A REVIEW OF THREE PBS STANDARDS

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Abstract

The National Heavy Vehicle Regulator (NHVR) administers Heavy Vehicle National Law (HVNL), provides leadership, and drives sustainable improvements to safety, productivity and efficiency outcomes across the heavy vehicle road transport sector and the Australian economy. This role includes administering the Performance Based Standards (PBS) scheme which provides an alternative approach to size and weight regulation. The Australian PBS system was introduced in 2007.

In 2018 the Transport and Infrastructure Council (TIC) endorsed the recommendations of the National Transport Commission (NTC) on 'Assessing the effectiveness of the PBS marketplace and identifying barriers to vehicle design innovation' policy paper. This paper outlined four recommendations, one of which was for the NHVR to complete a review of the PBS Standards to ensure the PBS Scheme remains the world's leading innovative design approach. The first phase of this review covers three standards where issues have been identified. In the medium term it is envisaged that all the PBS standards will be reviewed.

The three standards that were reviewed are:

- PBS Standard C8: Frontal Swing
- PBS Standard C16: Directional Stability Under Braking
- PBS Standard A2: Pavement Horizontal Loading

This paper presents a summary of this review.

Keywords: Performance Based Standards, Frontal Swing, Braking Performance, Horizontal Pavement Loading

1. What is the issue?

The National Heavy Vehicle Regulator (NHVR) administers Heavy Vehicle National Law (HVNL), provides leadership, and drives sustainable improvements to safety, productivity and efficiency outcomes across the heavy vehicle road transport sector and the Australian economy. This role includes administering the Performance Based Standards (PBS) scheme which provides an alternative approach to size and weight regulation. The Australian PBS system was introduced in 2007 and from 2014, the rules governing the PBS scheme were incorporated into the Heavy Vehicle National Law (HVNL). Its administration and development are being progressed by the NHVR

At the May 2018 meeting of the Transport and Infrastructure Council (TIC), Ministers endorsed the recommendations of the National Transport Commission (NTC) on 'Assessing the effectiveness of the PBS marketplace and identifying barriers to vehicle design innovation' policy paper. This project outlined four recommendations, one of which was for the NHVR to complete a review of the PBS Standards to ensure the PBS Scheme remains the world's leading innovative design approach. The first phase of this review covers three standards where issues have been identified. In the medium term it is envisaged that all the PBS standards will be reviewed.

The three standards that were reviewed are:

- PBS Standard C8: Frontal Swing
- PBS Standard C16: Directional Stability Under Braking
- PBS Standard A2: Pavement Horizontal Loading

These standards were selected for review because issues associated with them had been identified by the PBS assessors.

2. What did we do?

In February 2019, a briefing paper was prepared outlining known issues with the three standards together with suggested changes to the standards. This briefing paper was reviewed by NHVR and then circulated to all the PBS assessors for feedback. In May 2019, the NHVR organised a one-day stakeholder workshop which was held in Melbourne. There were 46 attendees at this workshop and all the key stakeholder groups were represented. In June 2019, an additional stakeholder workshop for the jurisdictions was held by teleconference. Following the workshops, the briefing paper was revised taking into the feedback and a set of recommendations was presented. These are now going through a process of implementation.

3. What did we find?

3.1 Frontal Swing

The manoeuvre used for characterising low speed turning performance in the Australian PBS system (National Heavy Vehicle Regulator 2020) is a 90° kerb-to-kerb turn with an outside

radius of 12.5m. For rigid trucks, prime movers[1], buses and coaches, frontal swing is the maximum extent to which the front outside corner of the vehicle passes outside of the path of the outer edge of outside front steer tyre. This is illustrated in Figure 1

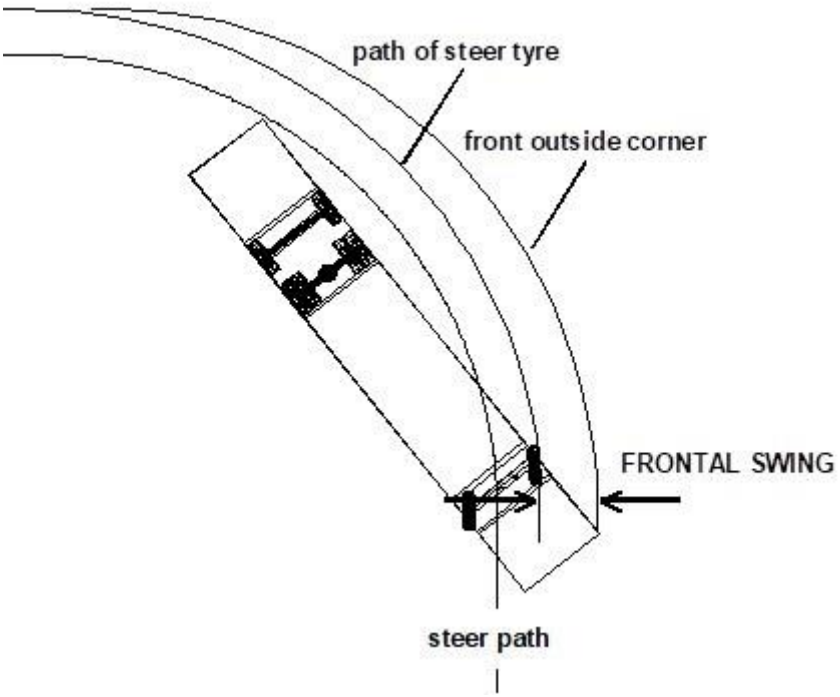

Figure 1. Illustration of frontal swing for a rigid vehicle.

For semi-trailers, two additional frontal swing measures apply. These are:

- Maximum of Difference (MoD), which is defined as the maximum of the difference between the frontal swing-out distances between adjacent vehicle units in the prescribed 90º low-speed turn.
- Difference of Maxima (DoM), which is defined ss the difference between the maximum frontal swing-out distances between adjacent vehicle units in the prescribed 90º low-speed turn.

Figure 2 illustrates the MoD and DoM for a particular prime mover semitrailer combination. Note that the x and y axes use different scales such that the magnitude of the frontal swing is amplified. In the case shown, the maximum frontal swing of the semitrailer is greater than the frontal swing of the prime mover. With different vehicle geometry the reverse may be true in which case the DoM is negative.

The feedback from the PBS assessors indicated that there were no issues arising from the MoD and DoM requirements but that the current frontal swing limit of 0.7m for rigid trucks and prime movers was overly restrictive for longer wheelbase vehicles fitted with bull bars such as twin steer trucks and prime movers. Furthermore, the frontal swing limit for buses and coaches is 1.5m and this does not appear to cause any additional safety risk. When the

[1] In many jurisdictions, prime movers are referred to as tractors. In this paper we have used the standard Australian terminology.

PBS system was first developed it was suggested that the level should be 1.5m for all vehicles (Prem, Ramsay et al. 2001) but this limit was reduced because the performance assessment of the fleet (Prem, de Pont et al. 2002) indicated that 0.7m was enough for all the rigid trucks and prime movers assessed at the time.

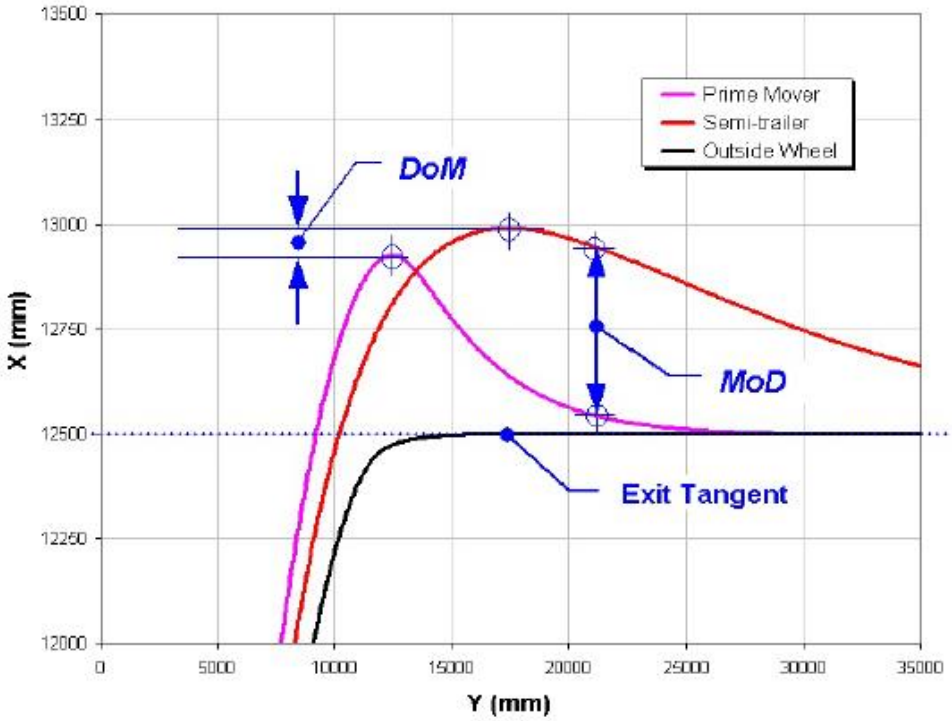

Figure 2. Example of MoD and DoM frontal swing standards.

The stakeholder workshop indicated that increasing the frontal swing limit for trucks and prime movers to 0.85m would resolve the current issues. It was also suggested that it would be simplest to make the limit 1.5m for all powered units thus removing any distinction between rigid trucks and prime movers, and bus and coaches.

To some extent, frontal swing is already incorporated in the low speed swept width performance measure and so there is an option to consider changing the test manoeuvre from the current kerb-to-kerb turn to a wall-to-wall turn of similar radius. This would eliminate the frontal swing requirements for trucks and prime movers and would simplify the frontal swing requirements for trailers. It also overcomes some issues where the steer axle track width is smaller, and the outside edge of the steer tyre is well inside the outside edge of the vehicle. However, this change would have implications for other performance standards that are not part of this review was therefore not recommended at this time.

3.2 Directional Stability Under Braking

The current braking requirements were developed prior to the introduction of the PBS scheme in 2007. As specified in the PBS rules (National Heavy Vehicle Regulator 2020), “the primary purpose of this standard is to manage safety risk of vehicle instability when braking in a turn or on pavement cross slopes”.

The PBS Rules specify a test procedure where the vehicle is decelerated from 60km/h at a specified deceleration rate and is required to not exhibit gross wheel lock-up in any load condition as well as remaining within the lane width specified for the "tracking ability on a straight path" performance standard. The deceleration rate required and the allowable lane width both vary with the access level. The Australian PBS system has four access levels with many of the PBS pass/fail criteria varying with access level. Thus, level 1, which is effectively general access, has the most demanding performance requirements while level 4, which applies to the road train routes in the most remote areas, has less demanding performance requirements for many of the performance standards.

However, the PBS Rules for this performance standard also include "deemed-to-comply" provisions based on vehicles meeting the Australian Design Rule (ADR) braking requirements. The testing option has rarely, if ever, been undertaken for assessing PBS combinations against the standard and all, or almost all, PBS applications use the "deemed-to-comply" option. We are not aware of any cases where the testing option has been used.

Brake technology is continually advancing with enhanced electronic control systems being developed to improve brake performance. Consequently, the ADR braking requirements have been updated several times since the PBS requirements were introduced to reflect these advances in brake technology. Our view was that there is no good reason to maintain separate braking standards for PBS vehicles compared to the general heavy vehicle fleet. This requires a lot of work to be duplicated and there is also the possibility of introducing inconsistencies between the two sets of braking requirements. However, one of the principles of the PBS system is that PBS vehicles should be safer than standard legal vehicles and therefore PBS vehicles should be at the forefront of adopting the new braking technologies.

One of the complicating issues of this approach is determining what "grandfathering" provisions should apply to PBS vehicles. PBS design applications are not always for new vehicles. For example, with existing vehicle combinations, it is normal practice to replace the truck or prime mover more frequently than the trailer(s). Unless the replacement vehicle is identical to the current vehicle, a new PBS design approval would be required. Without appropriate "grandfathering" provisions, a new PBS permit could require the existing trailer brake system to be upgraded to meet the current requirements for new vehicles, which would add significantly to the vehicle replacement cost. Although it could be argued that upgrading the trailer brakes has a safety benefit and is therefore desirable, it is likely that the increased cost would result in vehicle replacements being delayed and thus older, less safe trucks and prime movers will be kept running longer. It is important to get this balance right.

3.3 Pavement Horizontal Loading

The purpose of the Pavement Horizontal Loading standards is to regulate road wear by limiting the impact on the surface of road pavements of the horizontal tyre forces of a multi-axle group when turning; and the tractive tyre forces of the drive axle or axles when a vehicle is starting or climbing an upgrade. The highest horizontal forces are applied to the pavement when the tyres are at their maximum vertical load and on the verge of skidding, i.e., at the friction limit. This level of force can potentially be applied at all the axles under braking, at the drive axles under traction and at the extremities of an axle group in a tight turn.

The current PBS requirements are defined in terms of prescriptive limits because it had not been possible to establish an agreed performance-based standard. These prescriptive requirements are as follows:

In relation to axle groups:

- *for tandem axle groups with an axle spacing of more than 2 metres, at least one axle must be steerable; and*
- *for axle groups with three or more axles and a spread of greater than 3.2 metres, all axles beyond the 3.2 metre spread must be steerable.*

In relation to driving axles:

- *all driving axles in a drive axle group must distribute tractive forces, such that the maximum difference in tractive force between any two driving axles in the group is not greater than 10% of the total tractive force delivered by the drive axle group; and*
- *a vehicle or combination having one or two driving axles is not permitted when the gross mass of the vehicle or combination exceeds the relevant limit in Table 2.*

Table 2 shows different gross weight limits for vehicles with one or two drive axles for each of the access levels. These gross weight limits range from 35 tonnes for level 1 access for a vehicle with a single drive axle to 150 tonnes for level 4 access for a vehicle with two drive axles.

The limit cases for braking and traction are rarely applied in practice. Full brake application should only ever occur in an emergency and, in our view, should not be constrained. These events are relatively rare, and lives could be at stake. Restricting the vehicle's braking capacity to protect the pavement in these circumstances cannot be justified. Wheel spin or close to it in traction with fully loaded drive axles is generally only achievable with the engine operating at or near maximum torque while the vehicle is in its lowest gears. This is usually only done when necessary, such as when starting on a steep grade with a loaded vehicle.

In terms of pavement wear, the main concern is the scrubbing forces generated by axle groups in low-speed turns. The critical quantity here is horizontal stress rather than horizontal force. The stress calculation considers the contact area over which the force is applied. We proposed the following method for estimating the horizontal pavement stress.

For radial truck tyres, the stiffness of the sidewalls and the tread band is small compared to the stiffness provided by the air inside the tyre. Thus, the area of the contact patch, A, can be approximated by:

$$A = \frac{F_z}{P_{inflation}} \qquad \textbf{Equation 1}$$

where F_z is the vertical load in N
$P_{inflation}$ is the inflation pressure in Pa

The horizontal shear stress then is given by:

$$\tau_{zy} = \frac{F_y}{A}$$ **Equation 2**

where τ_{zy} is the shear stress in the y-direction on the plane perpendicular to the z-axis
F_y is the horizontal force in the y-direction

Substituting Equation 1 into Equation 2 gives

$$\tau_{zy} = \frac{F_y}{F_z} . P_{inflation}$$ **Equation 3**

In simple terms, this says that the horizontal stress is equal to the friction demand (F_y/F_z) multiplied by the inflation pressure.

The feedback from the State Road Authorities indicated that they would be comfortable with limiting the horizontal stress applied by PBS vehicles to the same level as that applied by standard legal vehicles.

4. What did we recommend and what happened?

4.1 Frontal Swing

We recommended that the simplest interim solution to the current issues is to relax the current frontal swing limit for truck and prime movers and set a new limit of 0.85m and that the MoD and DoM limits for trailers should be unchanged. Because the MoD and DoM limits are determined from the frontal swing of the semitrailer(s) relative to the frontal swing of the prime mover, increasing the allowable frontal swing of the prime mover does effectively also increase the maximum allowable frontal swing of the semitrailer(s).

We also recommended that, when the other low speed turning performance standards come up for review, consideration should be given to replacing the current kerb-to-kerb turning manoeuvre with a wall-to-wall manoeuvre of similar radius, which would enable the frontal swing requirements to be simplified.

The NHVR proposed increasing the frontal swing limit to 1.0m to give some increased future flexibility. Given that buses and coaches are already operating with a maximum frontal swing of 1.5m without any reported additional negative safety outcomes, the NHVR were confident that this 1.0m limit would not cause any measurable additional safety risk. However, the state and territory transport ministers took a more conservative approach and decided to follow the recommendation in the review with an increase to 0.85m. This has now been implemented and is in the current PBS Rules.

4.2 Directional Stability Under Braking

The current ADR35 and ADR38 requirements do deliver a satisfactory level of directional stability under braking and thus there is no need for a separate set of braking performance requirements within the PBS system. Existing PBS vehicles can be “grandfathered”, but issues do arise when an existing PBS vehicle requires a new PBS approval.

Thus, we recommended the following approach:

- For new PBS approvals all vehicles in the combination are required to meet the current ADR35 or ADR38 standards for new vehicles regardless of whether the vehicles are new or not.
- If any of the vehicles in the combination have previously been part of a PBS approved vehicle, then one prior PBS vehicle approval can be used to entitle the vehicles covered by that approval to only be required to meet the ADR35 or ADR38 requirements that were in force at the time of that approval.
- All other vehicles in the combination are required to meet the current ADR35 or ADR38 standards for new vehicles.

The NHVR reviewed these recommendations and have proposed the following:

- New PBS Vehicles (newly built & newly entering scheme) must comply with the latest ADRs.
- Older Vehicles new to PBS Scheme
    - Hauling unit must be fitted with ABS and EBS.
    - Trailing units must be fitted with ABS and roll stability function.
- Previously Certified Vehicle
    - Certification remains valid and vehicle components can be transferred across vehicle approvals (VA) without having to be re-certified.
    - This provision may be updated as the NHVR implements the 'Transitional Arrangements' relating to the braking safety outcome provisions

The NHVR proposal is broadly in-line with the recommended approach but is a little more liberal on the "grandfathering" provisions in that it allows "grandfathering" for all vehicle units in a combination rather than just one.

At the time of writing, these recommendations have not yet been implemented in the current PBS Rules.

4.3 Pavement Horizontal Loading

Good brake performance is a safety issue and therefore we recommended that the PBS requirements should not limit the horizontal pavement forces generated by the brakes.

The Startability and Low Speed Gradeability PBS requirements already limit the maximum gross combination weight of the vehicle based on the tractive forces that can be generated. Therefore, we recommended that there should be no additional limitations on the horizontal tractive forces included in this standard.

We recommended that the horizontal average stress on any axle loaded to general mass limits during the standard 12.5m outside radius kerb-to-kerb 90° turn should not exceed 510kPa. The inflation pressure used for this calculation should be the rated pressure for the tyres.

This pass/fail threshold was determined by using the Austroads 19m prime mover and semi-trailer design vehicle (Austroads 2013) shown in Figure 3 as the starting point. The rear axle spread on this vehicle is 2600mm, but the maximum legally allowable axle spread for a tridem group is 3200mm and we know that increasing the axle spread increases the horizontal

pavement forces. We modelled the vehicle with dual 11R22.5 tyres and with 385/65R22.5 wide single tyres each with both axle spread options. This showed that the 11R22.5 dual tyres with the 3200mm axle spread generated approximately the same friction demand as the 385/65R22.5 wide single tyres at 2600mm spread.

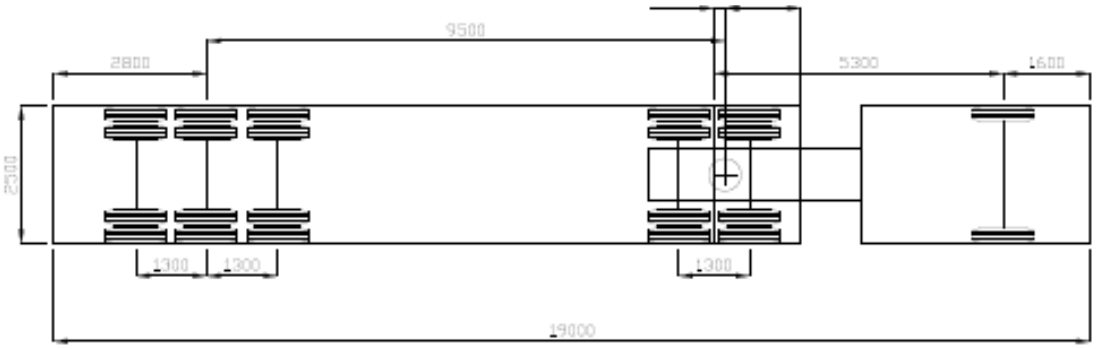

Figure 3. Austroads 19m prime mover and semi-trailer design vehicle.

To determine the threshold value we considered the average horizontal stress for the axle using the manufacturer-recommended inflation for the tyres at the rated load. Based on the results for the dual 11R22.5 tyres at the widest axle spread we determined the 510kPa limit. The inflation pressure for these tyres at the rated load is 690kPa and so this implies a maximum average friction demand for the axle of 0.74. The simulations assume that coefficient of friction for the tyres is 0.8, so this peak value is 92% of the maximum possible value.

When this proposal was put to the PBS assessors, the concept of specifying a horizontal papvement stress limit was generally accepted but there was considerable debate about the pass/fail criterion. Several assessors argued that the peak horizontal stress should be based on the value at the wheel rather than the average for the axle. This approach would result in a higher limit value. It was also argued that because shorter wheelbase semitrailers can legally be operated, the reference vehicle should have been a shorter wheelbase semitrailer which would also result in a higher limit value.

One of the main issues with using this approach to set a higher limit value is that the friction demand cannot exceed the coefficient of friction. If the friction demand at one of the wheel sets on an axle reaches the friction limit, the additional demand transfers to the other wheel set. Hence, if the upper limit for the horizontal pavement stress is set at a level that corresponds to a friction demand of 0.8, then tyre scuffing during a 90° 12.5m outside radius turn will be acceptable.

The principle of using a horizontal pavement stress calculation to quantify the pavement wear implications of horizontal pavement loading has been broadly accepted but there is an ongoing debate as the the appropriate level for the pass/fail criterion. At the time of writing nothing has been implemented.

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