

INNOVATIVE VEHICLES DESIGNED TO AUSTRALIAN PERFORMANCE-BASED STANDARDS

Robert Di Cristoforo

Roaduser Systems P/L
76-80 Vella Drive, Sunshine Victoria 3020, Australia.

ABSTRACT

The introduction of performance-based standards (PBS) to Australian heavy vehicle regulation has initiated the design of a wide variety of innovative vehicles in many industries. Some examples of these innovations are presented, highlighting the reasons they were developed and the ways in which they were designed to comply with PBS.

Although PBS is intended to improve safety and reduce impact on infrastructure, it still offers the scope to simultaneously achieve enormous productivity benefits. Consequently, most of the energy currently being put into PBS vehicle development is coming from road transport contractors seeking improved operational efficiency.

A shift towards more intermodal transport in Australia has brought about the need for viable road transport solutions for some of the larger and heavier containers often transported exclusively by rail and super-freight road vehicles. Example PBS road vehicle designs accommodating these longer and heavier containers are presented.

One of the observed side-effects of PBS is to allow more flexibility in road transport logistics. Modular trailer designs can now be more effectively developed to operate as large inter-city transports that can easily be dismantled into small distribution units in metropolitan areas. Under the prescriptive system of regulation this has not been able to be easily and efficiently achieved, but a viable PBS option is presented.

The Australian PBS has already produced vehicle innovations ranging from small urban vehicles to large multi-combination vehicles operating in the remote areas of central Australia. It is believed that the opportunities offered by PBS are endless, and only time will reveal its full potential.

INTRODUCTION

Australia's transport task

The Australian road transport task is projected to increase by 100% over the next ten years. Such an enormous increase in freight movement is not likely to be effectively achieved under current prescriptive regulations without a dramatic increase in the number of heavy vehicles using the road network. One of the aims of Performance-Based Standards (PBS) is to reduce future vehicle numbers by allowing innovative, high-productivity vehicles to access the road network safely and without posing additional damage to pavements and bridges.

Australia has an extensive rail network that covers many thousands of kilometres connecting the major capital cities, most of which are situated at around 1,000 to 2,000 kilometres from one another. The majority of the population resides within a relatively short distance from one capital city. Through greater utilisation of the rail network there is potential to contribute significantly to the point-to-point freight movements between the capital cities, and therefore to service much of the country's population. It follows that greater utilisation of the rail network is a viable means of reducing the load on the road network as freight movements increase. Consequently, government policy is increasing its support of rail transport in various ways. However, rail is not adequately structured for metropolitan distribution; any freight that is transported to a city by rail is most likely en-route to a final destination by road. Therefore, fostering intermodal

container transport for rail and road is critical to the success of the Australian transport industry in keeping up with projected increases in freight movement, and has been given due attention by road agencies.

Current regulatory climate

While the Performance-Based Standards regime currently being developed for Australia is not expected to be operational until 2005, the 16 safety-related standards and 4 infrastructure-related standards have been developed to such a level that road agencies are granting special permits and making policy decisions based on performance assessments against the interim standards. Some of Australia's major transport operators have been willing to trial PBS-style vehicle concepts under special permit, which has provided benefits to both the operator and the road agencies using the trial vehicles as case studies to aid further development of the PBS regime.

The amount of support offered to "early" PBS vehicles by road agencies has encouraged a significant number of transport operators to enter into conceptual design work on new, innovative vehicles to suit their operations. Operators hope to gain some competitive advantage by increasing their cubic capacity, mass capacity or accessibility in comparison with their competitors. While the number of PBS-style vehicle approvals is small, there are advantages to be gained. However, as the PBS regime matures and the take-up of the new rules increases, competitive advantage will be more difficult to maintain for any considerable period of time. New vehicles will be "on display" in the road network until other operators see them and decide to follow suit. It is unlikely that PBS vehicle concepts will be patentable; operators will need to use other means of maximising competitive advantage, such as making use of unique existing equipment or tailoring designs to suit specialised freight transport.

Vehicle design trends under PBS

The two distinct trends observed in recent years are towards increased cubic capacity and increased mass. Increases in cubic capacity, while theoretically achievable through increases in height, width and length, are generally targeted through increased length alone. That is because increasing height reduces access in most cases, and also has an associated stability penalty which adversely affects other aspects of the PBS approval. Increasing width tends to be a problem only in built-up areas, where lane widths are narrow and traffic is heavy. Although compliance with all PBS standards can be demonstrated, regulators are reluctant to allow increased width under PBS. The emergence of longer vehicles has seen more interest in the use of steerable axles and the development of innovative trailer steering mechanisms.

In the last 15 years, increases in mass have been achieved through regulatory reform of axle mass limits. Under PBS, however, operation at maximum legal axle mass limits can reduce the stability performance of some vehicles to the point of being close to the allowable limit of static rollover threshold. The trend, therefore, has been towards increasing the number of axles and reducing the load per axle, while still achieving an increase in gross mass. This trend has seen a marked increase in the number of vehicle designs incorporating quad axle groups in place of triaxle groups, and triaxle groups in place of tandem axle groups. While this trend reduces the effect of vehicles on pavements in the vertical direction, it increases pavement loads in the horizontal direction. This highlights the need for steerable axle technology in both high-cube and high-mass applications. Even with demonstrated improvements in pavement vertical loading and the use of steerable axle technology to reduce horizontal loads, there is still a significant mass-limiting factor: bridge loading, which is a developing area of vehicle assessment in Australia, is often the design criterion for high-mass vehicles.

TRANSPORTING LONGER INTERMODAL CONTAINERS

The transport of low-density freight usually results in the operation of cube-limited vehicles, where maximum cubic capacity is reached without reaching maximum axle loads. For high efficiency, the cubic capacity of a vehicle needs to be matched to the freight density so that maximum axle loads are approached at maximum cubic capacity.

The trend towards lower freight densities in Australia has seen an increase in the number of cube-limited vehicles and, hence, a reduction in overall transport industry efficiency. As a result, there has been considerable demand from industry for increased cubic capacity. Although this has been addressed by

changes to prescriptive regulations in the past, it is now more commonly channelled through PBS before a permit is granted.

Of the three basic dimensions (length, width and height), length offers the path of least resistance when seeking increased cubic capacity. Width and height are strongly restricted by the road network, while length can be accommodated with relative ease by mitigating swept path requirements through innovative vehicle design. Therefore there has been strong demand for innovative vehicles capable of transporting longer intermodal containers to connect with the extensive Australian rail network.

One example of an Australian PBS vehicle designed for this task is the 6-axle tractor-semi-trailer with 54'6" intermodal container (Fig. 1). This vehicle was specially designed to comply with Level 1 PBS safety standards for general access to the road network. The design is essentially a re-dimensioned standard tractor-semi-trailer, with the main changes being increases in trailer 'S'-dimension and rear overhang. The critical standards were Low-Speed Offtracking (due to the increased trailer 'S'-dimension) and Tail Swing (due to the increased trailer rear overhang). The final design was successfully arrived at through careful placement of the rear triaxle group such that Low-Speed Offtracking and Tail Swing standards were both satisfied simultaneously.



Figure 1. 54'6" intermodal container in 19 m tractor-semi-trailer combination.

Due to the early progression of PBS at the time of design, it was difficult to obtain permits for PBS vehicles that extended beyond the prescriptive length limits. A prescriptive length limit of 19 metres was enforced by road agencies, which resulted in a very tight design requiring the use of a special short-wheelbase prime mover with set-forward fifth wheel. In some cases, this may produce a vehicle having poor load distribution. The result is a reduced gross mass, as some axle groups will reach maximum load while others are under-loaded. However, for low-density freight, this is often not a problem.

The success of the 54'6" intermodal container as a Level 1 PBS vehicle has paved the way for potentially longer containers. However, while the 54'6" container is able to satisfy Level 1 PBS with standard trailer equipment, longer containers will most likely require special steerable axle technology to meet the stringent Level 1 PBS requirements. Automotive-type steerable axles may not be sufficient to allow quantum increases in trailer length; more innovative systems such as Australia's "Trackaxle®" pivotal bogie system need to be investigated (Fig. 2).

It is estimated that intermodal containers of over 60 feet in length could potentially be granted Level 1 PBS approval with the aid of such special steerable axle technology.



Figure 2. 52' trailer featuring "Trackaxle®" pivotal bogie system.

TRANSPORTING HEAVIER INTERMODAL CONTAINERS

Current Australian practice in container transport is to carry containers of up to 30 t gross mass on 6-axle tractor-semi-trailers with total gross mass of 42.5 t. Industry is now demanding the capability to carry heavier containers having gross mass of up to 40 t, which would utilise the maximum lifting capacity of container-handling equipment and therefore provide a means of transporting the maximum possible gross container mass.

One example of an Australian PBS vehicle designed especially for the transport of heavy containers is the 7-axle tractor-semi-trailer shown in Fig. 3. The semi-trailer features a quad axle group that contains a steerable rear axle. As well as aiding low-speed turning performance, steerable rear axles reduce tyre scrubbing and are therefore a requirement for quad axle groups under the PBS Pavement Horizontal Loading standard. This particular vehicle is designed for tipping loads such as recycled paper. It has a gross mass of 50 t and is capable of carrying a 35 t container on restricted routes.



Figure 3. 40' intermodal container (35 t) in 50 t quad axle tipping combination.

The vehicle configuration has been specially designed for three-way operation. Fig. 4(a) illustrates the vehicle shown above, while Fig. 4(b) shows how the quad axle group is moved forward and its first axle raised to convert the vehicle into a standard 6-axle configuration that is allowed general access on an “as-of-right” basis under prescriptive regulation. Fig. 4(c) illustrates a further enhancement to the configuration, where the quad axle group is moved further back to a third position and a special “load distribution dolly” is coupled between the prime mover and trailer to spread additional load. This configuration has the potential to carry containers of up to 40 t gross.

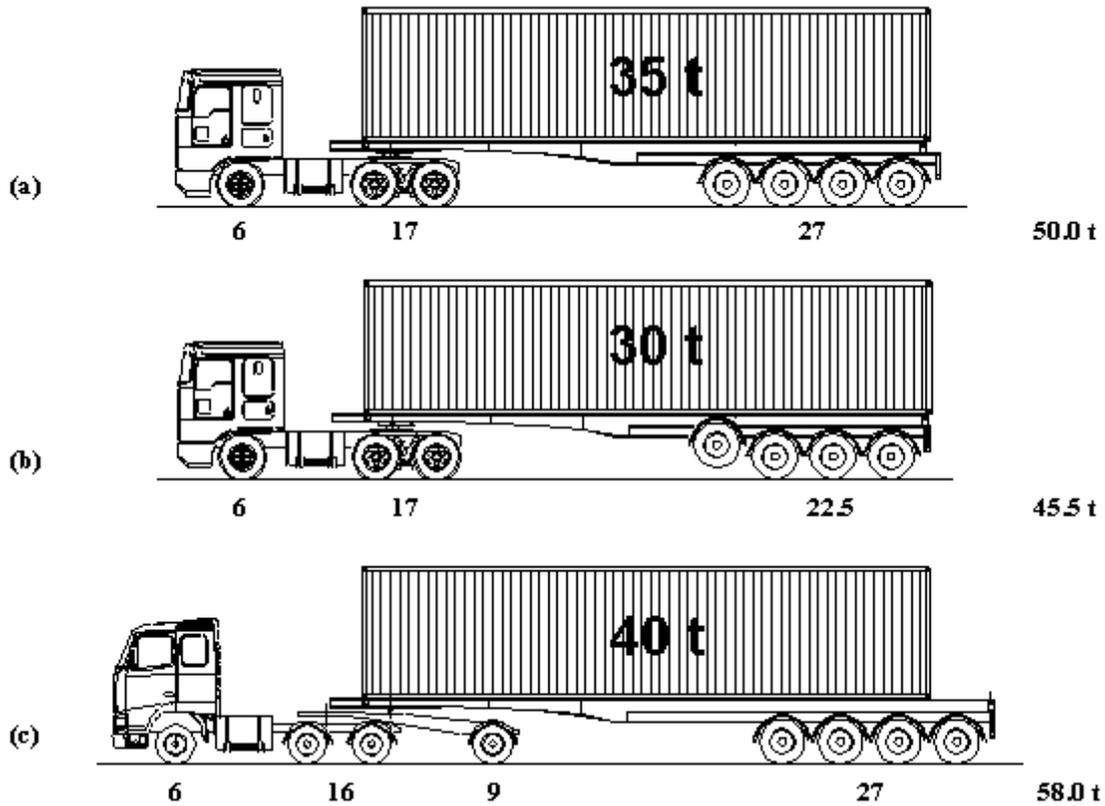


Figure 4. Three-way operation of special quad axle trailer.

When designing mass-limited vehicles such as these, a key part of the design process is to carefully lay out the axle groups, coupling positions and payload positions to achieve the desired axle load distribution and bridge loading qualities. Attention needs to be given to both bridge loading and axle group loading simultaneously, as the two are closely related. Spacing axle groups further apart to satisfy bridge loading requirements often upsets load distribution; adjusting the load distribution without violating the bridge requirements often results in an impractical design that either has excessive length or such undesirable features as excessive overlap between vehicle units around fifth-wheel couplings. All three of the above vehicles have been designed in this way through close cooperation with the transport operator and trailer manufacturer to ensure accurate tare mass and dimension details were used.

Figure 5 shows the results of a comparison between the innovative vehicle options of Figure 4 (4a = “Quad Semi”, 4c = “Quad Dolly Semi”) and the PBS reference tractor-semi-trailer and B-double. It can be seen that the peak bending moments induced in a simply-supported bridge span are less than for the reference vehicles. This shows the effect of the quad axle group having less load per axle and a wider spread than the triaxle group.

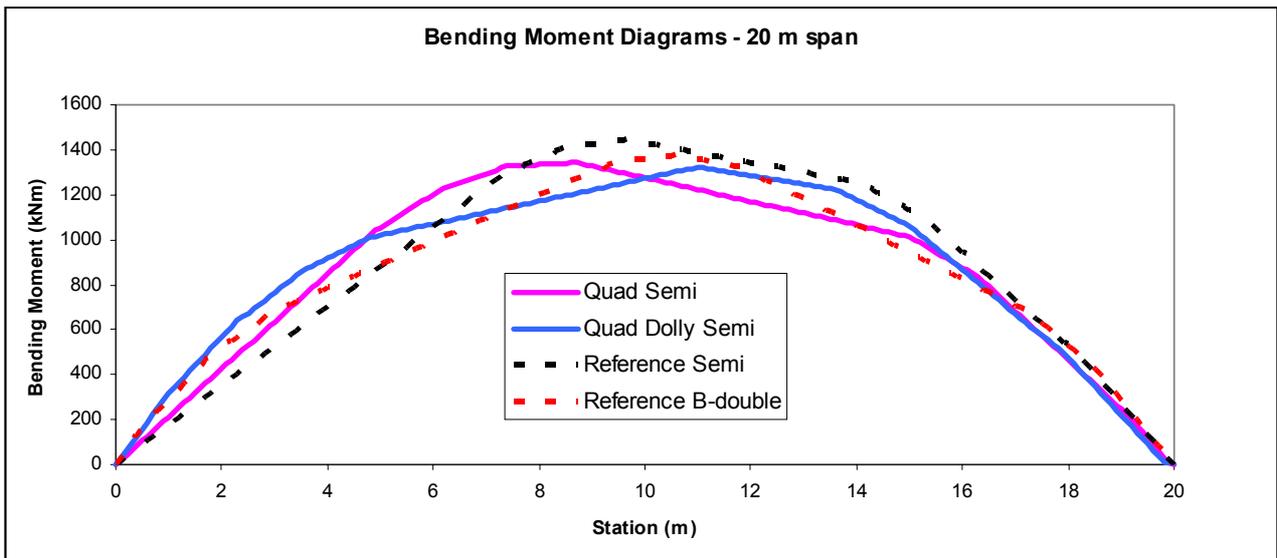


Figure 5. Bending moment diagram comparison.

EFFICIENCY THROUGH MODULARITY

Productivity increases for individual PBS vehicles can be easily quantified in terms of the percentage increase in payload volume or mass above that of the prescriptive vehicle being replaced. Gains in the vicinity of 15% would not be uncommon for typical PBS vehicles. However, on a system-wide scale this simplistic approach tends to under-estimate productivity increase, as there is a potential for further increases arising from other system-specific factors, such as the logistical changes that could be accommodated with better vehicle designs.

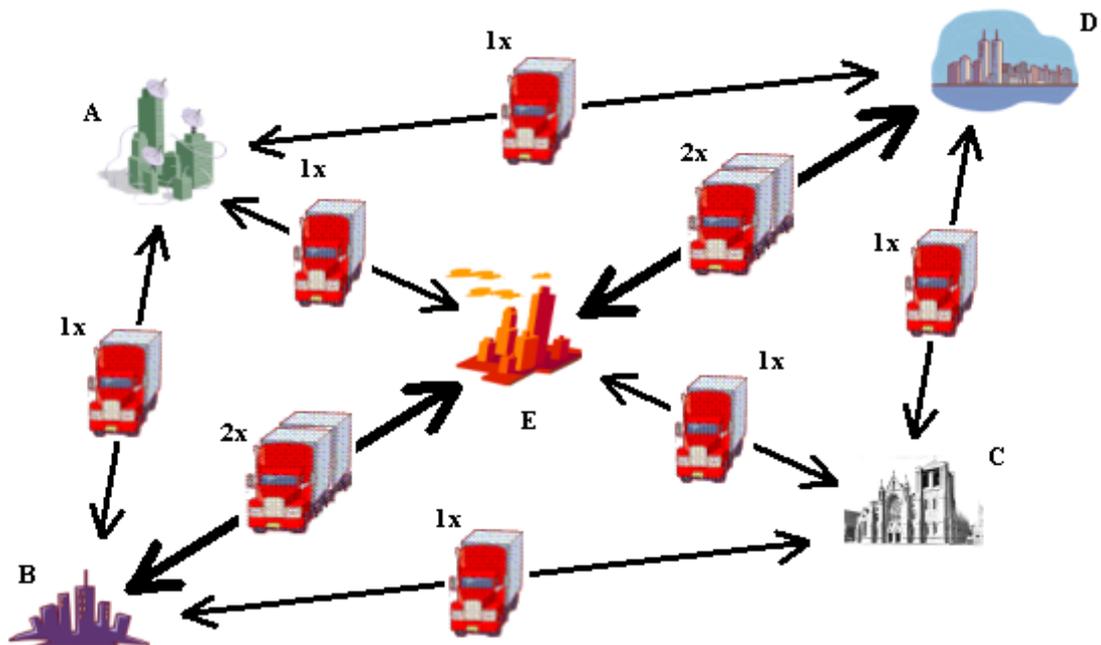


Figure 6. Current Australian logistics under prescriptive regulations.

Figs. 6 and 7 highlight a particular example of the part played by logistics under PBS through a stylised depiction of a typical Australian transport network. The cities marked B and D represent major capitals, while the remaining three cities represent smaller regional cities. Fig. 6 illustrates the current situation under prescriptive regulation, where the main route connecting the capitals is open to larger vehicles and is highly populated by B-doubles. The smaller routes connecting the other cities, while open to B-doubles, tend to be

more efficiently utilised by single articulated units due to the smaller amount of freight being moved along each of those routes. The traffic web is vast and results in many vehicles using many roads, often travelling empty.

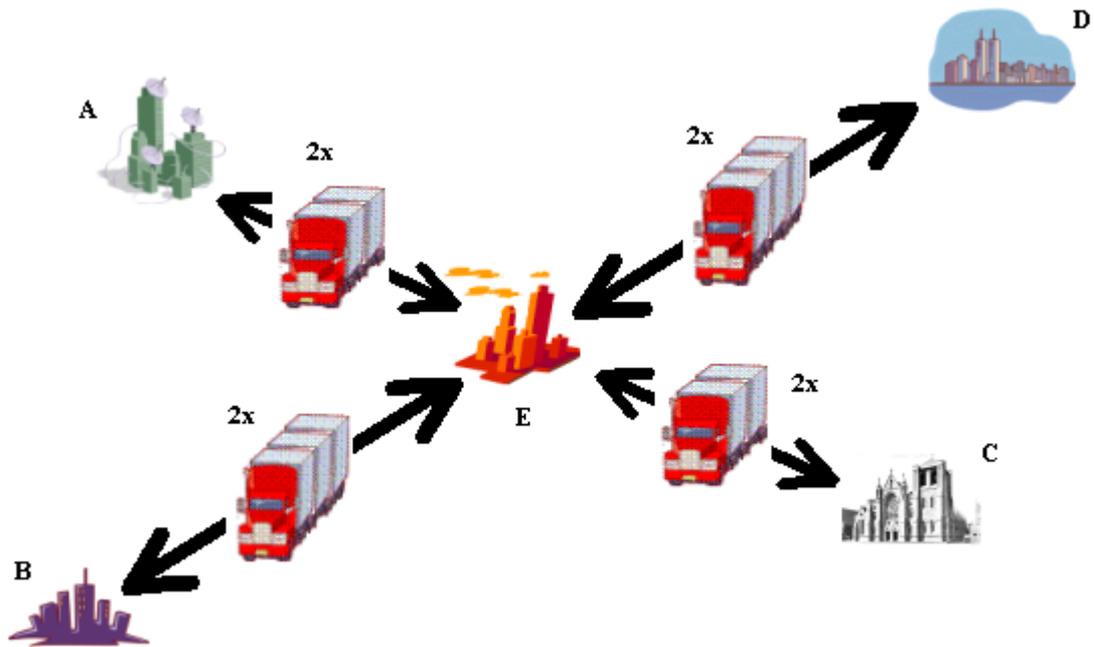


Figure 7. Future Australian logistics under performance-based standards.

Under a mature PBS system, the same transport task could be undertaken in a much more efficient manner. The main route connecting the two capitals could be open to larger “super-freight” vehicles (such as B-triples), which would allow more efficient use of B-doubles to the regional cities. Freight could be transported to and from the outer regional cities on specific routes via a central hub where units are added to and subtracted from the super-freight vehicles, not unlike a rail system. Since all freight is moved to and from the outer regional cities via the same route, B-double transport would be more efficient. This system would require a high degree of modularity in the PBS vehicle design.

The reduction in vehicle movements can be estimated from the diagrams assuming that each transport leg from one city to another takes one day.

Table 1. Estimate of the effect of PBS on transport system efficiency.

	Before PBS	After PBS
Truck trips per day on major route (total of B-E & E-D)	4	4
Truck trips per day on other routes	6	4
Total truck trips per day	10	8
Trailer trips per day on major route (total of B-E & E-D)	8	12
Trailer trips per day on other routes	6	8
Total trailer trips per day	14	20

By this simple analysis it is shown that the total number of trailer units moved per day could be increased from 14 to 20 while reducing the number of truck trips (hence drivers) from 10 to 8. Also, the number of routes used by heavy vehicles reduces from 8 to 4, however if the main route (B-E-D) is considered to be a primary truck route, the number of secondary routes used by heavy vehicles is reduced from 6 to 2. Empty

travel time could be reduced when the transport web is condensed down to a smaller number of routes, which would add further to these gains. For a large transport company managing the entire operation, efficiency could be made significantly better under the PBS system than under current prescriptive regulation.

The success of such a system is highly dependent upon a modular vehicle design. Single articulated vehicles can be converted into B-doubles and B-triples with the addition of one or two lead trailers as shown in Fig. 8. Being fully 'B'-coupled, this configuration would demonstrate exceptional dynamic performance in comparison with a traditional A-train and would be much more likely to meet PBS standards.

The base vehicle (tractor-semi-trailer) is the "work-horse" Australian heavy vehicle, being the most common articulated vehicle in the country. Australia's road network allows virtually unrestricted access to these vehicles, making them a viable configuration for large-scale distribution work, as carried out by supermarket chains. While the smaller rigid vehicle configurations lend themselves to distribution work (due to their access capability), the tractor-semi-trailer offers increased efficiency when the level of access allows its operation.

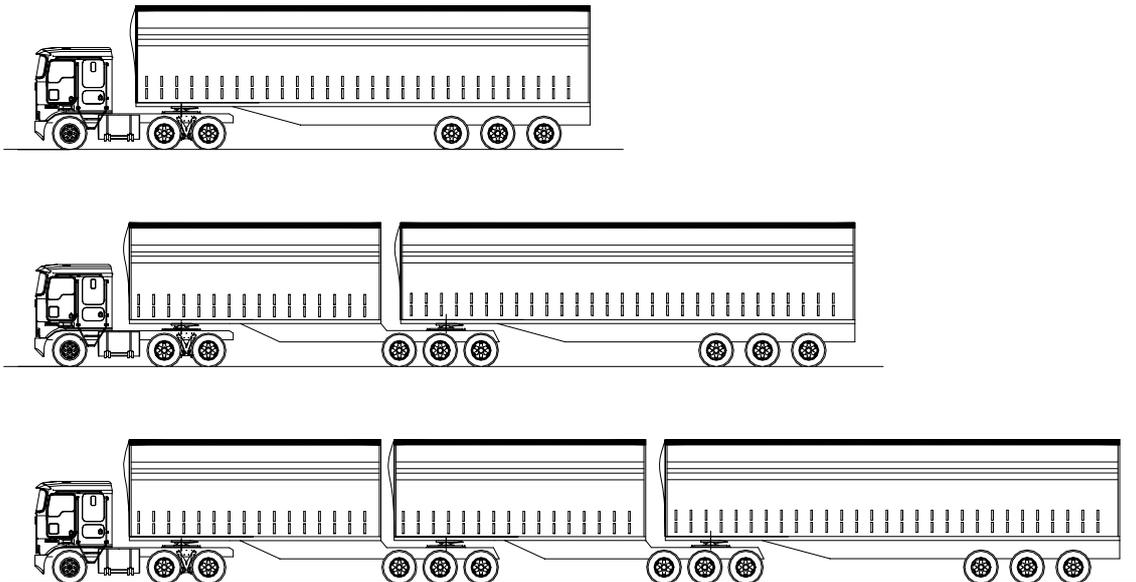


Figure 8. Potential modular vehicle design.

CONCLUSION

Performance-Based Standards have certainly "broken the shackles" of prescriptive heavy vehicle regulation in Australia. Innovative vehicle configurations that have been introduced in the early stages of deployment of the new regime have been found to be tailored specifically to individual industries and freight types. Vehicle designs can usually be classed as either cube-limited or mass-limited; living examples of each have been shown, each offering enormous increases in productivity for their particular transport task, whether in volume or mass.

While significant gains can be achieved through increasing the dimensions of standard heavy vehicle equipment, quantum leaps in transport efficiency require radical thinking. Steerable axles have been important in gaining extra length, with pivotal bogie systems offering the most tangible results. Gaining additional mass is essentially a case of increasing the number of axles; replacing triaxle groups with quad axle groups has been investigated, as has the addition of axle groups to existing configurations.

The current climate of the Australian transport industry strongly supports intermodal transport on road and rail. Rail is highly efficient in connecting the far-flung capital cities, but incapable of supporting distribution within those cities. While road transport is ideal for the distribution task, current prescriptive regulations do not allow the transport of larger and heavier intermodal containers. To help the transport system cope with

projected future growth in the freight task, it is imperative that effective intermodal PBS vehicles are designed and proven through the PBS framework.

Potential gains in overall transport system efficiency have been shown to be greater than just the percentage increase in payload volume or mass per vehicle. By allowing PBS vehicle designs to stretch beyond what is currently allowed under prescriptive regulation, the introduction of B-trains could dramatically reduce vehicle numbers to the extent where some routes would be obsolete. The B-train would need to be highly modular in design to allow maximum flexibility.

REFERENCES

1. National Road Transport Commission, PBS safety standards for heavy vehicles, January 2003.
2. National Road Transport Commission, PBS infrastructure protection standards for heavy vehicles, January 2003.
3. National Road Transport Commission, Steerable axles to improve productivity and access, December 2002.
4. Sweatman, P.F., Di Cristoforo, R. and Kalasih, D., Benchmarking heavy vehicle productivity and safety performance, Roaduser Systems Report RUS-03-898-01-01, September 2003.
5. Coleman, B.L., Sweatman, P.F. & Di Cristoforo, R., Approval for a 16.6m (54.5ft) intermodal container semi-trailer, Roaduser Systems Report RUS-03-837-01-03, June 2003.
6. Di Cristoforo, R. and others, Performance assessment of intermodal container skels, Roaduser Systems Report RUS-03-856-01-03, September 2003.
7. Sweatman, P.F., Coleman, M. and Di Cristoforo, R., Evaluation of an active-steering triaxle group (Trackaxle), Roaduser Systems Report RUS-03-1000-01-03, September 2003.