PERFORMANCE BASED STANDARDS AND ACTIVE VEHICLE STABILITY SYSTEMS

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Abstract
This paper assesses whether or not the Australian Performance Based Standards are still relevant in light of emerging active safety technologies. It includes are review of the various technologies available, how they effect on road PBS performance, the tensions between delivering safety and productivity and an evaluation of alternative regulatory mechanisms, in particular ECE R13.11. Finally, it proposes alternatives tests that might supplement the PBS Scheme and provide the possibility to improve safety and productivity outcomes.

Keywords: Performance Based Standards, Heavy, Electronic Stability Control, ESC, Roll Stability Control, Electronic Vehicle Control Systems

Résumé
Cet article a pour sujet les normes de performance en Australie et examine en particulier la question de leur pertinence à la lumière de technologies émergentes de sécurité active. Pour chacune des différentes technologies disponibles sont passées en revue leur interaction avec les normes de performance routière et les conflits qui résultent de la poursuite simultanée de gains en terme de productivité et de sécurité. L'article s'intéresse également à des mécanismes alternatifs de régulation, tels que ECE R13.11. Enfin, d'autres tests de performance sont proposés pour compléter l'évaluation des combinaisons routières dans le cadre des normes de performance, afin de poursuivre l'amélioration des véhicules ainsi évalués en terme de sécurité et de productivité.

Mots clés: normes de performance routière, poids lourds, camions, Contrôle de stabilité électronique, ESC, Anti-renversement, système électronique
de contrôle des véhicules.

1. Introduction

This paper explores the possibility of using active vehicle stability systems to meet the high-speed performance standards included in the Australian Performance Based Standards (PBS) Scheme. Whilst the paper will explore broader possibilities, the focus is on readily available technologies commonly referred to as Electronic Stability Control (ESC) and Roll Stability Control (RSC).

The paper concentrates on the PBS rollover standard, examining the proposition that RSC as defined by UNECE regulation number 13 (ECE 13.11) is a safe alternative to the PBS Static Rollover Threshold (SRT) measure. The author also offers some thoughts about directional stability control systems and the various PBS yaw stability measures.

1.1 Methodology

The author reviewed the vehicle stability requirements included in the Australian PBS Scheme and compared them with the electronic vehicle stability requirements contained in ECE R13.11. Additionally, the author reviewed relevant research pertaining to vehicle dynamics, road trauma, and the efficacy of electronic stability control systems. The author obtained further insight and information through consultation with vehicle manufacturers, control system suppliers, regulators and PBS Assessors.

1.2 The Australian PBS Scheme

The Australian Performance Based Standards (PBS) Scheme is a voluntary opt-in regulatory system designed to allow more productive (longer and heavier) commercial vehicles access to the road network provided they pass all sixteen safety and four infrastructure protection standards (NTC 2008). Whilst the scheme does provide for single unit trucks and buses, it primarily caters for combinations exceeding 42,500 kilograms. Figure 1 shows the structure of the performance standards.

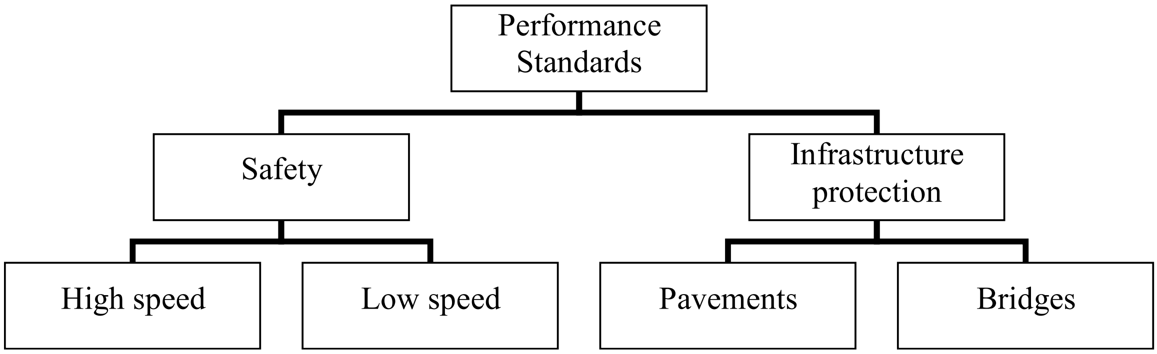

Figure 1 – Performance Based Standards Scheme Structure

This paper is concerned with the high-speed safety standards that relate to the dynamic stability of a heavy vehicle combination, they include:

- Tracking Ability in a Straight Path (TASP)
- Static Rollover Threshold (SRT)
- Rearward Amplification (RA)

- High-Speed Transient Offtracking (HSTO)
- Yaw Damping Coefficient (YDC)
- Handling Quality (Understeer/Oversteer) (HQ)
- Directional Stability Under Braking (DSUB)

Details of each standard can be found in the PBS Standards and Vehicle Assessment Rules (NTC, 2008), available online at www.ntc.gov.au.

1.3 Active Vehicle Stability Systems

Active vehicle stability systems refer to electronic control systems that improve vehicle roll and/or yaw stability. The systems work by measuring dynamic system variables in real time (e.g. wheel speeds, lateral acceleration, yaw rate and steer angle), detecting instability and taking corrective action by selectively applying the brakes, controlling engine power or applying a steering input.

Electronic Stability Control (ESC) typically refers to directional control function of the power-driven vehicle (truck or prime mover), whereas Roll Stability Control (RSC) typically refers to the rollover control function of the trailer. ECE R13.11 regulates these well-known Electronic Vehicle Control Systems (EVCS). However, there are other EVCS developed in Australia with the express purpose of meeting the PBS Scheme standards.

2. UNECE Brake Regulations – ECE R13.11

The United Nation Economic Commission for Europe (UNECE) has mandated the fitment of electronic stability control systems on certain classes of heavy commercial vehicles (ECE, 2008). The EU brake regulation - ECE Regulation No. 13 (ECE R13) - as amended in July 2008 outlines the technical requirements for EVCS:

"Vehicle Stability Function" means an electronic control function for a vehicle which improves the dynamic stability of the vehicle.

A vehicle stability function includes one or both of the following:
(a) directional control
(b) roll-over control

Control functions within a vehicle stability function:

"Directional control" means a function within a vehicle stability function that assists the driver, in the event of under steer and over steer conditions, within the physical limits of the vehicle in maintaining the direction intended by the driver in the case of a power-driven vehicle, and assists in maintaining the direction of the trailer with that of the towing vehicle in the case of a trailer.

"Roll-over control" means a function within a vehicle stability function that reacts to an impending roll-over in order to stabilise the power-driven vehicle or towing vehicle and trailer combination or the trailer during dynamic manoeuvres within the physical limits of the vehicle."

Annex 21 – Special requirements for vehicles equipped with a vehicle stability function, includes more detailed system requirements. For example, the EVCS for trailer directional control must have the ability to control left and right wheel speeds by means of selective braking.

Currently ECE R13.11 does not include a common test procedure for demonstrating the vehicle stability function. Until a standard procedure is agreed to, the vehicle stability function must be demonstrated using one or more of the dynamic manoeuvres included in Table 1.

Table 1 – Dynamic manoeuvres for demonstrating vehicle stability function

Directional Control	Roll-Over Control
Reducing radius test	Steady state circular test
Step steer input test	J-turn
Sine with dwell	
J-turn	
μ-split single lane change	
Double lane change	
Reversed steering test or "fish hook" test	
Asymmetrical one period sine steer or pulse steer input test	

The Australian PBS Scheme regulates vehicle stability somewhat differently. PBS lays out performance measures governing vehicle stability but does not specify how to achieve the performance outcome. Also, rather than explicitly differentiating between the truck and trailer(s) PBS regulates a complete vehicle combination. Table 2 groups the PBS stability measures with the applicable UNECE stability requirements.

Table 2 - PBS and ECE R13.11 stability requirements

		Roll stability	Yaw stability
Truck	ECE R13.11	• Power-driven vehicle roll-over control	• Power-driven vehicle directional control (ESC)
	PBS	• Static Rollover Threshold	• Handling Quality
Trailer	ECE R13.11	• Trailer roll-over control (RSC)	• Trailer directional control[1]
	PBS	• Static Rollover Threshold	• Rearward Amplification • High-Speed Transient Offtracking • Yaw Damping Coefficient

The rollover protection standards, RSC and SRT, are the most closely aligned; both in purpose (to reduce the risk of rollover) and applicability (both truck and trailer). There is strong evidence that both approaches are effective in controlling rollover crashes. In light of

[1] ECE R13 requires that power driven vehicles (categories M2, M3, N2 and N3) include directional control and roll-over control functionality whereas Trailers (categories O3, O4) need only include roll-over control function

this and the implications for both safety and productivity, a more detailed consideration of these rollover protection standards has been undertaken and is the focus of this review. However, aspects of yaw stability control and potential for harmonization of directional or yaw stability standards will also be explored.

3. Rollover

The purpose of the PBS rollover standard (SRT) is to limit the rollover tendency of a vehicle during steady turns. It is arguably the most important performance measure due to its strong link to rollover crashes (Winkler et al, 2000) (Mueller, de Pont and Baas, 1999). The SRT measure is essentially the same as the requirements specified for the rollover stability of tank vehicles in ECE R111 (ECE 2001).

PBS allows for SRT to be calculated using either of the following two test methods:

- A constant radius quasi-steady turn
- Tilt able – In accordance with recommended practice SAE J2180

PBS sets the minimum tolerance level for lateral acceleration during a steady turn. The required performance level for SRT is 0.40g for buses and dangerous goods vehicles or 0.35g for all other vehicles (NTC, 2008).

In contrast, the UNECE rollover control function mandates a system that - reacts to an impending roll-over in order to stabilize the vehicle within the physical limits of the vehicle (ECE, 2008). Here we can assume that the term 'physical limits' refers to the steady state rollover threshold (SRT), although it is important to note that a vehicles dynamic rollover threshold may be lower than the steady state static rollover threshold (Dahlberg and Stennson, 2006).

Therefore, two distinct approaches for mitigating the likelihood of rollover exist. One requires a minimum physical tolerance to lateral acceleration (SRT) whilst the other relies on lateral acceleration management (RSC).

Mueller, de Pont and Baas (1999) established that vehicles with SRT below 0.35g were more than 2 times more likely to be involved in a crash due to instability or rollover – these vehicles make up 15% of New Zealand's Heavy vehicle fleet but are involved in 40% of stability related crashes. Winkler et al (2000) indicate similar results, estimating that about 40% of single vehicle (5-axle tractor semi-trailer) accidents with rollover in the US can be attributed to vehicles with SRT below 0.35g.

In comparison Woodrooffe et al (2009) found that RSC would have been effective in preventing 3,282 (39.8%) of the 8,244 total annual rollover crashes (5-axle tractor semi-trailers) in the US. In addition, they found that RSC was effective in preventing 207 (1.6%) of loss of control crashes.

To compare the effectiveness of the two approaches SRT versus RSC; Mueller, de Pont and Baas' (1999) estimate of relative crash rates versus SRT has been used to estimate the number of crashes that are likely to be avoided by applying a minimum 0.35g SRT standard, refer Equation (1).

$$y = -63.2SRT^3 + 126.8\,SRT^2 - 85SRT + 19.4684 \quad (1)$$

The Mueller, de Pont and Baas (1999) study shows that vehicles with SRT ≤ 0.3 make up ≈ 2.5% of the fleet, whereas those with SRT between 0.3 and 0.35 make up ≈ 12.5% of the fleet. Using this data the average relative crash rate of poor stability and marginal vehicles (SRT ≤ 0.35g) is estimated to be 3.92, refer Equation (2).

$$z = \frac{2.5 \times y(0.25)}{15} + \frac{12.5 \times y(0.3)}{15} = 3.92 \qquad (2)$$

Modifying these vehicles so that they have an SRT of 0.35g or greater would cause the relative crash rate of that portion of the fleet to drop from an average of 3.92 to 2.54. They would therefore be 1.54 times less likely to be involved in a crash, and those vehicles would make up 30% of the total crashes involving rollover and instability (down from 40%). Therefore the overall crash reduction expected is about 14.1%. This assumes that there are no productivity impacts from increasing SRT to 0.35g and provides a rough but reasonable estimate of the benefits expected from an SRT standard set at 0.35g.

Contrasting the respective approaches would suggest that implementing RSC (39.8% reduction in rollovers) is a more effective counter measure than an SRT limit of 0.35g (14.1% reduction in rollovers). The safety benefit is clear, but productivity benefits are also available.

Many vehicle types cannot meet the SRT requirement without limiting their payloads. As a result there is often no incentive to participate in the PBS Scheme. Consequently, some industries are not able to access the productivity benefits of longer heavier vehicles, see Figure 3[2].

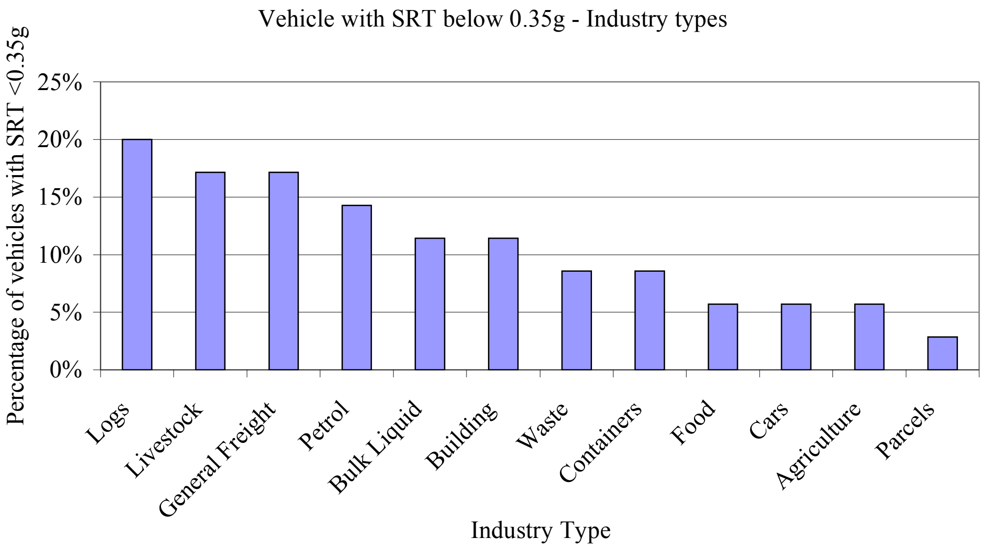

Figure 3 – Industries serviced by vehicles with low SRT

Therefore, the question becomes – can RSC safely overcome these productivity limitations? This implies that vehicles would pass the PBS Scheme standards with an SRT below 0.35g if fitted with RSC.

[2] This data is from the study of the commissioned by the NRTC (Prem et al, 2002). Of the 139 vehicles types assessed 35 failed SRT, i.e. 7 (20%) were typically used to transport logs.

One way to justify fitting RSC to overcome marginal SRT is to develop a performance test equivalent to the two already available for SRT. However, these tests do not represent real world driving scenarios as their purpose is to determine SRT. A vehicle with SRT < 0.35 will never pass the tilt test nor achieve the speed required to generate 0.35g on a quasi-steady state turn without rolling over. The purpose of a performance test for RSC is not to calculate SRT but to determine whether the RSC works effectively over a range of realistic operating scenarios.

Woodrooffe et al (2009) developed a number of scenario manoeuvres based on road geometries found in the crash data, including:

- Transient to constant curve (68m & 227m)
- Constant radius to diminishing curve
- Single lane change in curve
- Single lane change in straight (more sever than ISO lane change)
- Turn at intersection

Woodrooffe et al (2009) investigated the effect of RSC on both curved and straight road geometries, and found that of the 3,282 crashes benefiting from RSC - 2,692 (82%) were on curved dry roads, 406 (12.4%) were on straight dry roads, and 184 (5.6%) were on curved wet roads. The majority of the benefit (and the number of accidents) are on curved roads therefore this should be the focus for a performance test. Nevertheless, RSC is of benefit on straight roads and therefore consideration should also be given to a test that demonstrates RSC effectiveness on straight roads, e.g. the ISO single lane change, or more severe variation thereof.

ECE R13.11 lists two alternative tests for demonstrating rollover control functionality, but does not give specifics about the test parameters, e.g. curve radius, entry speeds, etc. Whilst this provides flexibility a clearly defined objective and consistent standard is preferable. Woodrooffe et al (2009) developed three manoeuvres, including detailed test parameters, to investigate RSC efficacy on curves. Key factors to consider when specifying such a test are: repeatability, comparability, safety, practicality, cost, and robustness[3]. A matter of particular relevance in Australia is the overall length of the vehicle combination because PBS vehicles are potentially 60m in overall length (NTC, 2007).

It is possible to construct a test that a vehicle with suitably high SRT would pass. For example Woodrooffe et al (2009) used a 68m transient to constant curve test with curve radius of 68m and a typical entry speed of 55km/hr; this translates to a lateral acceleration of 0.35g. A vehicle with SRT of 0.35g or greater should pass this test without rolling over. The test vehicle details and test results indicate that the vehicle Woodrooffe et al (2009) tested had a SRT of about 0.39g[4]. The data shows that with RSC active the vehicle is able to safety negotiate the turn at an entry speed of 71km/hr, without RSC an SRT of 0.58g would be required to pass the test at this speed, refer Figure 4. Importantly this shows that RSC is effective despite the SRT being significantly below the level that would be required otherwise.

[3] Here robustness refers to the adequacy of the test in ascertaining that the RSC system will work in real work driving scenarios

[4] The test vehicle used was 36,400kg 5-axle tractor semi-trailer with trailer CG height of 2.0m, Winkler et al provides a conversion table to SRT. Also during the ABS system test the vehicle decelerated to about 58km/h (0.39g) to navigate the turn without rollover.

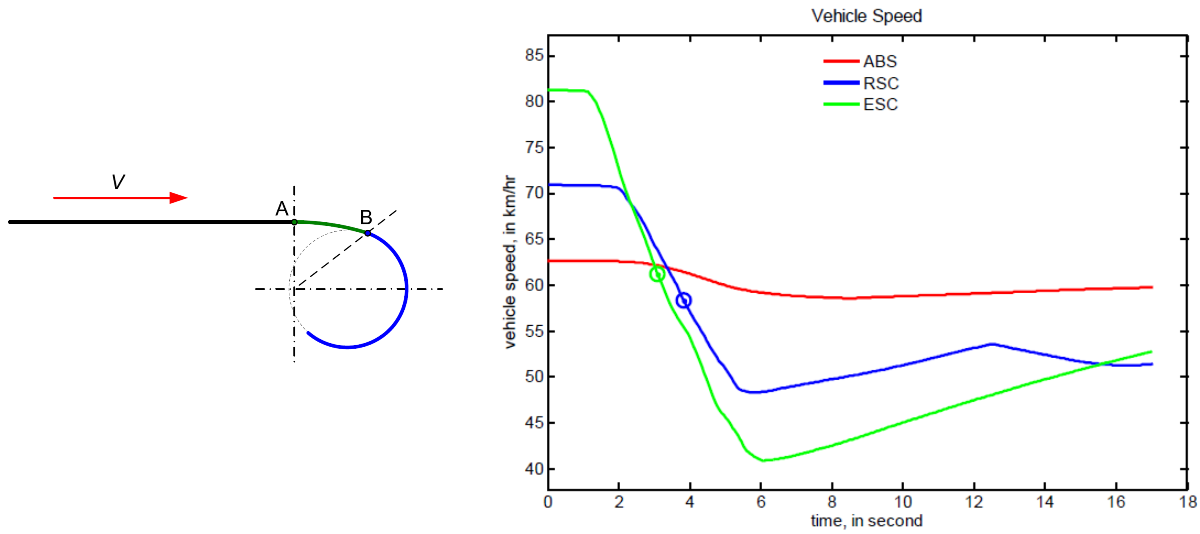

Figure 4 – Transient to constant curve manoeuvre and results (Woodrooffe et al, 2009)[5]

The test above allows for a comparison with the existing SRT test and provides a direct comparison of the capability between a vehicle fitted with RSC and one that meets the 0.35g SRT standard. An alternative manoeuvre that might be used is the constant radius to diminishing curve. This provides the feature of an entry speed matched to constant radius section generating 0.35g, while the diminishing curve ensures that operates effectively. This might be preferable in instances when the vehicle in question has an SRT which exceeds 0.35g. The important principle in either approach is that the test demonstrates equal or better performance than a vehicle without RSC but an SRT of 0.35g or more.

In terms of limits on curve radius, certainly there should be a lower limit to ensure that the kinetic energy that the braking system needs to overcome is sufficient to provide a real indication of the RSC effectiveness in real situations, also there is a need to cater for long combination vehicles. One could make a case for testing at the maximum intended operating speed. For Australia this would be 100km/h which translates to a curve radius of 227m. For in-field testing this becomes impractical. Currently the SRT quasi-steady turn test requires a minimum radius of 100m, which corresponds to an entry speed of 67km/h. Whilst, this is sufficient to cater for long vehicles, it is still quite a high speed and requires a large amount of space. The 68m selected above was based on an average of curve radii below 100m from the crash database. Whilst this is a sound basis for setting the test radius, if an equally robust test can be adopted on tighter radii and hence slower entry speeds then this should be adopted. Further work is required to understand how tight curve radius might be and possibly a criteria should be developed based on vehicle length.

Another concern is the issue of how low a SRT can be tolerated given the fitment of an effective RSC system. To answer this question, a review of what we know about the efficacy of SRT and RSC in reducing crashes should be undertaken. Figure 5 proposes a model for combining the two methods of mitigating rollover risk. The premise is that Equation (1) still holds; however, by fitting RSC you are proportionally less likely to have a crash. The estimated 39.8% reduction in crashes resulting from RSC means that with RSC fitted a crash is 1.6 times less likely. Dividing Equation (1) by 1.6 gives the curve shown gives Equation (3), shown as the dotted line in Figure 5.

[5] The circles indicate that wheel lift-off occurred

$$y = -38.05SRT^3 + 76.33SRT^2 - 51.17SRT + 11.72 \quad (3)$$

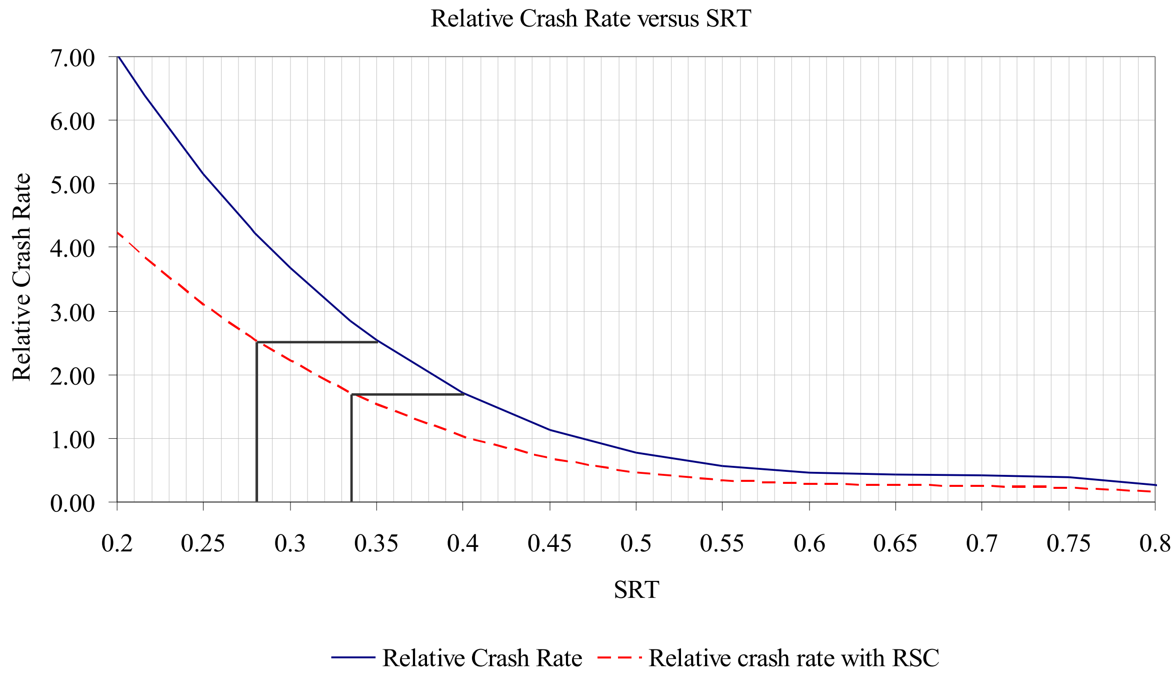

Figure 5 – Relative Crash Rate with RSC versus SRT

The concept described above is useful in aswering the question of whether or not a minimum limit of SRT should be set despite RSC being fitted. Alternatively, how much inherent instability can be tolerated with RSC before the rollover risk becomes too high. Equation (3) suggests that a vehicle with SRT of 0.28g fitted with RSC is equivalent to one with 0.35g SRT and without RSC (also, a 0.4g without RSC is equivalent to 0.335g SRT with RSC). Whilst this approach is crude numbers fall within reasonable limits. It suggests that despite fitting RSC there should be a lower limit for SRT. That limit will impact against few vehicles and guard against bad designs in the future; refer, (Prem et al, 2002) - 96% of the 139 Australian fleet vehicles assessed in that study would pass if the SRT limit was 0.335g for tankers and buses and 0.28g for all other vehicles. The vehicles that fail are typical for Livestock and Agriculture.

In summary, the findings of the analysis of the various methods of controlling rollover show that:

Electronic roll stability systems are effective in reducing rollover and road trauma

RSC is more effective at reducing rollover than setting a minimum SRT limit of 0.35g

There is a good case for allowing ECE R13.11 certified roll stability control in lieu of meeting the PBS SRT requirements.

The existing SRT test is insufficient for demonstrating the effectiveness of RSC; any alternative standard should demonstrate that the vehicle is as stable as a vehicle with SRT of 0.35g through realistic curved road geometry.

4. Directional control and yaw stability standards

Referring back to Table 2, as per the rollover standards, PBS Handling Quality and UNECE Power-driven vehicle directional control appears to align well. However, currently PBS has not defined the handling quality measure. Initial hopes for a performance based handling standard focused on the ‘three-point’ handling measure, developed by El-Gindy and Woodruffe in 1990; however, it was not considered to be robust enough to include in the PBS scheme, (NTC, 2008). Subsequent progress in developing a handling standard has stalled because of the difficulty in defining an effective objective measure. ESC may provide a way forward. However, one must remember the original motivation for the PBS Handling Quality measure which was the Federal Office of Road Safety (FORS) investigation of alleged problems with heavy truck dynamics (Sweatman, P. and McFarlane, S., 2000). This study was commissioned because FORS had received complaints from truck operators relating to ride quality and handling. The scale of the problem was small, with a total of 27 complaints being received on a total estimated air suspended prime mover population of 5700 vehicles. The report specifically recommended that regulatory controls be put in place to control certain characteristics of suspensions and steering systems fitted to prime movers (Sweatman, P. and McFarlane, S., 2000). Whilst Woodrooffe et al (2009) have proven ESC to be very effective in reducing road trauma, particularly in conjunction with RSC, ESC will not directly address the issues nor align with the recommendations of the FORS study.

Nevertheless, ESC offers the best hope for developing a robust handling quality standard. To avoid excessive and unsafe speeds ESC testing is conducted on a low surface friction (typically ice). This not only poses unique problems for Australia as there a simply no test facilities available for large vehicles, but it effectively puts the limits at a level that mandates the technology. This is not necessarily a bad outcome; however, the Australian Design Rules (ADRs) rather than the PBS Scheme is the appropriate regulatory mechanism. Also, the Australian truck industry has limited market power globally so it must wait until manufacturers based in Europe, America and Japan have ESC technology available on their Australian models. In line with the Australian National Braking Strategy, the best way forward for Australia is appropriately timed harmonization with ADR braking requirements and ECE R13.11.

PBS has very specific requirements for trailer yaw stability and they are key elements of the scheme. In contrast, ECE R13.11 does not mandate trailer directional control. Whilst the two approaches are significantly different, there is considerable potential for electronic stability control systems to allow marginal vehicles to pass the various PBS trailer sway standards. Such technologies are available in Australia and involve an innovative steering system which reduces rearward amplification and high-speed dynamic offtracking on a-coupled vehicles. These A-coupled vehicles types offer significant operation and productivity benefits when compared with B-coupled vehicles.

Tracking Ability on a Straight Path and Directional Stability Under Braking are judged not to directly relate to ECE R13.11 EVCS requirements. Whilst Tracking Ability on a Straight Path may be assisted by a trailer directional control system, it is a standard that attempts to manage lane width requirements, not to make the vehicle more stable during an emergency. Directional Stability Under Braking is a performance measure that aligns with the traditional ECE R13 braking requirements; DSUB requires certain average deceleration levels and no ‘gross wheel lock-up’ during a straight line deceleration test from 60km/hr – it essentially mandates load proportioning or anti-lock brakes (NTC 2008).

5. Conclusions and Recommendations

The key findings of this work are:

- Electronic roll stability systems are effective in reducing rollover and road trauma; moreover, RSC is more effective at reducing rollover than setting a minimum SRT limit of 0.35g.
- ECE R13.11 provides a method of regulating electronic stability control that is more advanced that the Australian PBS scheme. However, it is somewhat prescriptive and lacks an objective performance measure. Nevertheless, there is a good case for allowing ECE R13.11 certified roll stability control in lieu of meeting the PBS SRT requirements.
- There are potential productivity benefits from adopting RSC technologies on vehicles with marginal SRT performance.
- Despite the fitment of RSC technologies there should be a minimum level of SRT specified – 0.335g for tankers and buses and 0.28g for all other vehicles fitted with a compliant RSC system.
- The existing SRT test is insufficient for demonstrating the effectiveness of RSC; any alternative standard should demonstrate that the vehicle is as stable as a vehicle with SRT of 0.35g through realistic curved road geometry.
- The yet to be defined PBS handling quality standard could potentially be achieved with ECE R13.11 directional stability control requirements. However, this would essentially mandate the technology and ADRs are a better regulatory mechanism for phasing in this type of new technology.

The policy recommendations arising from this study are:

- Fitment of a rollover control system that complies with ECE R13.11 should be adopted as an alternative (Deemed to Comply provision) to the PBS Static Rollover Standard.
- Despite the fitment of RSC technologies there should be a minimum level of SRT specified – 0.335g for tankers and buses and 0.28g for all other vehicles fitted with a compliant RSC system.
- ADRs are the best regulatory mechanism for phasing in this fleet-wide take up of new RSC and ESC technology.

6. References

- NTC, (2008), The Standards and Vehicle Assessment Rules, Performance Based Standards Scheme, Australia, 2007
- Woodrooffe, J., Blower, D., Gordon, T., Green, P.E., Liu, B., Sweatman, P. (2009), Safety Benefits of Stability Control Systems for Tractor-Semitrailers, prepared for the U.S. Department of Transportation - National Highway Traffic Safety Administration, DOT HS 811 205, October 2009
- NTC, (2007), Network Classification Guidelines, Performance Based Standards Scheme, Australia, 2007
- Prem, H, de Pont, J, Pearson, B and McLean, J (2002). *Performance Characteristics of the Australian Heavy Vehicle Fleet*. Prepared for the National Road Transport Commission by RTDynamics, TERNZ Ltd., Pearsons Transport Resource Centre Pty Ltd. and Dr J.R. McLean, Melbourne, Vic. February 2002.
- ECE, (2001), Regulation No. 111 - Uniform provisions concerning the approval of tank vehicles of categories N and O with regard to rollover stability
- ECE, (2008), Addendum 12: Regultation No. 13 – Revision 6 – Amendment 1, 11th July 2008
- Dahlberg, E. and Stensson, A. (2006), "The dynamic Rollover threshold – a heavy truck sensitivity study," Int. J. Vehicle Design, Vol. 40, Nos. 1/2/3, 2006
- Winkler, C.B., Blower, D., Ervin, R.D., Chalasani, R.M. (2000), Rollover of Heavy Commercial Vehicles, ISBN 0-7680-0626-0
- Mueller, T.H., De Pont, J.J., Baas, P.H. (1999), Heavy Vehicle Stability Versus Crash Rates – Prepared by TERNZ for the Land Transport Safety Authority, New Zealand, July 9th 1999
- Sweatman, P. and McFarlane, S. (2000), Investigation into the Specification of Heavy Trucks and Consequent Efffects on Truck Dynamics and Drivers – Prepared by Roaduser International Pty Ltd for the Federal Office of Road Safety, Australian, 2000