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THE EVOLUTION OF HIGH PRODUCTIVITY VEHICLES IN AUSTRALIA AND THEIR BENEFITS

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Although the Australian road freight transport industry has seen three mass limits reviews in the mid 1970s, the mid 1980s and in the late 1990s, (Hassall, 2005), there were two very significant truck configuration changes that happened in the mid 1980s and then again in the early 2000s.

The first was the trials of a variant of the Canadian B-train (the B-Double) which was introduced into Australia in the mid 1980s. This 'Australian' B-Double could achieve payloads some 30% to 40% higher than the conventional 'semi trailer' articulated combination. By 2016 some 18,900 of these vehicles were operational in Australia.

The second adoption of new vehicle configurations started in 1999 through the National Road Transport Commission (NRTC), who adopted, and further developed, another Canadian concept, that of "Performance Based Standards" (PBS). This effectively allowed for new, flexible truck designs, as long as the vehicles performed against a set of 17 specific technical engineering performance criteria. This Performance Based Standards approach, since 1998, also allowed even larger configurations to B-Doubles to be used by operators. The benefits of these new configurations have already delivered billions of dollars in kilometre savings to the road freight industry and to its customers, as well as very significant safety benefits to the community.

Key wards: Productivity Vehicles, Performance Based Standards, B-Double, Australian Truck Design, Freight Transport, Freight Innovation, Urban Productivity, Freight Safety.

1. INTRODUCING THE B-DOUBLE INTO AUSTRALIA

The introduction of the Australian B-Double in the mid 1980s began very cautiously from a network perspective, however, as greater network access was granted the total uptake of these vehicles over the last 30 years has witnessed a growth rate, since 1986, of 30% compounding on a per annum basis. As Australia is a large continent, occupying 7.7 million square kilometres with only 24 million inhabitants, there are considerably large distances separating the major cities. The B-Double slowly emerged as the 'new work-horse' of the long distance road freight industry despite the fact that some 15% of its work is on zoned routes in major cities.

Table 1 presents the growth of the Australian B-Double, which was slow for the first decade, but has accelerated very rapidly over the last 20 years as its popularity increased amongst both fleet and single operators.

Figure 1 presents this growth in the B-Double truck population graphically, and figure 2 is a photograph of a specialist volumetric Australian 7 axle B-Double.

The most common configuration for a B-Double is 9 axles: 3 for the prime mover unit and three axles for the shorter "A-trailer" and three axles for the longer "B-Trailer".

Table 1: Australian B-Double population by selected year

1986	1988	1996	1998	2002	2004	2010	2014	2016
7	20	1265	3130	6233	9578	13800	17018	18889

Source: Australian Bureau of Statistics: Survey of Motor Vehicle Use, detailed data cubes selected years

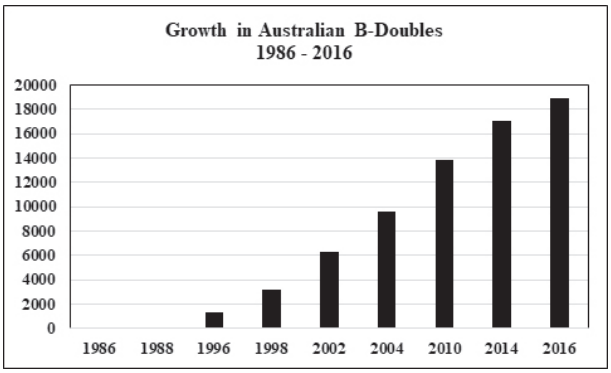


Fig. 1. B-Double growth in Australia 1986 to 2016

Source: Australian Bureau of Statistics: Survey of Motor Vehicle Use, detailed data cubes selected years

Fig. 2. An Australian 7 axle Volumetric B-Double

Source: ILI Photo archive, Australian High Productivity Vehicles

Figure 3 reflects three B-Double configurations and compares them to the very common, 6 axle single articulated truck and trailer combination, known in Australia as a 'semi-trailer'.

As at 2016, a 6 axle semi-trailer, on average, travelled 71,000 kilometres per annum, whereas a B-Double was averaging some 171,000 kilometres per annum (NTC, 2015). This reflected large operator productivity benefits as two B-Doubles equalled the capacity of three semi-trailers and were performing a considerable amount of extra work.

6 Axle Single Articulated Combination
(the work horse of the national fleet)
Length 19m, Width 2.5m Height max 4.3m
Weight 42.5 tonnes GVM (45.5 Tonnes with mass management accreditation)

Usual Australian B-Double Configurations

B-Double: 7 axle configuration
Length 25m, Width 2.5m Height max 4.3m
Weight 55.5 tonnes GVM (57 Tonnes with mass management accreditation)

B-Double: 8 axle configuration
Length 25m, Width 2.5m Height max 4.3m
Weight 59 tonnes GVM (62.5 Tonnes with mass management accreditation)

B-Double: 9 axle configuration
Length 25m, Width 2.5m Height max 4.3m
Weight 62.5 tonnes GVM (68 Tonnes with mass management accreditation)

Fig. 3. Comparing Standard B-Doubles against the common 6 axle articulated truck.

Source: Hassall, 2005, City Logistics IV, Conference Proceedings, Langkawi, 2005.

2. THE DEVELOPMENT OF THE HIGH PRODUCTIVITY VEHICLES THROUGH PERFORMANCE BASED STANDARDS

In 1999 Australia's National Road Transport Commission (NRTC) (now renamed the National Transport Commission, the NTC) extended the Canadian and New Zealand frameworks for the development of Performance Based Standards for flexible truck design. These frameworks in brief, suggested that, at that time, as long as a vehicle performed against some 18 specific technical performance criteria (now 17) then prescriptive regulations need not apply to the weights and dimensions of a specific vehicle. In effect the operator could design their own truck. Whilst the OECD, which also formed an international working party for this project, and reported in 2011, several major new truck designs were being implemented in Australia.

Some two dozen, assembled high productivity vehicle case studies were developed through simulations and reviewed by the National Road Transport Commission, (NRTC, 1999b). These case studies comprised both rigid truck and trailer combinations and multi-articulated vehicles. These vehicles could be up to, and beyond 50 meters in length and up to 170 tonnes Gross Vehicle Mass, although these large combinations did not get 'general' road access. Most PBS vehicles, however, are less than 30 metres in length.

The National Road Transport Commission also established the initial framework of approvals, testing and certification for those vehicles seeking operational approval under the Performance Based Standards scheme. This PBS approvals process is different to the State approved permit schemes by the fact that the PBS process is a national process and not restricted to a particular region or jurisdiction, although the State jurisdictions have a considerable say on an operator's desired road network which requires careful approval. The approvals will usually be very specific with regards the operator's designated road network.

Table 2: Performance Based Vehicles Engineering Standards

• Startability • Gradeability • Acceleration Capability • Tracking ability on a straight line • Low speed swept path	• Frontal Swing • Tail swing • Steer tyre friction demand • Static Rollover • Rearward amplification • Yaw Dampening coefficient	• High Speed Transient Off Tracking • Standard axle repetition • Pavement Vertical Loading • Pavement Horizontal Loading • Tyre Contact area • Bridge loading

Source: NHVR https://www.nhvr.gov.au/road-access/performance-based-standards/pbs-vehicle-standards

The initial 18 Performance Based Standards, now 17, have been modified on various occasions since their initial draft in the early 2000s. These current standards are those agreed by the federal and State Road Agencies and have now been implemented by the National Heavy Vehicle Regulator (NHVR). These standards are presented in Table 2.

Some common PBS vehicle types are shown in Figure 4. And their descriptions are listed in Table 3.

Fig. 4: Common Australia High Productivity Vehicles
Source: ILI truck photo archive – Australia

A more detailed description of the 14 common PBS vehicles classes, that currently operate in Australia, can be found in Appendix 2. A listing of the tare weights and gross combination weights for the tractor and trailer combinations are presented in Table 4, along with the average kilometres that these vehicle perform, on a per annum basis, as at 2017. Generally, PBS vehicle outperform their conventional road freight vehicle counterparts with regards to kilometres travelled and kilometres saved.

It should be noticed that some longer configurations can operate at greater mass than their shorter counterpart PBS vehicles if they participate in a Higher Mass Limits scheme.

ThisHigher Mass Limits (HML) scheme allows conventional and PBS vehicles to increase their Gross Combination Mass by around 10% to 23%, especially when more axles are added to the vehicle configuration. There are certifications schemes in place for PBS and non PBS vehicles to be allowed to participate in the HML scheme.

Table 3: Descriptions of Figure 4 PBS Vehicle Types

Types of Higher Productivity Vehicles Operating in Australia	
Heavy Rigid 12.85m 4 axle	Super B-Double 30m Quad-quad trailer axles
Heavy Rigid Truck with a 5 axle 'dog' trailer	AAB Quad Trailer vehicle remote use only' "Double B-Double"
B-Triple Container vehicle	A-Double Container vehicle

Source: ILI photo archives Australian PBS Vehicles

Table 4. Weights PBS Vehicles can operate to in Australia (tonnes)

HPV Truck Type	PBS Truck tare weight (t)	PBS Trailer tare weight (t)	PBS Gross Combination Mass (t)	PBS Gross Combination Mass on Higher Mass Limits (t)	Average Kilometres per annum
Twin Steer 20m semi (7AA)	10.5-11.5t	8.5-9t	49.50t	50.5t	na
20m semi (6AA)	9-10.5t	8.5-9t	42.50t	44.5t	279210
Quad axle Semi	9-10.5t	8.5-9t	43.00t	50.5t	na
HR3ATD	9.5-10.5 t	5-6t	48.50t	49.5t	130710
HR4ATD (19m)	10-11t	7-8t	50.50t	<=56t	115310
HR4ATD (20m)	10-11t	7.25-8.5t	50.50t	57.5t	na
HR5ATD	10-11t	8.5-9.5t	59.50t	63t	165200
HR6ATD	10-11t	9.5-10.5 t	63.00t	68.5t	164440
Super BD Quad-tri axle groups	9.5-11.5t	16-17t	68.50t	73.5t	379870
Super BD Quad-Quad Trailer axles	9.5-11.5t	16-17t	63.00t	77.5t	90440
AD 26m	9.5-11.5t	14-15t	68.00t	<=74.5t	Not Available
AD 30m	9.5-11.5t	16-17t	79.50t	<=85.5t	197880
B-Triple	9.5-11.5t	22-25t	<=82.5t	<=90.5t	212220
ABT 2D, 3T	9.5-11.5t	24.5-27.5t	92.50t	<=97.5t	227540
ABT 3D, 3T	9.5-11.5t	25.5-28.5t	96.00t	<=102.5t	227540
AAB Quad Trailer	9.5-11.5t	33-38t	119.00t	130t	187710
BAB Quad Trailer	9.5-11.5t	30.5-35t	119.00t	130t	187710

Source: ILI Quantifying the Benefits of the High Productivity Vehicles – Update (2017) for NTC

3. PBS TRUCK GROWTH RATES

In 2013 the operational rollout of the PBS scheme was transferred to the new National Heavy Vehicle regulator (www.nhvr.gov.au). Since that time nearly 6000 vehicles have been certified for operations, reflecting a growth rate of 49% per annum since that date.

However, some older vehicles, that were operating before the formal PBS scheme was adopted in 2006, were allowed to operate under various State permit systems, and these 'permit' vehicles numbered over 600. Many are still operating, especially the B-Triple configuration, which numbered 628 at the last vehicle census. These B-Triples were generally operating in rural and regional areas and are statistically the safest PBS vehicle operating.

Table 5: Growth in the Use of PBS vehicles

Year	PBS Population
2017	5803
2016	4624
2013	1169
Growth p.a	49.2%

Source: ILI 2017, NHVR Annual Report 2016-17

What do PBS Vehicles carry?

In early 2017 the largest commodity carried by PBS vehicles was quarry, sand, gravel, and construction rubble. This has meant that the PBS construction 'tippers' using 4,5 or 6 axle trailers represent the largest proportion of the PBS population. Many of these rigid 'truck and dog' construction trucks are in fact operating in urban areas.

However, as more of Australia's interstate highways, especially between major Capital cities, open to larger PBS vehicles, then longer PBS trucks like A-Doubles and B-Triples will become far more active, and the 'general freight' and 'container' commodity classes will increase markedly.

4. CALCULATING THE PRODUCTIVITY OF THE PBS FLEET

To calculate productivity of PBS vehicles a 'physical productivity measure' was chosen,

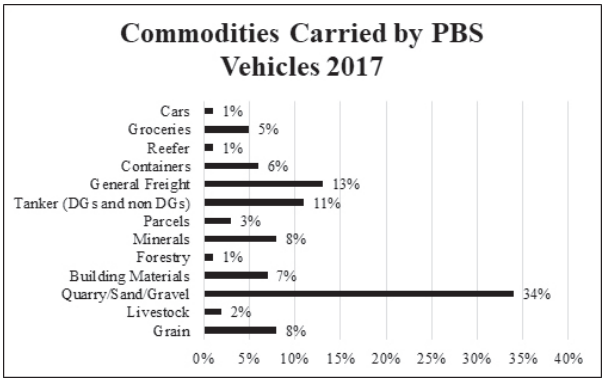


Figure 5: The PBS Task by Commodity Groups

Source: ILI Quantifying the Benefits of the High Productivity Vehicles – Update (2017) for NTC

and that was the PBS 'kilometres saved' metric. Initially in 2012 network and PBS simulations were conducted for the different vehicle classes for different commodities, (Hassall, 2012), to estimate the kilometre savings. However, from direct national operator surveys (Hassall et al 2014, and 2017) these 2012 simulations of 'kilometres saved' was shown to be underestimated. The operators themselves knew exceptionally well: how many trips they saved, their percentage of kilometres saved on a weekly or monthly basis and as such these 'kilometres saved' proportion could be converted into a 'kilometre reduction factor' which for the various PBS configurations is presented in Table 6.

As can be seen in Table 6 the PBS kilometres saved can range from 11.6% for a 3 axle PBS heavy rigid truck and dog tipper trailer combination to a 42.1% reduction for the larger Quad trailer (Double B-Double) configurations. The value of this saving, over a 20 year period, equates to several billion dollars in savings for operators and this is most often shared with their customers. (Hassall et al, 2017 for NTC) Also, as there are fewer Gross Tonne Kilometres (GTKms) performed on the roads by using these PBS vehicles, then there is also a saving in road pavement maintenance. This road pavement impact is not explored in this paper.

Possibly the most important social benefit of PBS vehicles is that they have achieved an excellent safety record. There are two metrics that safety is generally measured against: collisions per 100 million kilometres travelled, and accidents per 10,000 vehicles. Against the first metric, as over 1.1 billion kilometres was travelled by the surveyed PBS fleet then this gave a very credible accident metric.

Table 6: Productivity of each of the PBS vehicle configurations

Comparison Conventional vehicle	PBS Vehicle Type	Fractional km saving using PBS vehicle	Ave kms by PBS vehicle type
6 Axle semi	**6/7AA**	0.168	279,210
HR3ATD	**HR3ATD**	0.116	130,710
HR3ATD	**HR4ATD**	0.197	115,310
HR3ATD	**HR5ATD**	0.238	165,200
HR3ATD	**HR6ATD**	0.24	164,440
B-Double	**EBD**	0.234	379,870
B-Double	**SBD**	0.343	90,440
B-Double	**AD**	0.334	197,880
B-Double	**BT**	0.312	212,220
B-Double	**A Triples**	0.307	227,540
B-Double	**Quad Trailers**	0.421	187,710

Source: ILI, Quantifying the Benefits of Performance Based Standard Vehicles – Update for NTC 2017

But as there were far fewer than 10,000 PBS vehicles in the PBS surveys that were undertaken in 2014 and 2017, the accident rates per 10,000 vehicles was less meaningful but it too produced good results at the total PBS vehicle population level.

The types of accidents measured were 'high impact truck collisions' by vehicle type. This data was made available through Australia's largest truck insurer who also owns the National Truck Accident Research Centre (NTARC). NTARC produced the data that enabled the calculation for these metrics and the safety benchmarks for the conventional truck fleet, as well as a significant proportion of accident data on the PBS fleet accidents. The remainder of the PBS accidents' data were obtained through operator survey methods.

In the cases for both the rigid and articulated PBS trucks, there were significantly fewer accidents on a per 100 million kilometre basis, and at the total PBS population level there were solid savings in major collisions reflected in the 10,000 vehicle population metric.

5. CONCLUSIONS:

In the mid 1980s, the B-Double made its appearance on the Australian freight scene. These vehicles have proven to be highly successful and after 30 years there are some 19,000 B-Doubles operating. Their safety record is also 65% better than the standard single articulated 'semi-trailer' and their capacity productivity is some 33% better than the 'semi-trailer' vehicle.

The development of the Performance Based Standards (PBS) Scheme in 1998 and refined over the next decade has seen some 14 new classes of PBS vehicle configurations appear, including buses. These vehicle types have delivered very

Table 7: Comparing PBS safety benefits against the conventional Australian truck fleet.

Comparison Conventional Vehicle Configuration	Accident Rate per 100m km	Accident Rate per 10K vehicles	PBS/HPV Vehicle Configuration	PBS Accident Rate per 100m km	PBS Accident Rate per 10K vehicles
HR with 3A Trailer	9.5	76.3	HR 3ATD	8.4	nsv^3
HR with 3ATrailer			HR 4ATD	9.8	nsv^3
HR with 3ATrailer			HR 5ATD	2.3	nsv^3
HR with 3ATrailer			HR 6ATD	0.0	nsv^3
TOTAL Rigid Comb	9.5	76.3	TOTAL Rigid Comb	7.8	76.0
Semi-Trailer	20.9	148.0	6/7AA Semi	9.8	nsv^3
B-Double	9.4	145.1	EB-Double	6.5	nsv^3
B-Double			B-Triple	4.2	nsv^3
B-Double			A-Double	14.0	nsv^3
Road Train 1/2	26.1	335.9	AA, AB, BA Triple	4.2	nsv^3
B-Double	9.4	145.1	AAB BAB Quad	13.7	nsv^3
TOTAL Articulated	15.3	171.6	TOTAL PBS Artic	6.2	153.9
TOTAL Conventional Vehicles	13.6	143.3	TOTAL PBS	7.3	113.9

Source: ILI, Quantifying the Benefits of Performance Based Standard Vehicles – Update for NTC 2017, Hassall et al for Austroads 2014.

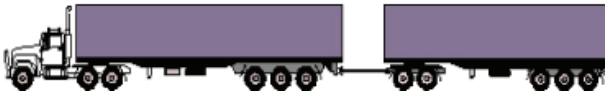
high levels of productivity benefits, 47% less high impact collisions than the conventional trucking fleet and even delivered road pavement benefits through performing less gross tonne kilometres when doing an equivalent road freight task. Both the introduction of the Australian B-Double and Performance Based Standards (PBS) scheme have proven extraordinarily successful and are very worthy of study by other road agencies in many countries.

ABBREVIATIONS

6/7AA	6 or 7 Axle Semi-Trailer Combination
AD	A-Double
AT	A-Triple
BD	B-Double
BT	B-Triple
C/km	Cents per Kilometre
EBD	Enhanced B-Double
GCM	Gross Combination Mass
GVM	Gross Vehicle Mass
HML	Higher Mass Limit
HPV	High Productivity Vehicle
HR	Heavy Rigid
HR3ADT	Rigid Truck plus 3 Axle Dog Trailer
HR4ADT	Rigid Truck plus 4 Axle Dog Trailer
HR5ADT	Rigid Truck plus 5 Axle Dog Trailer
HR6ADT	Rigid Truck plus 6 Axle Dog Trailer
ILI	Industrial Logistics Institute
NHVR	National Heavy Vehicle Regulator
NTARC	National Truck Accident Research Centre
NTC	National Transport Commission
p.a.	Per Annum
PBS	Performance Based Standards
QT	Quad Trailer Combination
SBD	Super B-Double
SMVU	Survey of Motor Vehicle Use

APPENDIX I

In Australia there are some regulated 'road train' combinations that service large rural and remote regions of Australia. These vehicles are referred to as Double Road Trains (Type I road trains) and Triple Road Trains (Type II road trains). These vehicles are not afforded the same access as either B-Doubles or the High Productivity Vehicles approved through the Performance Based Standards process, however, they are being used especially in the remote areas of Queensland, the Northern Territory and Western Australia.



11 Axle Double Road Train

Length 36.5m, Width 2.5m Height max 4.3m

Weight 79 tonnes GVM (85.7 Tonnes with mass management accreditation*)

16 Axle Double Road Train

Length 53.5m, Width 2.5m Height max 4.3m

Weight 115.5 tonnes GVM (125.2 Tonnes with mass management accreditation*)

Fig. A1. Long Distance Double Road Train and Triple Road Train Combinations

Source: Hassall (2005)

APPENDIX II: PERFORMANCE BASED STANDARDS VEHICLE DESCRIPTIONS

Table B1: Detailed Vehicle Abbreviations and Descriptions

Vehicle Type	Report Abbreviation	Description
1. Single Semi-Trailer 6 or 7 axles	6/7AA	Extendable to 20m, 6 axle semi-trailer or 7 axle semi-trailers with quad axle group. Can operate on Higher Mass Limits (HML) or Concessional Mass Limits (CML). Quad axles appeared in the survey.
2. Twin Steer Semi-Trailer 19 or 20m	6/7AA	Twin steer 7 axle semi-trailer. Can operate on HML or CML. Both configurations are reflected in the survey.
2. Enhanced B-Double	EBD	B-Double with either quad axle trailer groups or length up to 30m or both. Up to 11 axles. Can be operate on CML or HML
3. Super B-Double	SBD	B-Double up to 30m with equivalent length for A and B trailers. Can operate on HML or CML.
4. A-Double	AD	An A-Double can be considered a mini Type I Road Train. It is usually less than 30m long, with 11 or 12 axles. Can operate on HML or CML
5. B-Triple	BT	Triple trailer combination, up to 36.5m. 5 axle groups, 12 to 14 axles. Can operate under HML. BB, AB and BA configurations are operational.
6. Quad Trailer Combination	QT	Articulated combination with 4 trailers. 7 axle groups, with 17 or more axles. Various configurations such as BAB or AAB variations are usual. Often referred to as a double B-Double. Combinations are over 33m and can operate on HML.
7. A-Triple	AT	Triple trailer combination, up to 36.5m. 5 axle groups, 12 to 14 axles. Can operate under HML or CML. Can use AA, BA or AB dolly configurations of 2 or 3 axles.
8. Truck and 3 Axle Dog Trailer	HR3ATD	Three-axle truck and three-axle dog trailer. 6 axles, 4 axle groups. GCM over 42.5 tonnes. Can operate under HML.
9. Truck and 4 Axle Dog Trailer	HR4ATD	Three-axle truck and four-axle dog trailer. 7 axles, 4 axle groups. GCM over 42.5 tonnes. Can operate under HML.
10. Truck and 5 Axle Dog Trailer	HR5ATD	Three-axle truck and five-axle dog trailer. 8 axles, 4 axle groups. GCM over 42.5 tonnes. Can operate under HML.
11. Truck and 6 Axle Dog Trailer	HR6ATD	Three-axle truck and six-axle dog trailer. 9 axles, 4 axle groups. GCM over 42.5 tonnes. Can operate under HML.
12. Buses 1	BC	Coach, up to 14.5m. 3 axles one being rear steerable tag axle Long distance operations
13. Buses 2	BA	Double or multi articulated bus 14.5m or longer. 3 or 4 axles. Major urban arterial road operations.
14. Buses 3	BR	Route Buses. Generally used in urban public transport systems.

Source: Quantifying the Benefits of Performance Based Standards, ILI for NTC 2017

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