when vehicle mass is increased for Level 2 operation, RA very quickly becomes critical. This limits the extent to which productivity may be increased for Level 2 operation.

3.3. Other standards

Other high-speed dynamic performance standards include Tracking Ability on a Straight Path (TASP) and Yaw Damping Coefficient (YDC), neither of which is a critical factor for these vehicles in the consultant's experience. This project therefore did not need to focus on these standards other than to perform some basic checks. HSTO and RA (with SRT) were used to 'design' the regulatory proposal, saving time and increasing the efficiency of the process.

Standards related to low-speed turns are generally very far from limiting for a truck and dog configuration. Again, this project only needed to focus briefly on these standards for checking purposes.

Standards related to driveline performance are very far from limiting in the case of these vehicles based on the typical level of engine specification used by operators. In the consultant's experience, a 'minimum engine specification' with low power and torque by industry standards is typically used. Performance tends to be close to the PBS limits only because the engine is deliberately chosen to be a conservative parameter of the design.

Bridge loading is obviously a limiting factor in the longitudinal dimensions chosen for a vehicle. The industry is used to designing vehicles according to the regular bridge formulae, which are the same as those used in PBS Tier 1 bridge assessment. Therefore bridge assessment is only limiting in the same sense that it is already limiting for non-PBS operation. It will be necessary to ensure compliance with bridge formulae in the regulatory proposal.

4. Research method

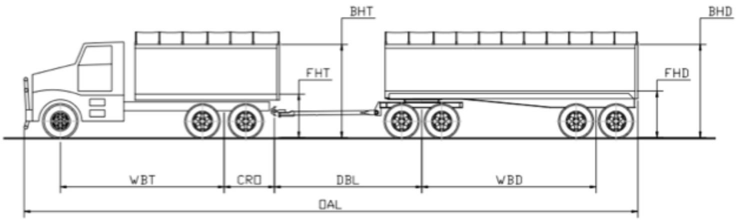
4.1. Vehicle specification envelopes

Vehicle Specification Envelopes (VSEs) were created to define minimum and maximum acceptable values for a number of vehicle design parameters. Some parameters were given a minimum and maximum value because low values are critical in some aspects of vehicle performance and high values are critical in others. Some parameters required only a minimum or maximum value. These limits on vehicle parameters were selected in consultation with the industry, chosen to align with typical truck and trailer equipment used in the market. The worst-case possibilities for vehicle dynamic performance within these desired ranges were checked against PBS standards.

The VSEs defined:

- acceptable minimum and maximum truck and trailer wheelbase, coupling position and drawbar length
- acceptable maximum floor height and total body height
- acceptable minimum critical axle distances for bridge loading
- acceptable maximum overall length
- acceptable maximum axle loads and gross mass
- acceptable minimum engine horsepower and driveline ratios.

Figure 4 depicts the primary longitudinal and vertical dimensions on which limits were placed, and the minimum and maximum values selected based on industry consultation.



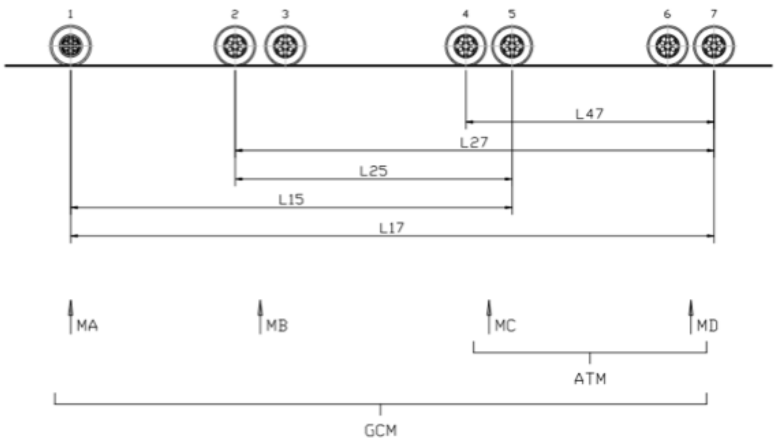
PRIMARY DIMENSION LIMITS (METRES)									
	WBT	CRO	DBL	WBD	FHT	FHD	BHT	BHD	OAL
MIN	4.500	1.500	3.300	4.500	-	-	-	-	-
MAX	5.800	1.650	5.600	6.950	1.400	1.450	3.000	3.000	20.000

Figure 4 – Primary longitudinal and vertical dimension limits

The overall length constraint (OAL) prevents the combination from exceeding 20 metres long, so it is not possible to select large values for every longitudinal dimension parameter. Without additional constraints, however, it would be possible to construct a very short combination that fails to satisfy bridge formula requirements. An axle spacing and mass schedule was therefore developed as part of the VSE. This schedule specified the maximum axle group loads and the minimum distances required between certain axles to achieve various gross combination masses (Figure 5).

NOTE: In this schedule, three different existing vehicle loading schemes are supported:

- GML means General Mass Limits. These limits apply to all vehicles on all roads.
- CML means Concessional Mass Limits. These limits apply on all roads if the operator has special mass management accreditation that ensures less chance of overloading.
- HML means Higher Mass Limits. These limits apply on selected roads if the vehicle has Certified Road Friendly Suspensions. HML allows higher mass than CML in most cases.



AXLE SPACING AND MASS SCHEDULE (METRES & TONNES)									
MA	6.5								
MB/MC/MD	16.5 (GML) 17.0 (CML/HML)								
GCM			ATM		L47 MIN	L27 MIN	L25 MIN	L15 MIN	L17 MIN
GML	CML	HML	GML	CML/HML					
RESTRICTED ACCESS (B-DOUBLE NETWORK)									
56.0	57.5	57.5	33.0	34.0	6.833	13.333	6.833	8.833	17.333
55.5	56.5	57.0	32.5	33.5	6.667	13.000	6.750	8.750	17.000
55.0	56.0	56.5	32.0	33.0	6.500	12.667	6.667	8.667	16.667
54.5	55.5	56.0	31.5	32.5	6.333	12.333	6.583	8.583	16.333
54.0	55.0	55.5	31.0	32.0	6.167	12.000	6.500	8.500	16.000
53.5	54.5	55.0	30.5	31.5	6.000	11.667	6.417	8.417	15.667
53.0	54.0	54.5	30.0	31.0	5.833	11.333	6.333	8.333	15.333
GENERAL ACCESS									
50.5	-	-	27.5	-	5.000	11.500	5.917	7.917	17.500
50.0	-	-	27.0	-	4.833	11.000	5.833	7.833	17.000
49.5	-	-	26.5	-	4.667	10.500	5.750	7.750	16.500
49.0	-	-	26.0	-	4.500	10.000	5.667	7.667	16.000

Figure 5 – Axle spacing and mass schedule

If the hauling unit is not eligible for a 6.5-tonne steer axle load ('MA') then the GCM values are reduced by 0.5 tonnes.

The axle spacing and mass schedule can be used to determine the minimum dimensions required to achieve a desired mass limit, or it can be used to determine the mass limit that applies to a particular vehicle design. (NOTE: Despite L17 only needing to be 17.333 metres to achieve the maximum Level 2 (restricted access) masses, most combinations aim for L17 to be at least 17.5 metres so that the maximum Level 1 (general access) mass can also be achieved.

5. Checking PBS performance of worst-case mass and dimension scenarios

The 20-metre maximum overall length limit and the minimum inter-axle spacings governed by the axle spacing and mass schedule provide a high degree of constraint to the available vehicle design options. For a given vehicle mass there is only a certain range of dimensions possible for the key parameters such as truck and trailer wheelbase and drawbar length. The PBS performance of vehicles built to the full range of possible dimensions and masses could be checked by examining only the worst-case dimension combinations. It has been established through experience that the worst-case performance in the critical standards (HSTO and RA) tends to occur when truck and trailer wheelbases are minimised and coupling rear overhang is maximised.

It was necessary to check not only the maximum mass scenario but also each of the lower mass scenarios. Performance can be worse for a lower mass scenario because it allows dimensions to be shorter and therefore promotes more dynamic activity ('twitchiness') in the combination. The advantage of less mass is therefore overcome by the disadvantage of less favourable longitudinal dimensions.

As well as the dimension and mass limits specified by the VSEs, popular truck and trailer suspensions were assumed to be fitted, and the 'reference tyre specification' used in the development of the PBS Scheme was used on all axles. Under these conditions it was found that vehicles built to the VSEs generally satisfied PBS requirements.

In practice, if the operator is not restricted in suspension and tyre specifications, it is considered that performance in the critical standards may potentially degrade slightly but not to the point of being patently unsafe. HSTO could increase by around 100 mm (17%). SRT could decrease by around 0.02 g, which would remain well in excess of the PBS standard. This however would have the effect of increasing RA by about 5%. There are many non-PBS combinations in operation that would have worse performance than this.

6. Minimum driveline specifications

Under the PBS Scheme a vehicle must meet four minimum performance levels based on driveline specification: Startability (maximum upgrade on which forward motion can commence from rest), Gradeability A (maximum upgrade on which forward motion can continue once moving), Gradeability B (maximum continuous speed on a 1% upgrade), and Acceleration Capability (time to travel 100 metres from rest).

Performance against these standards depends on such things as the engine torque curve, driveline gear ratios, mechanical losses, tyre rolling resistance and aerodynamic drag. It would be difficult to develop a workable regulation for use outside of PBS that addresses all of these parameters.

Driveline minimum standards have been proposed in a form that is simple to work with yet still satisfies PBS requirements with sufficient certainty:

- Peak engine power must be at least 302 kW (405 HP)
- Peak engine torque (in Nm) must be at least 92,000 divided by (LGR × FDR), where LGR is the lowest forward gear ratio of the gearbox and FDR is the final drive ratio of the drive axles.

The power requirement is sufficient to ensure that Gradeability B and Acceleration Capability are satisfied based on typical values for mechanical, rolling and aerodynamic losses. The torque requirement is sufficient to ensure that Startability is satisfied assuming that the torque during clutch engagement is half of the peak torque. If Startability is satisfied then Gradeability A is satisfied for these vehicles under these conditions.

These power and torque requirements could easily be checked by a roadside enforcement officer if the operator carried a certificate from the manufacturer stating that the vehicle met these design requirements. Analysis has been conducted to demonstrate that this approach is sufficient to ensure suitable driveline performance, and that driveline specifications typically used in the market will comply.

7. Conclusions

It is possible to develop simple prescriptive rules that can be written into regulations to allow popular PBS vehicle configurations to be accessed outside of the PBS Scheme. In developing these rules it is necessary to make some assumptions about the vehicle specification (such as the suspensions and tyres) and to simplify some of the calculations (as was done for driveline performance). Then by performing PBS Assessment of the worst-case possibilities under the prescriptive approach, it can be determined whether the performance of a vehicle operated under the prescriptive approach will have sufficient alignment with the intended safety outcomes of the PBS Scheme.

8. Acknowledgements

The author acknowledges Mr. Sridaran Kannan of the National Transport Commission for managing and funding this research. The author also acknowledges Mr. Les Bruzsa, Ms. Sue Mackenzie and Ms. Elena Petlivanova of the National Heavy Vehicle Regulator for advice on PBS approvals and providing the PBS approval data. Numerous dog trailer manufacturers contributed industry knowledge to the research, which is also gratefully acknowledged.