TO BE TRIPLE OR NOT TO BE: PERFORMANCE-BASED PRESCRIPTIVE RULES FOR AUSTRALIAN MODULAR B-TRIPLES

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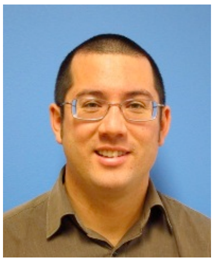

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Abstract

In 2006, the Council of Australian Governments decided that an objective for Australian road transport is to enable the wider use of safe and productive B triples on an approved national road network under a single set of agreed national vehicle specifications and operating conditions. It was envisaged that B triple operations would ultimately connect all Australian capital cities via the key freight corridors.

The true potential for B-triples lies in enabling a quantum leap in productivity and safety of the kind that B-doubles brought when introduced over the past 20 years. Contained within this paper is quantitative evidence of the benefits that the B-triple offers in comparison with the conventional A-double. A method was developed to allow road access for B triples under prescriptive rules using a Performance Based Standards approach to setting those prescriptive rules.

Keywords: Heavy vehicles, B-triple, Performance Based Standards, High Productivity Freight, Modular

1. Introduction

A B-triple is a modular road freight vehicle that is effectively an extension of the common B-double configuration, having an additional lead trailer. In terms of mass and dimensions, at around 82.5 tonnes and 35 metres long, Australian B triples (Figure 1a) are comparable with Australian double road trains (Figure 1b, also referred to as A-doubles) but they have vastly improved safety and productivity characteristics. While B-triples presently operate in many parts of Australia, they are disadvantaged by inconsistent treatment between each state and territory, and their access to the road network is often not commensurate with their safety and productivity offering.

(a)

(b)

Figure 1 – (a) B-triple configuration and (b) Double road train configuration

The Council of Australian Governments (the peak intergovernmental forum in Australia, comprising the Prime Minister, State Premiers, Territory Chief Ministers and the President of the Australian Local Government Association) decided in 2006 that a medium-term objective for Australian road transport is to enable the wider use of safe and productive B-triples on an approved national road network under a single set of agreed national vehicle specifications and operating conditions. It was envisaged that B-triple operations would ultimately connect all Australian capital cities via the key freight corridors.

The true potential for B-triples lies in enabling a quantum leap in productivity and safety of the kind that B-doubles brought when introduced over the past 20 years. Contained within this paper is quantitative evidence of the benefits that the modular B-triple offers in comparison with the conventional A-double. Benefits derive from:

- improved productivity that results in fewer trips and therefore fewer vehicles required to service a given freight task
- improved safety due to (a) the B-triple‘s vastly superior on-road dynamic performance and (b) reduced vehicle numbers
- reduced wear and tear on road pavements on both a per-vehicle and a per-tonne-of-payload basis
- reduced or equivalent impact on most bridges.

A method was developed to allow road access for modular B-triples under prescriptive rules using a Performance Based Standards approach to setting those prescriptive rules (1).

2. Research method

The hypothesis was that if prescriptive rules allowed the connection of any standard B-double equipment into a modular B-triple configuration, such that the following criteria are met, then the modular B-triple would have acceptable safety and infrastructure performance:

- Must be constructed from a prime mover having a single steer axle and a tandem drive axle group towing three triaxle semi-trailers all connected by fifth-wheel couplings.
- Must form a compliant 26-metre B-double when one lead trailer is removed, regardless of which one is removed. The purpose of this requirement is to mitigate the risk of non-compliance with B-double requirements when one trailer is removed.
- Maximum overall length of 35 metres.
- Maximum kingpin-to-rear dimension of 29.6 metres.
- Mass limits either 'General Mass Limits' (82.5 tonnes) or 'Concessional Mass Limits' (84.5 tonnes) that already exist Australia-wide.

Based on existing standard B-double equipment, modular B-triples will generally be 31.0 to 35.0 metres long, with a typical range being 32.5 to 33.5 metres. Modular B-triples will generally perform at least in accordance with Level 3 of the Performance Based Standards (PBS) scheme simply by meeting the prescriptive modular requirements.

To test the hypothesis, the range of modular B-triples that could potentially be constructed from a multitude of existing B-double prime movers and trailers was evaluated against the PBS criteria using computer simulation of vehicle dynamics, and calculations of pavement wear and bridge loading.

3. Results

3.1 Computer simulation of vehicle dynamics

A study was performed in order to examine the performance of the modular B-triple combinations. The study was based on computer simulations of the modelled vehicles. A wide range of modular, 12-axle B-triple vehicle models were created, and compared against reference non-modular, 12-axle B-triple combinations and 11-axle A-double road trains using the PBS scheme (2). All vehicles were compared against the PBS Level 3 requirements, despite the B-triples not being required to meet this standard. However, as the modular B-triples are intended to be run under the current double road train network, a close approximation to PBS Level 3, it was acceptable to compare all of the vehicles against the Level 3 requirements.

A range of modular vehicle combinations were assessed, covering variations in dimensions possible under the modular concept, six different freight types (general freight, refrigerated general freight, low density bulk materials, high density bulk materials, livestock and liquid goods) and up to five different loading conditions (at tare, 90% of general mass limits (GML), 100% of GML, concessional mass limits (CML) and higher mass limits (HML)).

The vehicle combinations were examined against three driveline standards, four low-speed dynamic performance standards and five high-speed dynamic performance standards. One low-speed standard (low speed swept path) and two high-speed standards (static rollover threshold and high-speed transient offtracking) will be examined in greater detail in this paper.

Low Speed Swept Path (LSSP)

The low speed swept path is the maximum width of the swept path of a vehicle simulated driving through a 90º turn of 12.5 m radius at a speed of 5 km/h as shown in Figure 2.

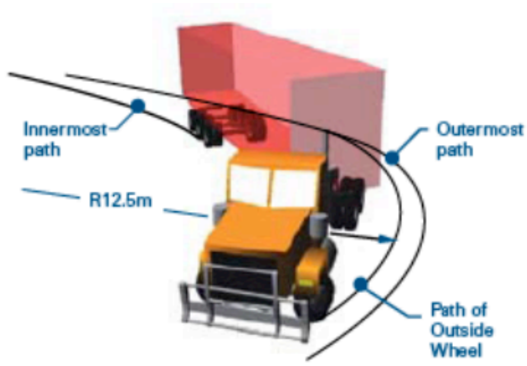

Figure 2 – Low speed swept path manoeuvre

The results of the swept path analysis can be seen in Figure 3. The graph shows the results for a variety of vehicle dimensional options under the modular concept, grouped into freight types. Each grouping is also compared against a non-modular B-triple and reference road train. In the background of the graph the gradations indicate the PBS level that each of the vehicles achieve. Figure 2 only shows the results of the GML loading condition, though there was minimal difference for different loading conditions.

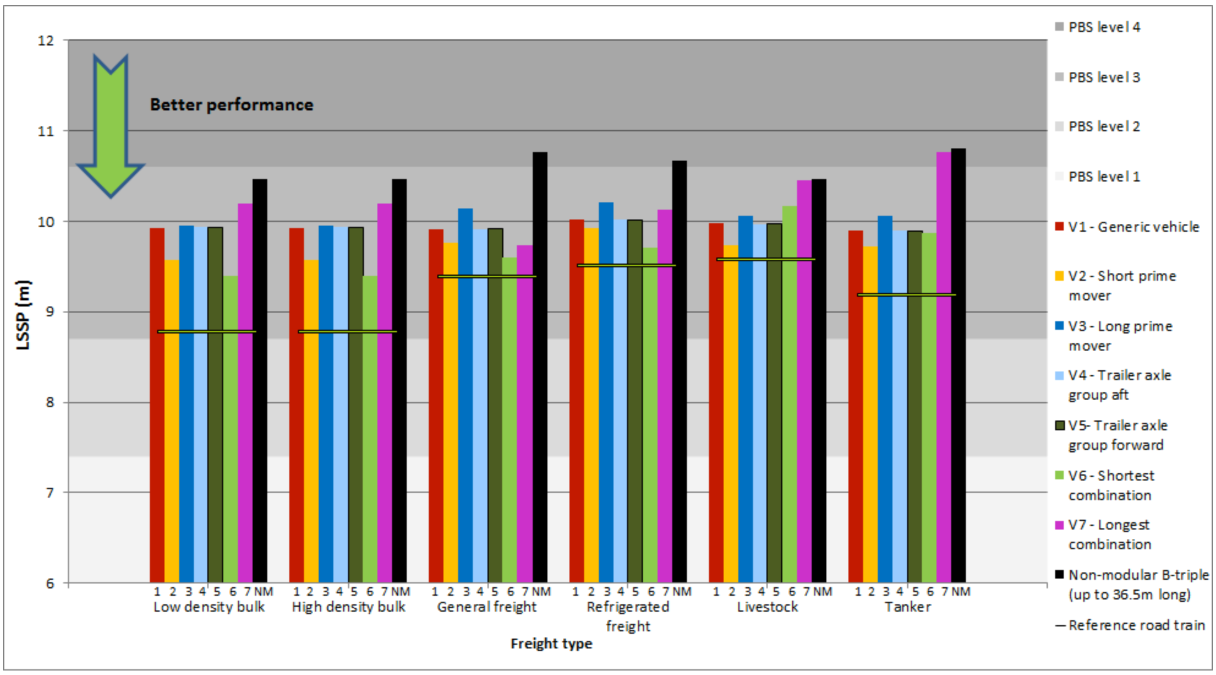

Figure 3 – Low speed swept path (LSSP) - GML loading

The modular B-triples mostly achieved a LSSP value ranging between 9.40 m and 10.45 m, under the LSSP PBS Level 3 limit of 10.6 m. Only one of the vehicle combinations, the tanker variant 7 (longest combination) did not meet Level 3, achieving a LSSP value of 10.76 m, instead passing PBS Level 4.

Each of the reference non-modular (existing operational) B-triple vehicle combinations achieved a larger LSSP value (poorer performance) than the proposed modular B-triple vehicles for the same freight type, with three of the freight types passing Level 3 while three others only passed Level 4. Each of the reference A-double road trains achieved a lower LSSP value (better performance) than the B-triple values due to their different trailer coupling.
The major influence on LSSP was the longitudinal vehicle dimensions and combination type. In general, longer vehicles with longer vehicle units (i.e. trailer wheelbases) achieved a larger swept path. The combination and coupling types also had major influences on the LSSP, with A-double road trains producing much better performance than the B-triples. A-double road trains include an extra pivot point due to the dolly which enables greater manoeuvrability. The coupling point at the rear of the first trailer is well behind the centre of the axle group, which induces a steering effect towards the outside of the turn and reduces offtracking.

The proposed modular B-triples performed better than the existing reference B-triples and poorer than the A-double road trains, but still largely passed PBS level 3 for LSSP.

Static Rollover Threshold (SRT)
Rollover stability is a significant safety issue and arguably the most important performance measure for heavy vehicles because it has been strongly linked to rollover crashes.

The measure of rollover stability is static rollover threshold (SRT) which is the level of lateral acceleration that a vehicle can sustain without rolling over during a turn. The SRT is expressed as a fraction of the acceleration due to gravity in units of 'g', where 1 g is an acceleration of 9.807 m/s2 corresponding to the force exerted by the earth's gravitational field. High values of SRT imply better resistance to rollover.

To determine the SRT the vehicle must be driven along a specified circular path at an initial speed that is at least 10 km/h slower than the speed at which the rollover instability will occur. From the initial speed, the driver must increase the speed of the vehicle at a slow, steady rate until the point of rollover.

The results of the SRT analysis can be seen in Figure 4. The graph only shows the results of the GML loading condition, with the worst case SRT out of the two roll-coupled units reported for the road trains. In general, the front roll-coupled unit of the road trains had the poorer SRT, with the rear roll-coupled unit typically achieving a SRT of 0.02 – 0.03 g higher. If tankers are transporting dangerous goods they must achieve an SRT $\geq$ 0.40 g to pass PBS, otherwise they will need an SRT $\geq$ 0.35 g like all other vehicles.

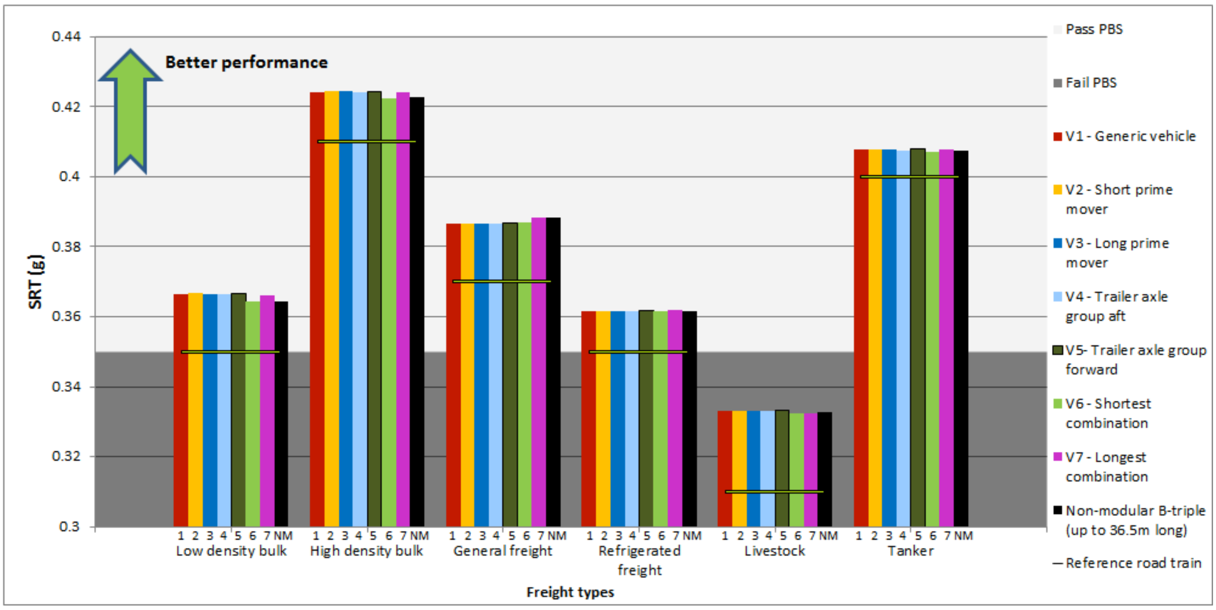

Figure 4 – Static rollover threshold (SRT) - GML loading

The performance of the modular B-triples were very similar to the non-modular B-triple combinations and better than the reference A-double road trains by approximately 0.01 g.

All freight types met the PBS SRT requirement of ≥ 0.35 g (or ≥ 0.40 g for tankers transporting dangerous goods), except for the livestock vehicles mainly due to their extra height. It should be noted that even though livestock B-triples did not meet the PBS requirement, they still performed better in SRT than livestock A-double road trains.

The most important factor for SRT was centre of gravity height, which is influenced by trailer deck and body heights and the payload centre of gravity height as a percentage of available body height. The higher the centre-of-gravity, the poorer the SRT performance. Longitudinal dimensions had minimal effect on the SRT performance.

The laden masses also had an influence on the SRT performance, with the greater the axle masses, the poorer the performance. The combinations at HML (greatest combination mass examined) had the poorest performance, followed in turn by CML (next highest mass), GML, 90% of GML and at tare (lightest combination mass).

High Speed Transient Offtracking (HSTO)

A lane change manoeuvre is the method used to measure the high-speed transient offtracking (HSTO) of a vehicle combination. 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 and swing-out experienced at the rear unit.

During the manoeuvre, the lateral displacement of the rear end of the last trailer of an articulated vehicle may overshoot the final path of the front axle of the hauling unit. The lateral overshoot may interfere with overtaking or passing vehicles and thus represents a safety risk. HSTO measures this lateral overshoot.

The results of the HSTO analysis can be seen in Figure 5. The graph only shows the results of the GML loading condition.

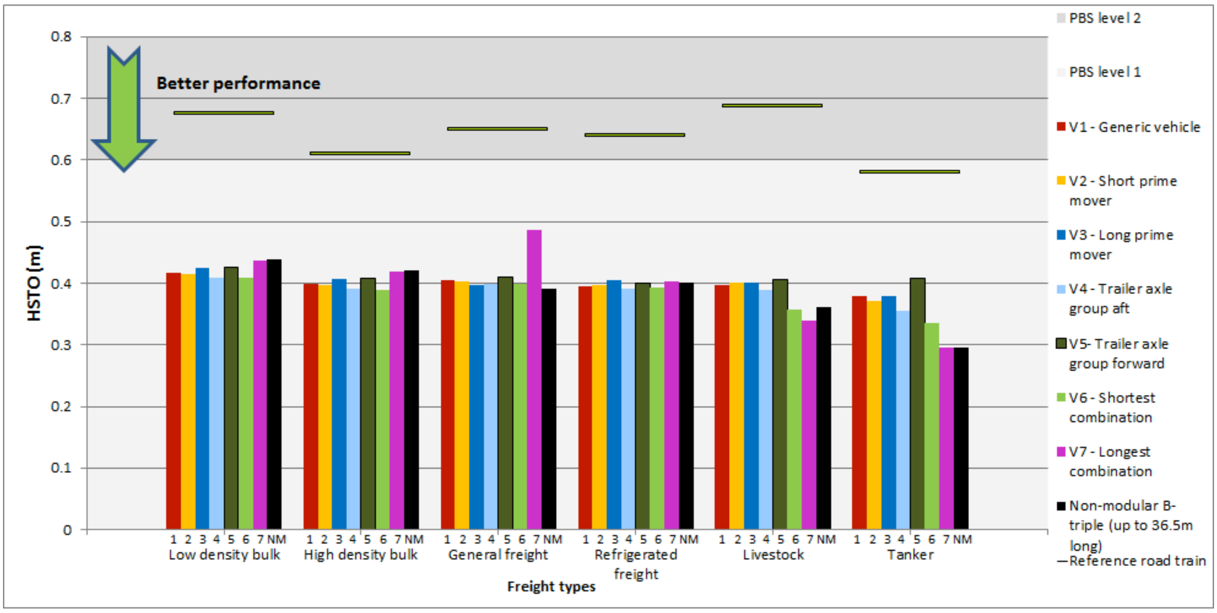

Figure 5 – High speed transient off-tracking (HSTO) - GML loading

All of the standard B-triples achieved an HSTO value in the range of 0.25—0.50 m. These combinations would comfortably pass the Level 1 PBS requirement of ≤ 0.6 m.

There was no major difference in HSTO between the different freight types, except for tankers which performed slightly better than other freight types. Trailers with their axle groups rearward tended to perform better in HSTO than generic trailers or trailers with their axle groups forward; this was especially true for the tanker vehicles due to having the largest difference in spacing between forward and rearward axle groups. No other parameters had a large influence on HSTO.

Laden road trains achieved an HSTO range of 0.58—0.73 m and managed to pass the Level 2 PBS requirement of ≤ 0.8 m. Both the modular and non-modular B-triples performed considerably better in HSTO than road trains likely due to the fifth wheel couplings providing greater lateral stability than dolly couplings.

On-road testing

On 5 September 2011, several High Productivity Vehicles including a modular B-triple were assembled and observed in Dubbo by Rod Pilon Transport, as shown in Figure 6. This trial enabled the Roads and Traffic Authority (now Roads and Maritime Services), the National Transport Commission (NTC), the Australian Trucking Association (ATA) and Natroad to monitor the performance of these vehicles. The trial found that the performance of the vehicles were similar to that expected from the simulation study.

Figure 6 – On-road testing of B-triple vehicle

Summary

All of the simulated modular B-triples were found to meet at least Level 3 requirements for all PBS measures except for the following two measures:

- static rollover threshold (SRT), which was not satisfied by any of the laden livestock combinations
- low speed swept path (LSSP), which was satisfied by all combinations except one - tanker variant 7 which satisfied LSSP at Level 4 only.

Comparing modular B-triples to reference A-double road train counterparts it was found that:

- Modular B-triples had an equal or a higher static rollover threshold than their A-double road train counterparts and passed the requirement of 0.35 g for all freight types and load conditions except livestock, whereas the road trains did not satisfy this requirement for refrigerated freight and low density bulk freight when loaded to CML or HML in addition to the livestock combinations.
- Modular B-triples performed significantly better in HSTO. The simulation results showed that the B-triples were superior to the A-double road trains in these high speed avoidance manoeuvres.
- Modular B-triples performed worse in LSSP. The simulation results showed that B-triples required approximately 0.5—1.0 m more swept width but still passed PBS Level 3 except for one combination (tanker variant 7).

3.2 Cost-benefit analysis

A cost-benefit analysis was undertaken to estimate the savings that could be gained from national B-triple operation during the period between 2011 and 2030.

The cost-benefit analysis considered three scenarios, low, median and high take-up scenarios of B-triples, and was performed assuming that B-triple access will be limited to road train routes, will require no major infrastructure modifications and there will be no extra cost to operators over conventional road trains.

Estimates were made for changes in total truck numbers, vehicle-kilometres travelled, road fatalities and CO_2 emissions, with a monetary figure assigned to these changes. Based on the median take-up scenario, which estimated 3,665 B-triple vehicles to be used, the cost-benefit analysis estimated (by 2030):

- In total, over 1,000 fewer heavy vehicles trucks on the network
- Over 1 billion fewer vehicle-kilometres travelled
- Over 25 fewer road fatalities
- Over 1.1 million tonnes fewer of CO_2 emission
- Total savings of almost $1.1 billion Net Present Value.

3.3 Pavement wear

The impact of B-triples on the infrastructure was examined in terms of both pavement loading and bridge loading. A pavement loading analysis using the Standard Axle Repetition (SAR) approach shows that B-triples induce less wear and tear on road pavements than conventional A-doubles because of their more efficient carriage of mass over more tyres; they also satisfy current and proposed future PBS Pavement Vertical Loading Standards.

3.4 Bridge loading

As detailed in the relevant axle spacing mass schedules enforced by jurisdictions where applicable, B-triples satisfy the same bridge loading formula that applies to A-doubles. Although they can be slightly heavier than A-doubles (82.5 tonnes against 79.0 tonnes), modular B-triples will not necessarily induce greater structural effects in all bridges. This is because bridge loading depends on the distribution of load to the vehicle's axles and the spacing of the vehicle's axles relative to the dimensions of the bridge spans. A bridge loading analysis demonstrates that in the vast majority of cases, the impact of B-triples on bridges is less than that of the 'design' double road train. In a very limited number of cases (particularly hogging moments in continuous spans between 20 and 35 metres), the impact of B-triples is higher than that of the design double road train. In these cases the magnitude of the additional effect is limited to a maximum of 16%. This does not necessarily mean that bridge capacities will be exceeded. Unless a specific bridge is considered inadequate by a bridge owner for particular reasons (e.g. on the basis of a bridge inspection and a special assessment of capacity), the calculation of structural effects detailed in this analysis confirms that bridges that are currently suitable for A-doubles are suitable for modular B-triple operations.

4. Conclusions

In May 2012, the Standing Council on Transport and Infrastructure (SCOTI) approved the NTC's final policy paper and agreed to the adoption of a single national modular B-triple vehicle specification which will enable modular B-triples to have access to the current road train network on the same basis as A-double (Type 1) road trains. This decision must be formally implemented by individual states and territories before transport companies can legally operate the vehicles.

5. References

1. National Transport Commission, *A National Framework for Modular B-triple Operations*, ISBN: 978-1-921604-25-6, National Transport Commission, Melbourne, 2012.
2. National Transport Commission, *PBS Scheme – The Standards and Vehicle Assessment Rules*, National Transport Commission, Melbourne, 2008.