

CONCEPTION, APPROVAL AND IMPLEMENTATION OF THE HAULMARK STEERING A-DOUBLE

AN AUSTRALIAN PERFORMANCE BASED STANDARDS (PBS) CASE STUDY

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Abstract

Haulmark Trailers Australia Pty Ltd has developed under the framework provided by the Performance Based Standards (PBS) regulatory regime a highly innovative steerable A-Double combination culminating in an exceptionally productive freight vehicle. In some cases this has led to a 100% productivity gain by comparison to the most productive combination operating under the Prescriptive regulatory regime for the same level of access.

This project has very clearly demonstrated the potential of the Performance Based regulatory system to facilitate the development of a significantly more productive and dynamically safer heavy vehicle combination solution for the growing freight tasks.

This paper will describe the challenges that Haulmark Trailers (Australia) Pty Ltd ("Haulmark") faced when developing and implementing this new innovative combination and will also compare the operational performance data of the typical baseline vehicle being used for the same freight tasks to that of the new innovative Haulmark PBS A-Double vehicle combination.

Keywords: Performance Based Standards (PBS) Australia, high productivity vehicle, computer simulation, field testing, vehicle dynamics, A-Double, improved safety, steering system, steering dolly, steer by wire.

1. Introduction

In Australia, Performance Based Standards (PBS) is an alternative regulatory scheme to that of the Prescriptive regime that can be utilized by vehicle designers and manufacturers to develop innovative vehicle combinations. PBS offers the flexibility to design and manufacture vehicles based on the specific heavy vehicle combination's "on road dynamic performance" in a wide range of precisely defined scenarios rather than simply weight and dimension.

The PBS scheme mandates 16 performance requirements and 4 infrastructure requirements relative to the level of road network access required. This provides an opportunity to design vehicles for a specific level of access and /or a specific freight task culminating in a highly productive, dynamically safer freight vehicle that in some cases has led to a 100% productivity gain by comparison to the most efficient combination operating under the prescriptive regime for the same or similar level of access.

PBS has introduced a new approach to the regulation of heavy vehicles in Australia as it encourages safer and more productive outcomes from heavy vehicle operations and utilizes the existing infrastructure more efficiently. Under the PBS approach, safety and infrastructure standards specify the performance outcomes required from vehicle operations rather than mandating how this level of performance is to be achieved.

Haulmark Trailers (Australia) Pty Ltd ("Haulmark") has utilized the PBS scheme to develop a highly innovative steering A-Double combination that at 30m overall length can include two 12.2m semi-trailers, a standard Cab Over Engine (COE) 6 x 4 truck or bonneted day cab 6 x 4 truck and enjoys the same level of access (Level 2B) generally as a 26 m B-Double combination. The Haulmark Steering A-Double is nationally approved in Australia to operate at up to 85.5t Gross Combination Mass (GCM) subject to infrastructure approval while the conventional prescriptive B-Double is limited to 68.5t GCM.

The Haulmark Steering A-Double can be configured to include trailers of varying body designs ranging from container skel trailers, flat tops, drop decks and even bulk tipping trailers for products such as grain and coal.

Overwhelmingly, the impetus behind this project was to develop an innovative combination under the PBS scheme that would provide significant productivity gains to that of the most efficient prescriptive vehicle combination (B-Double) operating in the high volume freight sector of urban distribution and major strategic freight corridors, or in other words the existing B-Double network.

2. PBS Approval Process

PBS was first introduced in Australia in 2004 and since then has undertaken a number of process and approval reforms culminating in the current approval process.

The proponent of a PBS vehicle concept is required to submit a PBS assessment submission to the National Transport Commission (NTC) PBS Review Panel (PRP) for review and approval. The assessment submission details the specific vehicle concept by dimension, required axle mass and detailed vehicle specifications relating to the truck and trailers

ranging from Engine, transmission, suspension types, tyre size and brand and other related details.

An approved PBS assessor must be an independent person to that of the PBS proponent (Haulmark Trailers) and prepares the PBS submission and associated computer modeling based around the 16 performance and 4 Infrastructure requirements as detailed under the PBS guidelines relevant to the required level of access for the proposed vehicle. There are 4 levels of PBS access, 3 of which, levels 2 - 4 have a sub level b, this then covers the entire road network. Vehicle overall length limits access to the PBS road network as shown below in Table 1.

Table 1 - PBS Access Levels

Vehicle Performance Level	Network Access by Vehicle Length, L (m)	
	Access Class 'A'	Access Class 'B'
Level 1	L ≤ 20 (General Access*)	
Level 2	L ≤ 26	26 < L ≤ 30
Level 3	L ≤ 36.5	36.5 < L ≤ 42
Level 4	L ≤ 53.5	53.5 < L ≤ 60

Once the PBS submission has been approved by the PBS review panel (PRP) a Design Approval (DA) is issued by the PRP to the proponent which is then used to obtain route approval from the State and Local authorities for the PBS vehicle. Manufacturing of a new PBS vehicle generally doesn't commence until an approval has been issued. Once the route approval is received the vehicle is manufactured strictly in accordance to the PBS submission and the DA. Upon completion of the manufacturing of the PBS vehicle combination a PBS certifier (different to the PBS assessor) is then engaged to check and sign off on the actual vehicle to ensure it strictly complies with the approved dimensions and specifications as submitted to and approved by the PRP.

Upon receipt of the PBS certifiers report and assuming a satisfactory outcome the NTC will issue a Final Approval (FA) to the PBS vehicle proponent which is then used to gain an "operational permit" for the vehicle from the State jurisdiction. Once the operational permit has been granted the PBS vehicle is then able to start its intended on road operation.

3. Development of the Haulmark Steering A-Double Combination

As shown in Table 1 above, PBS Access level 2b provides an opportunity for vehicles up to 30 m overall length. Given the B-Double combination was the base reference vehicle for Haulmark's identified target market of urban distribution and strategic freight corridors, an innovative vehicle combination was needed that would provide a quantum step in mass (GCM) and an increase in available trailer deck lengths.

Due to commercial implications and operational benefits there is a growing trend away from the 6m (20') shipping container to the more cost effective 12.2m (40') shipping container. Given the initial target market identified by Haulmark was containerized freight, clearly this PBS innovative vehicle needed to provide an opportunity to carry two 12.2 (40') shipping

containers concurrently, something the prescriptive B-Double could not achieve due to its overall length limitation of 26m.

Specifically, the design terms of reference over and above a prescriptive B-Double were,

- A. Extra mass, meaning more axles on the ground. Suspension and axle loadings must stay within the currently accepted National mass limits schemes (ie. 22.5t on a tri axle group and 17t on a Tandem group)
- B. Extra deck length, must be able to carry two 12.2m (40') shipping containers concurrently

Evaluation of the design terms of reference appeared to provide two options that would potentially comply with PBS level 2b access.

- A. An enhanced B-Double concept utilizing quad axle groups that would provide a 77t GCM and would probably require self-steering axles on both quad axle groups in order to meet the PBS Low speed swept path requirement of 8.7m for Level 2b access.
- B. The A-Double concept potentially at 85.5t but the convertor dolly arrangement between the two trailers would require intelligent active (forced) steering to meet the high-speed dynamics requirements of PBS, namely, Lane change and Pulse steer manoeuvres .

Both combinations could accommodate two 12.2m (40') shipping containers within the 30m overall length limit, however, the A-Double combination was the vehicle of choice as it would provide a number of significant benefits over the enhanced quad/quad B-Double.

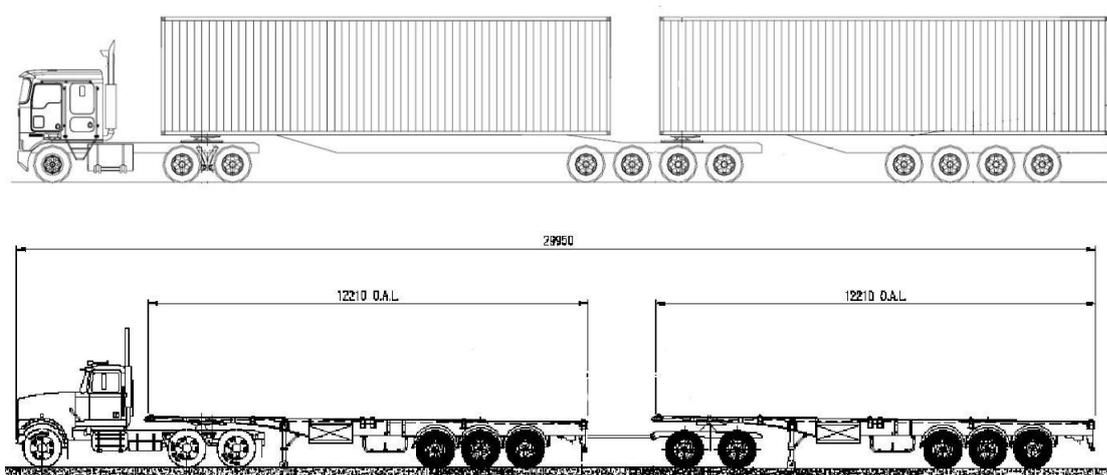


Fig. 1 - Proposed Haulmark A-Double and Quad/Quad B-Double combinations

4. Haulmark A-Double Benefits

After an initial detailed analysis of the two combinations the following benefits of the A-Double over the Quad/Quad B-Double were identified.

- A. An additional 8t payload (ie. 85t GCM – 77t GCM, tare weights of both combinations were expected to be very similar)
- B. Industry standard 12.2m tri-axle semi-trailers could be utilized in lieu of specialized Quad axle B-Double semi-trailers. The steering dolly in the A-Double combination would contain all the specialized technical hardware.
- C. Better weight distribution outcomes for the A-Double combination as there is no weight transfer interaction from one trailer to the other as there is in a B-Double combination. The A-double provides better load placement opportunities)
- D. The A-Double trailers being industry standard could also be utilized in a single trailer application if required which would provide greater fleet utilization for the Transport operator.
- E. The Haulmark A-Double combination can accommodate an industry standard COE or bonneted day cab prime mover within the 30m overall length PBS level 2b access requirement.
- F. It was anticipated the capital cost and to some degree the operational costs of both combinations would be similar however until the full extent of the steering system required on the A-Double converter dolly was understood this issue remained to some degree unanswered.

Clearly, the Haulmark PBS Steering A-Double combination will provide significant operational benefits over the enhanced Quad/Quad PBS B-Double. The issue at hand, however, was to understand what level of steering was actually required to ensure adequate PBS level 2b compliance at the required GCM of 85.5t while at the same time providing a suitably high load CG for the intended freight tasks such as containerized export of grain .

Extensive computer modeling was undertaken so as to benchmark a non-steering A-Double's dynamic performance both at low and high speed for PBS level 2b compliance thereby identifying the areas that would require specific control or performance enhancement.

The positioning of suspension groups and rear tow coupling overhang is a critical element in the way a conventional A-Double performs on road, however an associated negative issue related to suspension positioning is the resultant weight distribution of the trailer. It is one thing to get the vehicle to perform theoretically correctly, it is another thing entirely to ensure operationally the trailer distributes the laden weight correctly in an effort to comply with the approved on road axle group weights.

Once it was understood what the specific dynamic performance areas of the A-Double were that needed enhancement in order to meet the requirements of PBS level 2b at our required GCM of 85.5t and a high CG load it became very clear that a speed-dependent forced steering system was required.

Given the steering requirements for the convertor dolly were very idiosyncratic and there were no proprietary steering systems suitable it was decided to develop a specific steering system for the Haulmark A-Double combination that would provide enhanced performance and have abundant reserve capacity that could be utilised in other applications if and when required.

The specific areas of performance of the A-Double that required enhancement in order to comply with PBS level 2b were primarily high speed transient offtracking and rearward amplification, clearly enhancing the high speed dynamic performance of the A-Double was critical in order to achieve our required outcome.

5. Proof-of-Concept Test Vehicle

In order to test and validate the steering systems performance under a wide range of challenging conditions and suitability for the A-Double combination it was necessary to carry out testing in a proof-of-concept vehicle shown below in Fig 2. Consideration was given to the type of combination that should be used in this test that would best indicate the dynamic potential of the proposed steering system. It was agreed a rigid truck and dog trailer arrangement would provide the best indication of the steering systems performance as the proposed test vehicle was designed to have very poor dynamics due to unfavourable dimensions (short wheelbases, large coupling rear overhang) and high CG loads. The proof-of-concept test vehicle was comprehensively tested in simulation before the field trials to establish baseline results and identify risks so they could be managed.



Fig 2 – Proof-of-concept test vehicle, actual and modelled

Rigorous dynamic track testing of the proof-of-concept test vehicle was carried out covering both low and high-speed manoeuvres with the steering both active and in separate tests non active thereby identifying and quantifying the dynamic benefits of the steering system. Separate testing was also performed to get formal sign-off as part of the PBS approval process.

Clearly testing the proposed steering system was necessary in order to suitably test the robustness of the steering and associated failsafe systems and validate its performance for the A-Double concept. It was also imperative that the necessary data were collected relevant to

the steering systems performance so it could be potentially utilized in other vehicle combinations at a later date.

Table 2 below details the main low-speed turn and high-speed performance measures that are key to the approval of a PBS vehicle. The table includes results of the convertor dolly both steering and non steering used in the proof-of-concept test vehicle and indicates the performance improvement gained from the steering system for that specific vehicle.

Significantly, and as expected from the extensive initial work-up and testing in simulation, the steering provided the greatest improvement in the high speed manoeuvres with a substantial improvement in Rearward amplification of 51% and an even greater 63% improvement in High-speed Transient offtracking. These two performance measures were identified early as the key ones to target and control in order to produce a highly productive A-double that would comfortably satisfy all of the PBS performance requirements.

Clearly the steering system will provide significant performance benefits when incorporated into a multi vehicle combination and can therefore be utilized in various vehicle combinations other than the proposed A-Double in order to gain a level of access that otherwise would not be available .

Table 2: PBS Key Performance Results from Numerical Modelling for the Proof-of-Concept Test Vehicle

PERFORMANCE MEASURE	PERFORMANCE RESULTS (NETWORK ACCESS)		PERFORMANCE IMPROVEMENT (%)
	Conventional Dolly	Steering Dolly	
Low Speed Swept-Path Width	L1	L1	2%
Rearward Amplification	Fail	Pass	51%
High-Speed Transient Offtracking	L3	L1	63%
Static Rollover Threshold	Pass	Pass	1%

6. Performance of the Haulmark Steering A-Double

Safety Standards

The PBS safety standards relate directly to the on-road performance of the heavy vehicle combination therefore the safety performance of the combination can be quantified in absolute terms. The PBS regime has four levels of route classification, three of these four also have a sub level (see Table 1 PBS access levels), however the performance of the vehicle must meet the requirements of the higher level not the sub level. There is no reduction in the performance requirements of a vehicle operating in level 2b at 30m

maximum overall length compared to level 2a at 26m maximum overall length, they must meet the same performance criteria.

Set out below is the PBS Level 2 performance standards the Haulmark steering A-Double has been fully tested and approved to operate under. Actual test results are “commercial in confidence “ and cannot be released.

PBS Level 2 Performance Standards

Startability - Ability to commence forward motion on specified grade, at least 12%

Gradeability - a. Ability to maintain forward motion on specified grade, at least 15%
b. Ability to maintain a minimum speed on a 1% grade, 70 km/h

Acceleration capability - Ability to accelerate from rest on a road with no grade – time to travel 100m must be not greater than 23s.

Overtaking Provision- No longer required, transferred to Network Classification Guidelines

Tracking ability on a straight path – Total swept path no greater than 3.0m

Ride Quality- Assessment against this standard not required

Low speed swept path - The maximum width of the swept path in a prescribed 90 degree low speed turn – no greater than 8.7m

Frontal swing - The maximum lateral displacement in a prescribed low speed turn between the path of the front outside corner of the vehicle and the outer edge of the front outside wheel of the hauling unit - for trucks and prime movers no greater than 0.7m

Tailswing - The maximum lateral distance that the outer rearmost point on a vehicle unit moves outwards in, perpendicular to its initial and final orientation when the vehicle commences and completes a prescribed low speed turn- not greater than 0.35m

Steer tyre friction demand - the maximum friction level demanded of the steer tyres of the hauling unit in a prescribed low speed turn – not more than 80% of the maximum available tyre/road friction limit.

Static Rollover Threshold - The steady state level of lateral acceleration that a vehicle can sustain during turning without rolling over.- no less than 0.35g and for Dangerous Goods vehicles 0.40g

Rearward amplification - Degree to which the trailing unit amplify or exaggerate lateral motions of the hauling unit- Rearward amplification no greater than 5.7 times the static rollover threshold of the rearmost roll-coupled unit taking account of the stability of the roll coupling.

High speed transient off tracking - The lateral distance that the last axle on the rear trailer tracks outside the path of the steer axle in a sudden evasive maneuver- no greater than 0.8m

Yaw Damping Coefficient -The rate at which ‘ sway’ or yaw oscillations of the rearmost trailer decay after a short duration steer input at the hauling unit – no less than 0.15 at the certified vehicle speed.

Handling quality- assessment against this standard not required.

Directional stability under braking - The ability to maintain stability under braking. Deemed to comply if the combination is fitted with ABS/EBS or load proportioning.

Infrastructure Standards

Pavement vertical loading standards limit the stress on the surface of the road while pavement horizontal loading standards control the road wear by limiting the impacts of horizontal tyre forces on the surface of the road, these prescriptive requirements are used by PBS, the Haulmark PBS A-Double complies .

PBS details a specific bridge formula for the level of access required however given the overall length restriction of 30m for Level 2b vehicles in order to be bridge formula compliant we would be limited to a 77t GCM.

PBS does however provide an alternative opportunity for vehicles to be approved at a higher mass than allowed by the relevant bridge formula but operational route approval is based on a Tier 3 bridge assessment which looks at the specific capacity of the infrastructure on the requested route relevant to the specific PBS vehicle.

Given our desire to maximize GCM to the 85.5t in line with the higher mass limits axle mass the Haulmark PBS A-Double generally operates under a Tier 3 route assessment. The Haulmark PBS A-Double is fitted with Hendrickson Intraax airbag suspensions, Wabco EBS/ABS brake systems and the trailers have 11R22.5 tyres while the steering dolly has 275/70R22.5 tyres.

PBS Infrastructure Standards Level 2

Pavement vertical loading – Degree to which vertical forces are applied to the pavement. Limiting axle group mass limits to those that presently apply, GML, CML and HML mass.

Pavement Horizontal Loading - Degree to which the horizontal forces are applied to the pavement. This is a prescriptive requirement that allows a Maximum GCM of 85.5t with front under run protection.

Tyre Contact pressure distribution - The maximum local vertical stress under a tyres contact patch for a given vertical load type and tyre inflation pressure. This is a prescriptive requirement.

Bridge Loading - The bridge loading standard addresses the issue of bridge strength and ensures that a vehicle does not induce effects on bridge structures that exceed accepted limits as specified by the bridge owner. At 85.5t the A-Double is a Tier 3 – specific link access and the assessment is undertaken by the bridge owner.

Bridge formula for access to the Level 2 road network is: $M = 3L + 12.5$ for $M \leq 46.5t$ and $M = 1.5L + 29.5$, for $Mass \geq 46.5t$, where L = the minimum distance (m) between the external axles of any two axle groups for a given total gross mass M (tonnes).

7. Haulmark Steering A-Double Freight Task Case Study

In order to best demonstrate the benefits of the PBS scheme and more specifically the PBS approved Haulmark steering A-Double, set out below is a case study of a specific freight task in operation in South East Queensland comparing the benefits of the Haulmark steering A-Double to that of the baseline vehicle previously utilized .

Freight Task: Export Containerised Grain

Transporting 120,000t per annum of export containerized grain from Toowoomba to the Port of Brisbane.

The grain is transported in 6m (20') shipping containers at a gross weight of 27.5t (25t of grain plus the container weight of 2.5t) .

The route from Toowoomba to Port of Brisbane is 280 km's return trip, the trip from the Port of Brisbane to Toowoomba is generally unladen or at best empty containers.

Previous method of transport:

Due to the weight of the laden containers (27.5t) it was not possible to utilize a B-Double combination (max GCM 68t) and carry two containers at a time therefore these containers were being transported one container per trip on a six axle articulated vehicle operating at 42.5t GCM.

Therefore transporting 120,000t of grain at one container per trip equates to,

4800 return trips

1,344,000km's travelled (4800@280km's)

640,000 litres of fuel burnt (fuel burn is approx 2.1 km/litre)

Approximately 1400t of exhaust emissions

Introduction of the Haulmark Steering A-Double:

By introducing the Haulmark A-Double into this freight task it enables the transporting of two containers per trip due to the increased GCM (in this case 79.5t) the operational results are as follows,

2400 return trips

672,000km's travelled (2400@ 280km's)

395,295 litres of fuel burnt (fuel burn is approx 1.7km/litre)

Approximately 869t of exhaust emissions

Haulmark A-Double Nett Benefit:

By the introduction of the Haulmark Steering A-Double the NETT positive result is,

A saving of 672,000 km's NOT travelled and 2400 fewer truck trips

A reduction of 539t in exhaust emissions

A saving of 245,000 litres of fuel @ A\$1.45 per litre = A\$ 355,350 saving

Freight task summary:

Evidenced by the case study detailed above the PBS regime has facilitated the development and introduction of the Haulmark Steering A-Double which has produced significant tangible benefits to the Exporter, Transport operator, Government regulators and the broader community alike by way of,

REDUCING TRUCK TRAFFIC FOR A GIVEN FREIGHT TASK

- Reducing traffic congestion

REDUCING EMISSIONS

- Reduced fuel burn for the freight task

IMPROVING SUPPLY CHAIN PRODUCTIVITY AND EFFICIENCY

- Reducing transport costs per container

IMPROVED ROAD SAFETY

- Significantly reduced on road exposure

Through the ongoing development of approved PBS level 2b routes, ultimately forming a strategic freight network the Haulmark PBS A-Double will facilitate a significant reduction in truck traffic congestion and emissions while at the same time provide a quantum step in productivity and efficiency together with a clear increase in road safety.

8. PBS approval process and on road compliance issues

Currently there are a number of significant concerns with the approval process and the on road compliance of PBS vehicles such as .

- A.** Given the heavy reliance on the height of the CG of the load in order to comply with the required PBS performance approvals any deviation (higher) to the approved load CG will result in the vehicle not being PBS compliant. It is a challenge from an enforcement perspective to be able to ensure operator compliance.
- C.** In most cases the PBS approval process is based on computer simulation only, there is no on road validation required of the vehicle combinations' PBS compliance, therefore the approval process is susceptible to inaccuracies and is only as good as the model and data set being used in the modeling. The Haulmark steering A-Double HAS been dynamically tested in order to validate the computer modeling and performance outcomes with and without steering capability.
- D.** Some PBS approved vehicles only just meet the requirements for the requested mass and load CG (based only on computer modeling and associated modelling assumptions). That is, there is no additional performance capacity, the concern is if the loading isn't properly controlled, or as the vehicle ages or the operating conditions

vary slightly the vehicle will not comply with the performance and safety requirements.

- E. Overwhelmingly proponents of innovative PBS vehicles like the Haulmark A-Double commit significant amounts of development funding to these projects and as such must have total confidence in the approval process, ongoing compliance and on road enforcement in order to ensure the integrity of the performance of other PBS approved vehicles is maintained. If the approval process is such that it fails to highlight inaccuracies in an application, and given there is no on road performance validation of the vehicle only a computer model, there is a very real chance that some vehicles will be approved to operate that don't meet the PBS performance standards. This then clearly has significant safety implications but also creates a gross commercial inequity between those proponents spending significant amounts of money to ensure performance compliance and those that have gained approval for marginal vehicles without any verification of performance through formal field testing.

Conclusion:

The importance of the road freight industry to Queensland and indeed Australia's economy cannot be overstated. Australia has a significant reliance on road transport and has successfully addressed many technical issues related to the operation of innovative heavy vehicle combinations, PBS is perhaps the best example of this.

The Haulmark PBS approved steering A-Double has pushed the boundaries of the PBS regime and paved the way for other manufacturers and transport operators to think outside of the prescriptive system in search of better solutions to the growing freight task.

The development, approval and subsequent commercialization of the Haulmark steering A-Double through the PBS regime has brought about what some in the broader Transport and Logistics Industry have described as the "Game Changer".

By that they mean this combination has provided a quantum step in vehicle productivity, potentially of similar proportions to that of the introduction of the B-double combination in Australia in the mid 1980's.



Fig. 3 - PBS approved Haulmark Steering A-Double