DEVELOPMENT OF PERFORMANCE STANDARDS FOR AUSTRALIAN HEAVY VEHICLES

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ABSTRACT

The National Transport Commission, Australia, and Austroads are developing performance-based standards (PBS), which will augment prescriptive regulations for heavy vehicles in the areas of mass, dimensions and configurations. The adoption of PBS is expected to lead to more predictable and consistent regulatory outcomes and to provide scope for the design of innovative and more productive vehicles.

Under the existing regulatory model applying to heavy vehicles desired vehicle performance is controlled indirectly by prescriptive regulations. Under the performance-based regulatory model standards would specify the performance required from vehicle operations, in terms of road safety and infrastructure protection.

Each performance standard assigns a numerical limit (performance level) to a performance measure, defining a boundary between what is acceptable and unacceptable. A performance measure quantifies how a vehicle performs for a specific circumstance or manoeuvre.

A set of 20 performance measures has been submitted for approval to Australian Transport Council (ATC) and detailed rules for their implementation are being developed. This paper presents this set of performance measures.

INTRODUCTION

Heavy vehicles in Australia are regulated predominantly by prescriptive standards that evolved over a long period and often differed between States and Territories. Modernising regulations by moving to a nationally consistent performance-based approach to the regulation of heavy vehicle operations is now being undertaken as a voluntary optional alternative to the existing prescriptive regulations. Policy proposals are being developed by a joint National Transport Commission (NTC)/Austroads project.

Under a performance-based approach to heavy vehicle regulation, standards will specify the performance required from vehicle operations rather than mandating how this performance is to be achieved. In Australia this approach to regulation has been adopted in other sectors, such as occupational health and safety and food standards, and is now well established as the approach preferred by regulatory review agencies.

Performance-based standards (PBS) seek to align regulatory requirements more closely with the performance capabilities of vehicles, how they are driven and operated, and the characteristics of the road network. This approach aims to significantly improve safety and can also increase productivity and reduce the amount of road wear caused by heavy vehicles undertaking a specific transport task.

Traditionally, heavy vehicles have been regulated by tightly defined prescriptive limits, such as mass and size limits, which provide little scope for innovation. This method of control is very crude, with no guarantees that vehicles meeting the current requirements do not have relatively poor performance. Many of the intrinsic safety issues such as stability, handling and controllability, high-speed tracking, and gradeability are not evaluated and are only indirectly controlled, if at all. Less than optimal safety outcomes can result from the prescriptive standards, and some potentially beneficial technologies are excluded from consideration.

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Under performance-based standards, the interactions of vehicles with the roads they will be used on are taken into account more explicitly. In determining whether a specific vehicle can operate on a particular road, the vehicle's capabilities and the relevant road standards and traffic conditions can be examined jointly to decide whether the whole operation meets the performance standards.

A wide range of performance measures has been developed over many years of international research for the evaluation of heavy vehicle performance. These were reviewed and a key selection has been carefully developed for the evaluation of the Australian heavy vehicle fleet. Crash studies have found some relationships between these measures and crash risk, providing some basis on which to set minimum performance levels. Road network and geometric factors together with road agency experience with managing safety and access of specific vehicle classes were also used to determine the performance requirements.

The set of performance standards aims to improve the intrinsic safety performance of heavy vehicles and achieve a better fit between them and the classes of road on which they may be used. The cost of road wear and damage caused by heavy vehicles can be reduced, and increased productivity can reduce the number of trucks required for the transport task providing further safety benefit by reducing crash risk exposure.

Better outcomes for safety, the environment and for all road users and communities are expected to result from the performance-based regulation of heavy vehicles.

A policy overview of the complete PBS project is given by (Calvert 2004) in another paper at this symposium. The process of technical development of the standards has been previously reported, and is further described in the Standards and Measures Regulatory Impact Statement (RIS) (NRTC 2003). The RIS provides full references to the extensive technical and policy documentation which can also be found on the NTC website www.ntc.gov.au.

THE RECOMMENDED SAFETY AND INFRASTRUCTURE PERFORMANCE –BASED STANDARDS

Following the approval of a set of five overarching policy principles by state transport ministers in 2001 a set of 20 performance standards for safety and infrastructure protection have been developed for their consideration.

Sixteen of the proposed performance measures are safety related. They have been selected to cover all the critical safety issues in consultation with the state road jurisdictions, local government, the commonwealth government and the transport industry. Taken as a package these performance measures are intended as a significant increase over the safety performance capability currently required of the heavy vehicle fleet.

For the purpose of determining vehicle performance requirements, the road and highway network has been categorised into four road types, known as Level 1 to Level 4. Where appropriate, different vehicle performance levels are specified according to these road types.

Road controlling authorities will use a set of Road Classification Guidelines (NTC 2004), which are currently being trialed, to classify their road networks into the four levels. PBS vehicles that meet the respective performance levels will have access to that level of road, taking account of local amenity, network and planning issues.

The performance measures and levels according to road type are shown below in Table 1.

Table 1. Proposed standards according to road access type.

Performance standard	Performance measure	Performance level for each road type			
		Level 1	Level 2	Level 3	Level 4
Longitudinal performance (low speed)					
Startability	Ability to commence forward motion on specified grade.	at least 15%	at least 12%	at least 10%	at least 5%
Gradeability	(a) Ability to maintain forward motion on specified grade.	Maintain forward motion on grade			
		at least 20%	at least 15%	at least 12%	at least 8%
	(b) Ability to maintain a minimum speed on a grade.	Minimum speed on 1% grade			
		80 km/h	70 km/h	70 km/h	60 km/h
Acceleration capability	Ability to accelerate either from rest or to increase speed on a road (no grade).	Acceleration no worse than specified by the distance-time curves in Fig 2(a) of NRTC (2003a).			
Longitudinal performance (high speed)					
Overtaking time (1)	Time taken for a passenger car to safely overtake the subject PBS vehicle to be no greater than can be accommodated by overtaking opportunities provided by the road at the specified traffic flow level of service (*LoS*).	Level of Service C	Level of Service C	Level of Service B	Level of Service B
Tracking ability on a Straight Path	The total swept width while travelling on a straight path, including the influence of variations due to crossfall, road surface unevenness and driver steering activity.	no greater than 2.9m	no greater than 3.0m	no greater than 3.1 m	no greater than 3.3m
Ride Quality (Driver Comfort) *(Standard to be Developed)*	*The level of vibration that a vehicle's driver is exposed to during a working shift that leads to reduced comfort and decreased proficiency, and contributes to fatigue.*	*Performance levels to be developed as no suitable measures currently exist.*			
Directional Performance (low speed)					
Low Speed Swept Path	The maximum width of the swept path in a prescribed 90^{o} low speed turn.	No greater than 7.4m	no greater than 8.7m	no greater than 10.1m	no greater than 13.7m

Table 1. continued.

Frontal Swing	The maximum lateral displacement in a prescribed low-speed turn between the path of the front outside corner of the vehicle (or vehicle unit) and: (a) the outer edge of the front-outside wheel of the hauling unit or motive vehicle; or (b) the outside part of a semi-trailer during a small radius turn at low speed.	Part (a) for trucks and prime movers no greater than 0.7m for buses no greater than 1.5m Part (b) no greater than 0.40 m Trailer value not to exceed prime mover value by more than 0.20m.			
Tail Swing	The maximum lateral distance that the outer rearmost point on a vehicle unit moves outwards in, perpendicular to its initial and final orientation, when the vehicle commences and completes a prescribed low-speed turn.	not greater than 0.30m	not greater than 0.35m	not greater than 0.35m	not greater than 0.50m
Steer Tyre Friction Demand (2)	The maximum friction level demanded of the steer tyres of the hauling unit in a prescribed low speed turn.	Not more than 80% of the maximum available tyre/road friction limit.			
Directional performance (high speed					
Static Rollover Threshold	The steady-state level of lateral acceleration that a vehicle can sustain during turning without rolling over.	Road tankers hauling dangerous goods in bulk and buses – no less than 0.40g. All other vehicles – no less than 0.35g (g is acceleration due to gravity in m/s^2)			
Rearward Amplification	Degree to which the trailing unit(s) amplify or exaggerate lateral motions of the hauling unit.	Rearward amplification no greater than 5.7 times the static rollover threshold (g) of the rearmost roll–coupled unit taking account of the stability of the roll coupling (3).			
High Speed Transient Offtracking	The lateral distance that the last-axle on the rear trailer tracks outside the path of the steer axle in a sudden evasive manoeuvre.	no greater than 0.6 m	no greater than 0.8 m	no greater than 1.0 m	no greater than 1.2 m
Yaw Damping Coefficient (4)	The rate at which 'sway' or yaw oscillations of the rearmost trailer decay after a short duration steer input at the hauling unit.	No less than 0.15 at the certified vehicle speed.			
Handling quality (Understeer/Oversteer) *(Standard to be Developed)*	*Ratio of the response to steering (change of vehicle direction) to the steering wheel input, and its dependence on vehicle speed and severity of the manoeuvre.*	*Performance levels to be developed as no suitable measures currently exist.*			

Table 1. continued.

Directional Stability Under Braking	The ability to maintain stability under braking.	(a) A vehicle must not exhibit any wheel lock, and must remain in a straight lane of width equal to that specified in the standard 'Tracking Ability on a Straight Path' for the corresponding level of operation, when it is braked at a deceleration rate of 0.45g from an initial speed of 60 km/hr on a high friction pavement in both unladen and laden states (momentary wheel-lock associated with ABS brake modulation is acceptable); and. (5) (b) A vehicle must meet the stopping distance performance levels in the relevant versions of Australian Design Rules 35 and 38 (as applicable); and (c) Auxiliary brakes (if fitted) must not apply automatically if the computed friction utilisation at any wheel can exceed 0.1 when the vehicle is braked from a road speed corresponding to three quarters (3/4) governed engine speed (unless the motive vehicle has an acceptable ABS).
Infrastructure related performance measures-pavement related		
Pavement Vertical Loading	Degree to which vertical forces are applied to the pavement.	The Average Road Wear Per Axle Group (SARs/AG) shall not exceed the level calculated for a vehicle with the same number of rigid parts and the same number of axles on each rigid part as is permitted by prescriptive (or equivalent) regulations.
Pavement Horizontal Loading *(Prescriptive Requirement)*	*Degree to which horizontal forces are applied to the pavement.*	*(a) Steerable axles* *(i) at least one axle of any two axles joined by a load sharing suspension system and greater than 2 metres apart must be steerable; and* *(ii) with all other groups of axles joined by a load sharing suspension system with a spread of greater than 3.05 metres, all axles beyond the 3.05 metre spread must be steerable.* *(b) Driving axles* *(i) the maximum gross mass of a vehicle with either one or two driving axles will be detailed after further discussion with the road jurisdictions.* *(ii) all driving axles must distribute tractive forces between all axles in the drive axle group, such that the maximum difference in tractive force between any two axles in the group is not greater than 10% of the total tractive force delivered by the drive axle group.*
Tyre Contact Pressure Distribution *(Prescriptive Requirement)*	*The maximum local vertical stress under a tyre's contact patch for a given vertical load type and tyre inflation pressure.*	*Existing prescriptive requirements relating to maximum pressure be retained and applied to PBS vehicles.*
Infrastructure related performance measures-bridge related		
Bridge Loading	The maximum effect on a bridge measured relative to a reference vehicle.	Bending moments and shear forces no greater than the moments and forces induced in the bridge by representative Austroads Bridge Assessment Guidelines (ABAG) configured vehicles with axle group loadings set at General Mass Limits (GML) or Higher Mass Limits (HML) as appropriate for the road class or route. (5)

Notes to Table 1:

- Development of the Overtaking time measure is discussed in PBS Safety Standards for Heavy Vehicles (NRTC 2003). Level of Service is an extension of the traffic capacity analysis developed by the US Bureau of Public Roads, and used in the Austroads (1988) guidelines for traffic capacity based on the 1985 US Highway Capacity manual.

- The method of calculation of Steer Tyre Friction Demand and a discussion on tyre/road friction values is presented in Definition of Potential Performance Measures and Initial Standards (NRTC 2001).
- The development of this relationship between rearward amplification and static rollover threshold is discussed in Performance Characteristics of the Australian Heavy Vehicle Fleet (NRTC 2002). It also shows that, given this performance measure, Load Transfer Ratio (LTR) is not required. LTR was therefore omitted due to high sensitivity to modelling methods, the non-availability of a field testing option.
- Yaw damping is discussed in Definition of Potential Performance Measures and Initial Standards (NRTC 2001).
- High friction surface means a surface with friction coefficient 0.8 or greater in the dry. A full discussion of PBS braking issues is presented in Review of Heavy Vehicle Braking Systems Requirements (NRTC 2003).
- GML and HML are mass limit classifications applicable to highways in Australia.

Standards in Italics are standards that are yet to be developed or are prescriptive substitutes for a performance standard.

Some auxiliary provisions associated with infrastructure protection standards are not detailed in Table 1.

Performance measures generally involve some standardised test manoeuvre or procedure that is representative of actual operating conditions but do not and cannot cover all possible operating scenarios. Thus, although the performance measure on which a performance standard is based is more directly linked to the safety outcome it is targeting, it is not necessarily a perfect match.

Although for all of these measures it is obvious what constitutes good and bad performance and that poor performance will lead to worse safety outcomes in most cases, relatively little research and few data are available to quantify the relationship between performance and safety. For some key measures where the negative safety outcome is dramatic (eg vehicle roll-over) some studies have attempted to relate vehicle performance as indicated by Static Roll Threshold (SRT) to roll-over crash risk. Research investigating performance levels and crashes have been well reported elsewhere and has been conveniently summarised in a draft discussion paper prepared for the OECD. (OECD 2004).

Accredited vehicle assessors will be required to evaluate candidate PBS vehicles against the above standards and certify compliance. Rules for vehicle assessment are to be developed for this purpose. These rules will specify in detail how the accredited assessors will conduct computer modelling or field testing for PBS approvals.

MATCHING VEHICLE PERFORMANCE TO THE ROAD NETWORK

The performance measures listed in Table 1 attempt to reflect a fit between the vehicle's performance and the infrastructure's capacity to accommodate the vehicle. Thus there is a need for both vehicles and the infrastructure to meet a common standard. The values specified for each performance standard in Table 1 are, where appropriate, specific to the type of road that a vehicle may be allowed to operate on as determined by the Road Classification Guidelines (NTC 2004).

In developing the performance level for each road type (Level 1 to Level 4) considerable tension existed between the need to provide for maximum flexibility in vehicle design and potential productivity and the conflicting need to ensure a good "road fit" at each level. In respect to the latter, the need for road user and community acceptance of PBS vehicles was a major concern of the road agencies.

Startability and Gradeability reflect the vehicle's ability to start from rest on a grade and to maintain speed on a grade. Poor performance can lead to vehicles getting stuck and creating an obstruction or creating congestion so this is clearly undesirable. Provided road designers ensure that the maximum grades are within vehicle capabilities, the system should perform adequately. Quantifying the increased crash risk associated with a mismatch between the road geometry and the vehicle capabilities is very difficult.

Acceleration capability reflects the vehicle's ability to clear intersections and rail crossings etc For the infrastructure designer this relates directly to sight distances and speeds. Again the vehicle standard and the infrastructure standards need to match but the increases in crash risk associated with a mismatch are not known and difficult to determine.

Considerable debate surrounded the establishment of the performance levels for Startability, Gradeability and Acceleration Capability. Vehicle operators and suppliers considered that the proposed values would be very difficult to meet particularly when the additional impacts of other regulatory proposals for engine emission and sound levels, which could diminish existing engine power output levels, are considered.

Jurisdictions generally agreed with the proposal for Overtaking time, which is based largely on network geometric and traffic conditions. While transport operators were not familiar with this approach it does address their concern that earlier proposals were effectively an indirect measurement of vehicle length and were therefore fundamentally prescriptive.

Tracking Ability on a Straight Path describes the total width occupied by the vehicle in motion (at high speed factoring in road roughness and the driver's steering input) and thus is directly related to the lane and road width requirements. There have been studies relating road width and/or lane width to crash rate. These studies generally relate to two-lane roads (ie with opposing traffic). They have typically found that crash rates reduce with increasing width up to some point, typically a 3.7m lane width or 7.5m road width, and then either flatten out or in some studies increase. All of these studies are, of course, based on the mix of vehicles operating on the roads being analysed. It is difficult to use these findings to determine the safety impact of changing the width occupied by moving vehicles. Directional Stability Under Braking is a related measure as it controls the lane width occupied by the vehicle during hard braking. There does not appear to be any information available on the relationship between crash rate and this performance characteristic, although it is widely recognised that heavy vehicle braking performance remains one of the most problematic safety regulation issues for heavy vehicles around the world and in Australia.

Low-Speed Swept Path, Frontal Swing and Tail Swing all relate to the width requirements of the vehicle during low speed turning manoeuvres. These performance standards should be consistent with the standards for the geometric design of intersections and roundabouts and the associated lane markings. Again it is clear that a mismatch between the vehicle and infrastructure will increase the crash risk but it is difficult to quantify this effect. The Level 2 value of 8.7m will exclude a small proportion of existing B-double combinations from these routes. This remains of considerable concern to industry who consider that current B-doubles[1] should have access to Level 2 routes. The L3 value of 10.1m will exclude most B-triples that are already successfully operating on similar routes. There is concern that road authorities failure to agree that the Level 3 network could safely accommodate a swept path of up to 11.0m could impede fleet migration to superior performing vehicles.

Ride Quality (Driver Comfort) represents the vehicle's response to the surface profile of the road but the relationship is complex. From a safety point of view it affects driver fatigue, alertness, and potential vibration induced driver health problems, but this is difficult to quantify. Further research, which needs to be undertaken on an internationally cooperative basis, is required to complete the development of this measure.

Steer Tyre Friction Demand was agreed to by all parties. This measure was initially applied to tri-drive vehicles only but it was later agreed to apply to all PBS vehicles.

The values for Static Rollover Threshold, Rearward Amplification, High Speed Transient Offtracking and Yaw Damping Coefficient were generally supported by both road authorities and industry although they were considered stringent. The main debate on these measures centred on whether in aiming to upgrade the overall fleet performance by setting demanding standards some preferred roll-coupled[2] combinations would be excluded from PBS. This could limit the extent to which existing poorer non roll-coupled combinations could be replaced by better performing PBS vehicles.

Handling Quality (Understeer/Oversteer) reflect the vehicle's handling performance during low speed and high speed manoeuvres respectively. Clearly performance or lack of it in this regard will have an impact on safety but it has not been quantified. In the case of Handling Quality there is still debate over how it should be characterised and what constitutes acceptable performance.

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[1] B-doubles and B-triples consist of a prime mover connected by 5th wheels to 2 or 3 semi-trailers respectively.

[2] Roll–coupled is a combination in which the connection between the vehicles in the combination can transfer roll-over forces between them (eg semi-trailers).

Directional Stability Under Braking replaced an earlier proposal to mandate Anti-lock Braking Systems (ABS) which was not considered to be a performance standard, and was strongly opposed by industry stakeholders. Three deemed to comply arrangements are proposed to be optionally available as alternatives to establishing compliance with this standard by using first principles or testing. These options are (a) full brake compatibility and load proportioning on all axles and component vehicles, (b) an acceptable form of Anti-lock Braking System (ABS)/Electronically-controlled Braking System (EBS) and automatic slack adjusters on component vehicles, or (c) an acceptable form of ABS/EBS and automatic slack adjusters on prime movers and full brake compatibility and load proportioning on all trailer axles.

Analysis of the development and impact of the PBS Infrastructure Standard presented in Table 1 are presented at this seminar in a paper by Pearson and Leyden (2004).

The safety and infrastructure protection performance standards are to be accompanied by additional standards for noise and emissions, the details of which are still under development. These additional standards will ensure that performance-based vehicles are quieter and cleaner than other heavy vehicles.

CONCLUSIONS

The set of safety and infrastructure protection performance standards will comprise the performance measures and performance thresholds set out in Table 1. These standards will form the criteria for establishing whether proposals for vehicle operations meet the required safety and infrastructure protection standards to operate under the performance–based standards approach to regulating heavy vehicle operations. This approach is being developed as an optional alternative to existing prescriptive rules on vehicle mass, dimensions and configuration, in accordance with the set of policy principles agreed by the Australian Transport Council (ATC).

Applied together, as proposed, the performance standards constitute demanding criteria which will produce a significant improvement in safety performance for PBS vehicles and ensure no greater wear or damage to infrastructure. While there is some concern that the set of standards provide only limited productivity opportunities at this stage, they represent the best agreement that could be achieved at this time between the conflicting interests of safety and productivity. It is recognised that safety performance has been significantly increased, and some productivity gains are available particularly in relation to vehicle configuration and volume constrained loads. A Regulatory Impact Statement (NRTC 2003) has been prepared for the PBS Standards and Measures. This fully documents their development and provide references to the extensive supporting documentation. This documentation may be found on the NTC website www.ntc.gov.au

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