HYBRID TESTING METHOD TO PROVE THE COMPLIANCE OF HEAVY VEHICLES

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ABSTRACT

It is predicted that the road freight task is to double within the next decade. This creates a need for improved vehicle productivity that demands a progressive approach to vehicle regulation. Current regulation involves assessing vehicle design against a series of design rules and prescriptive vehicle limits. Applying prescriptive limits places restrictions on design but does not directly address the performance of the vehicle. It is vehicle performance – the way it interacts with the road environment – that should determine whether a vehicle is allowed on the road.

Performance Based Standards is an initiative of the National Transport Commission that has been introduced in Australia to achieve this goal. The two methods to assess the performance of a vehicle are computer simulation and testing. Each method has its own particular advantages and limitations. The current practice is to select one of these methods. However the best approach to prove compliance is to combine both methods into a hybrid method. This paper explores the details of the hybrid simulation-testing method. Case studies are cited from both an assessors and regulators point of view. These examples illustrate the benefits of the hybrid method.

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1 INTRODUCTION

It is predicted that the road freight task is to double within the next decade. This creates a need for improved vehicle productivity that demands a progressive approach to vehicle regulation. Current regulation involves assessing vehicle design against a series of design rules and prescriptive vehicle limits. Applying prescriptive limits places restrictions on design but does not directly address the performance of the vehicle. It is vehicle performance – the way it interacts with the road environment – that should determine whether a vehicle is allowed on the road.

Performance Based Standards (PBS) is an initiative of the National Transport Commission (NTC) that has been introduced in Australia to achieve this goal. PBS, currently in the implementation stage, is being used successfully by heavy vehicle regulators to assess the performance of new and innovative vehicles in Australia.

It is becoming evident that the best method of completing a PBS assessment is one that combines simulation and field testing; a hybrid method. The NTC are assimilating the knowledge acquired from their observation and participation in PBS projects as the initiative continues to evolve. This paper explores the details of the hybrid testing-simulation method. Case studies are cited from both an assessors and regulators point of view.

2 THE PBS PROCESS

Performance-Based Standards (PBS) is a national alternative to the current system of heavy vehicle regulation. PBS focuses on performance outcomes, whereas current vehicle regulation is prescriptive, specifying limitations on mass and dimensions. The intention of PBS is to release the shackles, fastened by current regulation policy, these could restrict vehicle innovation and productivity gains required to meet the road freight task. The introduction of PBS is a bold and refreshing decision, offering a system which will allow better designed, more productive vehicles onto Australian roads. Australia, being the first to initiate a move towards the implementation of PBS, has attracted worldwide interest.

Under development for nearly ten years, PBS is approaching the final stages of implementation. Recently, a discussion paper for the rules of PBS assessment (NTC, 2003) was released. This document clearly outlines two possible methods to assess the performance of a vehicle; computer simulation or field testing. Each method has its own particular advantages and limitations. As PBS formed it was expected, even intended, that the common practice would be to select one of these methods for the assessment. However assessors and regulators involved in assessing the very first PBS vehicles, including ARRB Group Ltd and Queensland Transport, have used an approach which encompasses both simulation and field testing. Table 1 lists all the PBS dynamic performance related standards. Beside each standard is the corresponding method assessment based on the first full PBS assessment conducted by ARRB Group.

Table 1: Performance Standards.

Performance Standards	Method of assessment
1: Startability	Validated simulation
2: Gradeability	Validated simulation
3: Acceleration Capability	Testing and validated simulation
4: Overtaking Provision (not finalized)	Not assessed
5: Tracking Ability on a Straight Path	Validated simulation
6: Ride Quality (not finalized)	Not assessed
7: Low-Speed Swept Path	Simulation
8: Frontal Swing	Simulation
9: Tail Swing	Simulation
10: Steer-Tyre Friction Demand	Simulation
11: Static Rollover Threshold	Validated simulation
12: Rearward Amplification	Testing and validated simulation
13: High-Speed Transient Offtracking	Testing and validated simulation
14: Yaw Damping Coefficient	Testing and validated simulation
15: Handling Quality (not finalized)	Not assessed
16: Stability Under Braking (not finalized)	Not assessed – Testing if required

Of the standards not assessed, “ride quality” and “handling quality” are not yet developed; suitable methods have yet been developed for simulating “directional stability under braking” or “overtaking provision”.

The ‘testing’ and ‘simulation’ methods of assessment are already well defined in the rules for assessment discussion paper (NTC, 2005). The discussion paper also allows for some standards to be assessed using simulation and some using testing. What distinguishes the Hybrid method is combining testing and simulation to determine if a vehicle satisfies certain standards. This is only necessary for some of the above standards and the approach for each is explained below.

3 HANDS ON INVOLVEMENT: THE SD2255 PBS VEHICLE

The first full PBS assessment was completed by ARRB Group under the supervision of Queensland Transport in June 2005. This project provided an insight into the benefits of a hybrid testing simulation methods.

3.1 The PBS design method

Shell DIRECT Pty Ltd (a major Australian fuel distributor) proposed building truck trailer combination only possible under PBS. This vehicle would offer a substantial efficiency gain and improve the overall safety of their fleet. Shell DIRECT approached Queensland Transport for endorsement to commence a design that would go beyond prescriptive size and weight limits. The aim was to design and build a truck trailer combination 22 meters (72 feet) in length with a GCM of 55 tonnes (121,000 pounds), whilst achieving the best possible safety outcomes. The PBS vehicle was consequently referred to as SD2255. The SD2255 would meet the most demanding requirements of PBS in order to be granted ‘general access’ to road networks in Australia. The first step Shell DIRECT took towards achieving their aim was to conduct field testing of existing company vehicles. This would provide a baseline from which improvements would be made. The original truck trailer design is Figure 1.

Figure 1. Original truck trailer design -19 meters (62 feet), 50 tonnes (110,000 pounds)

Design of the SD2255 PBS vehicle was completed using an ‘iterative’ simulation process. This involved multiple simulations to fine tune critical dimensions such as wheelbase and drawbar lengths, resulting in a vehicle configuration with optimized vehicle performance. The base configuration evolved from its original limitations of 19 meters to a longer, lower vehicle with an increased payload. The SD2255 truck trailer combination is shown in Figure 2.

Figure 2. PBS vehicle–SD2255–22 meters (72 feet), 55 tonnes (121,000 pounds)

3.2 The hybrid approval process

The SD2255 was built and full-scale field testing was conducted at Darlington Park Raceway in Queensland, Australia. The testing program used to assess the SD2255 included the following stylized maneuvers:

- acceleration capability
- single lane change
- pulse input

A survey of the geometry of the test track was conducted. The average grade was measured to be 2.69% and average crossfall 1.5%. This geometry does not exactly meet the requirements of the PBS rules, and therefore the results obtained from field tests would not have been acceptable for approval under PBS. However, since the road surface and input conditions were measured and precisely known, the data collected during the field testing was suitable for calibration of a computer model. Therefore PBS approval of the SD2255 would be completed using the hybrid method.

3.3 Low speed longitudinal performance

The first 3 standards, startability, gradeability and acceleration capability relate to low speed longitudinal performance.

A vehicle's performance for each of these standards is limited by either the available torque or the available friction. The vehicle performance for this standard can be accurately assessed using simulation. To employ field testing would require a test track with the near impossible road surface with grades of exactly 5%, 8 %, 12% and 15% (and preferably 1% increments in between).

The standards for acceleration capability and gradeability introduce the need to model more than simply friction and torque. Acceleration capability is the measure of the vehicle's ability to accelerate from rest on a road with no grade. Gradeability relates to maintaining forward motion and a minimum speed on a specified upgrade.

The parameters associated with mechanical losses and resistance to forward motion are relevant to the assessment of these acceleration capability and gradeability. If a computer model is used to assess these standards it must include the mechanical efficiency of the driveline, aerodynamic drag, tyre rolling resistance and mass moments of inertia of rotating components (wheels, shafts, gears, and the like) gear change etc. Accurate and credible data for these parameters can be difficult to source.

To determine the acceleration capability of the SD2255, it was tested on a straight section of the Darlington Park race track (which had a grade exceeding that allowed under the PBS rules). Three tests were performed in both directions to give an average time for traveling 100 m. A model of the SD2255 was created and simulated traveling on the same road geometry as measured from the test. The various driveline parameters (most of which had been supplied by the manufacturer) were then adjusted slightly so that the acceleration time history from the simulation matched that from the tests on the upgrade. This ‘calibrated’ model was then simulated traveling on the downgrade to check that the results again matched those from the test (they did). The model was then considered ‘validated’ and was used to simulate the vehicle traveling on a flat grade. Acceleration capability of the SD2255 was determined from this simulation.

Figure 3 shows a comparison between simulation and field test results for acceleration in the uphill and downhill directions. The result of the standard conditions simulation, ’flat – simulated’ is also presented in the figure below.

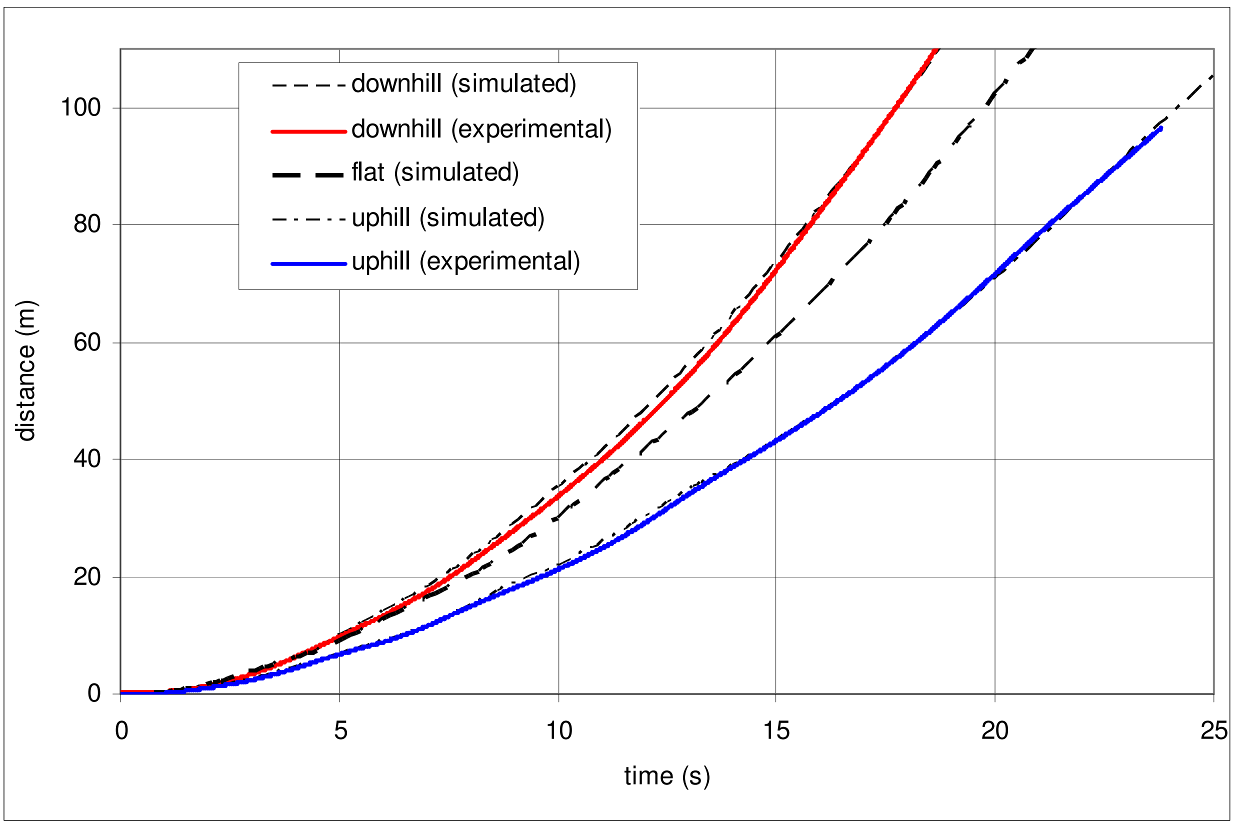

Figure 3. Comparison of simulation and testing acceleration results

3.4 High speed longitudinal performance

Tracking ability on a straight path (TASP) is defined as the total swept width while traveling on a straight path, including the influence of variations due to crossfall, road surface unevenness and driver steering activity.

The road surface required must have an unevenness level in each wheel path, reported every 100 m, of not less than 4.0 m/km IRI (International Roughness Index). The average crossfall over the test length must be not less than 3.0%. The average crossfall must have a crossfall standard deviation of not less than 1.0%. To ensure consistency, the rules for assessment actually specify, via a data set with elevation and crossfall every 250mm, the exact geometry that the road must have. TASP was not measured during field testing as a road section matching this specification is impossible to find.

As TASP is a high speed directional stability, the results are sensitive to suspension and tyre properties. There is a high reliance on the accuracy of these parameters; therefore it is important to use a validated model. The TASP of the SD2255 was assessed using a model calibrated against data acquired during high speed test maneuvers for the Lane Change and Yaw Damping.

3.5 Static Rollover Threshold

Static Rollover Threshold (SRT) is the steady state level of lateral acceleration that a vehicle can sustain without rolling over during turning. SRT is assessed to the point of rollover; therefore to be completed in field this test would require the use of outriggers. This method is costly, has associated risks and limitations. The other field testing option is to use a tilt table. Again, this is a costly option and not always available. The method used for assessing the SD2255 was to use a calibrated model. The roll gradient of the suspension was obtained during field testing and the model suspension parameters were adjusted to so that the simulation produced a matching roll gradient. The validated model was then used to determine the Static Rollover Threshold for the SD2255.

In this particular case, Queensland Transport had access to a tilt table tests and so performed a tilt test on the SD2255 truck (the trailer was too long for the tilt table) to give them confidence in the results. The results were only made available to ARRB after the calibrated model had been used to determine the SRT, and the results showed an exact match. Without the calibration process, the simulation results would have been around 5% high.

3.6 High speed directional performance

High speed directional performance standards include Rearward amplification (RA), yaw damping coefficient (YDC), and high speed transient offtracking (HSTO). These standards are sensitive to suspension parameters, and the centre of gravity (COG) heights of both sprung and unsprung masses. If assessed by simulation, it is imperative that the input data is accurate.

Rearward amplification and high speed transient offtracking are both assessed during a lane change maneuver. The intention of the lane change manoeuvre is to produce a known lateral acceleration at the steer axle, at a given frequency, and to record the lateral acceleration experienced at the rear unit. HSTO is a measure of this lateral overshoot during the lane change maneuver. HSTO is difficult to measure accurately in the field but can be determined with confidence from a calibrated computer model of the vehicle.

Figure 4 shows the SD2255 fitted with sensors and a data acquisition system during the testing program.

Figure 4. SD2255 during a lane change maneuver

A set of markers clearly defined the path the driver would follow to correctly execute the maneuver. The lane change maneuver was first completed at low speeds, before being performed at 88 km/h, this allowed the driver to become familiar with the steering task. The steering angle input was measured and a video camera observed the position of the steer tyre in relation to the marked path. The test driver selected by Shell was unable provide the steering input required. The driver, selected because of his skill and experience, determinedly repeated the test over 15 times with not one satisfying the requirements of the PBS rules, illustrating the difficulty of the driving task. So, while the test results could not be used for a PBS application, the steering input and speed were accurately measured so the data acquired was suitable for model validation. The calibrated model was simulated using the same speed, steer input and road-geometry as the test and when the results showed a good match, the model was considered validated. This model was used under ideal, PBS conditions to obtain the result for the PBS application.

As well as being necessary for model calibration and validation, the tests clearly demonstrated the performance of the vehicle to all in attendance. On occasion, the efforts of the driver resulted in a steering frequency that produced a lateral acceleration input higher than anticipated. Despite this, at no time did the vehicle appear unstable. Observations such as this, made during the testing program, give the vehicle regulator a better understanding of the vehicle performance.

The Yaw Damping Coefficient (YDC) performance measure quantifies the rate at which yaw oscillations decay after a short duration steer input (pulse input) at the hauling unit. The intention of the yaw damping response test is to provide a steering input that will excite the rear unit of the combination into a yawing motion. The manoeuvre requires a pulse steering input, 3.2 degrees in magnitude with a duration of 0.6 seconds. It is recommended that the test be performed on a grade of less than 1% and at the certified vehicle speed of 88 km/h. YDC is highly sensitive to variations in grade, speed and steering input.

The SD2255 performed the YDC test maneuver on a downgrade of 2.69 %. The driver was unable to perfectly replicate neither the required steering input nor the required speed of 88 km/h. The calibrated (based on roll gradients) model was used to simulate the SD2255 on the same road geometry, with the same steer input and speed profile as for the YDC test. Having shown a reasonable match, this validated model was used to perform a simulation to determine compliance to the YDC standard.

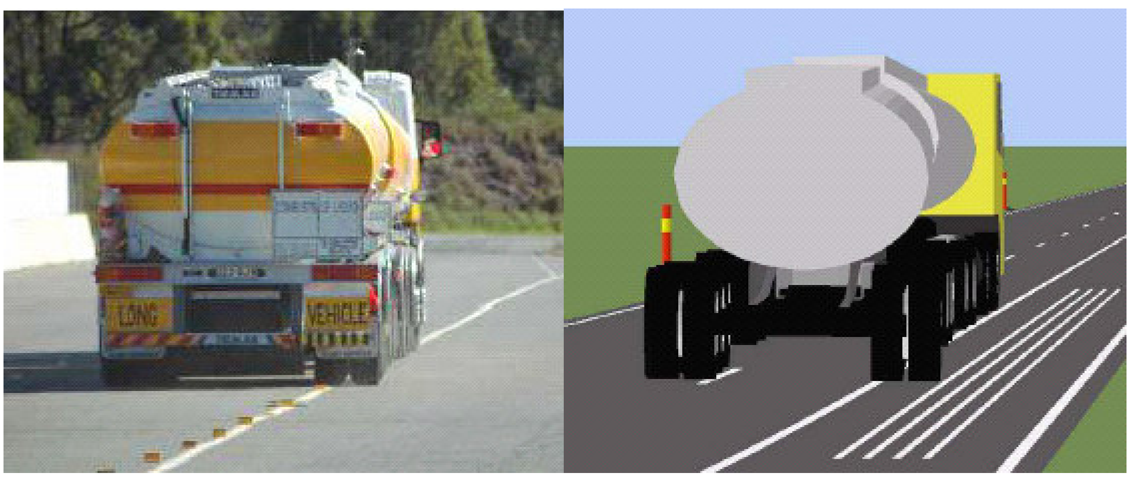

Figure 5. The calibrated model (left) based on test results (right)

3.7 Low speed directional performance

Low speed swept path, frontal swing, tail swing, and steer tyre friction demand are all low speed maneuvers. These standards are less sensitive to inaccuracy of suspension parameters and therefore less reliant on a validated model. Even fairly simplistic models have been used for a long time to assess low speed swept path, with reasonably high accuracy.

To assess low speed performance standards in a testing situation requires the driver to follow a very precise path. The swept width is difficult to measure as the position of all extremities of the vehicle must be tracked. It is not sufficient to track simply the corners of the vehicle. Consequently, the SD2255 low speed directional assessment was completed using the simulation only.

4 CONCLUSION

The assessment methods used to determine the performance of the SD2255 proved to be effective for certifying a potential PBS vehicle. Using the hybrid method of assessment, the drawbacks of field testing (e.g. non-ideal conditions) are offset by the ideal nature of computer simulation. Furthermore, the drawbacks of simulation (does it match the real-world?) are also reduced. The combination of these two assessment methods ensures a robust assessment is made.

Current Australian transport regulators and experts have an improved understanding of vehicle dynamics and performance relating to PBS. PBS appears to be capable of evolving with this acquired knowledge. Over time, as more innovative vehicles appear on our roads this knowledge and understanding will filter through the industry.

The Shell DIRECT project is a sound case study for Australia to learn from in the early stages of the PBS regulatory regime. The project has resulted in the development of a truck-trailer configuration that exceeds prescriptive size and weight limits, but demonstrates safety and performance such that regulators are able to grant unrestricted access to the Australian road network.

5 REFERENCES

National Road Transport Commission, Performance Based Standards Phase A – Standards and Measures: Regulatory Impact Statement, December 2003.

National Transport Commission, Rules for Assessment of Potential Performance Based Standards Vehicles – Discussion Paper, June 2005.