Report to VicRoads
as lead agency for the National Transport Commission

Twin-Steer Axle Mass Limits Project

Discussion paper

prepared by

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Preface

The Twin-Steer Axle Mass Limits project is an Industry Sector Reform initiative of the Third Heavy Vehicle Reform Package. VicRoads is the Lead Agency responsible for the management of this project on behalf of the National Transport Commission (NTC).

The project seeks to establish the axle mass limits at which a twin-steer prime mover and single semi-trailer combination should be allowed to operate. However, a B-double combination will also be considered as an adjunct to the project. The work will consider the vehicle configurations from a Performance-Based Standards (PBS) perspective, and complement work that has previously been undertaken by VicRoads and the NTC.

The consultant that VicRoads has engaged for this project is Mr Bob Pearson of Pearsons Transport Resource Centre Pty Ltd, who has formed a consortium including Dr Hans Prem and Dr Luan Mai from Mechanical Systems Dynamics Pty Ltd, and Mr Damian Yeo from Economic Associates Pty Ltd.

The project outputs will be this Discussion Paper, a Final Report and a Regulatory Impact Statement (RIS) for recommendation to the Australian Transport Council.

A workshop will be held at VicRoads on 27 July from 10 am to 3 pm. Please email Bob Pearson (bobp@ptrc.com.au) prior to 25 July to register.

Comments on the Discussion Paper are invited, and should be submitted by 20th August, 2004. Comment should be addressed to:

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1. INTRODUCTION

The *Twin-Steer Axle Mass Limits* project is project 1.8 of the Industry Sector Reform of the Third Heavy Vehicle Reform Package. VicRoads is the lead agency responsible for the management of the project on behalf of the National Transport Commission (NTC). The purpose of the project is:

> to establish the axle mass limits for twin-steer prime mover and semi-trailer combinations, considering the safe operation of the vehicle, the impact on infrastructure and operational practicality.

VicRoads identified three mass limit approaches as being potentially feasible:

1. the first approach is aimed at all jurisdictions. This approach will consider the operation of the twin-steer prime mover and semi-trailer combination at the sum of the axle loads under General Mass Limits (GML), up to a maximum Gross Combination Mass (GCM) of 47.5 tonnes, compared to the present GCM limit of 42.5 tonnes;
2. the second approach is aimed at jurisdictions that have introduced Higher Mass Limits (HML) for vehicles with road friendly suspensions. This approach will consider a total vehicle combination at the sum of the axle mass limits, where the drive and trailer axle groups operate at HML, up to a maximum GCM of 50.5 tonnes; and
3. the third approach will seek to establish a mass limit for a twin-steer axle group with a road friendly suspension and use this higher mass limit to determine the total mass limit for the vehicle combination. The GCM of this vehicle may be in excess of 50.5 tonnes.

As part of the project, potential twin-steer vehicles will be assessed against the standards developed by the NTC/Austroads in the Performance-Based Standards (PBS) project. The PBS project aims to establish a set of performance standards against which innovative vehicles will be assessed. The performance standards limit safety and infrastructure risks while allowing more flexible vehicle operations. There are currently sixteen safety performance standards and four infrastructure performance standards approved by the Australian Transport Council (ATC).

Five of the most common and practical twin-steer prime mover and semi-trailer combinations will be assessed in detail. The use of a twin-steer prime mover within a B-double combination is seen as the next logical step, and one twin-steer B-double combination will also be considered. The B-double combination is to have a maximum length of 26 metres and a 20.6 metre trailing length in line with a current proposal regarding the length of B-doubles. A PBS assessment will be conducted for each combination with each of the above three axle mass limit approaches.

The five main tasks in the project are:

- identify technical and policy issues;
- determine the axle mass limits at which twin-steer combinations should be allowed to operate, including a possible level for a twin-steer with road friendly suspension;
- produce a Discussion Paper for consultation;
- undertake a PBS assessment for five twin-steer prime mover and semi-trailer combinations, and one B-double combination for each of the three mass limit approaches; and
- produce a Regulatory Impact Statement (RIS) for consideration by Transport Agencies Chief Executives (TACE) and Ministers of ATC.

Consultation is to take place with a range of industry and state road authority stakeholders.

This Discussion Paper deals with the first two tasks as well as presenting a proposed approach to the PBS assessment and some initial results for the assessment of vehicles against the PBS infrastructure standards.

The Discussion Paper is an important part of consultation and comments are invited. Following receipt of comments, a detailed PBS analysis will be conducted as outlined above and a Final Paper and RIS will be prepared. Some issues relating to the RIS are included for comment in this Discussion Paper.

Section 2 of this paper examines a range of technical and policy issues that are relevant if the sum of axle masses is to be adopted. The potential mass limit for twin-steer vehicles is discussed in Section 3 while Section 4 outlines various issues relating to the assessment of vehicles against the PBS performance standards.

Section 5 provides an initial assessment against some infrastructure standards, and Section 6 is a summary and identifies the main issues for comment.

2. TECHNICAL AND POLICY ISSUES FOR TWIN STEER VEHICLES AT THE SUM OF AXLE MASS

A range of technical and policy issues need to be considered if a policy to increase the allowable gross mass on twin-steer combinations is to be implemented. These issues are discussed in this Section. In addition, issues potentially relevant to the Regulatory Impact Statement (RIS) are discussed.

2.1 Industry Issues

2.1.1 Productivity

If twin-steer vehicles were permitted to operate at the sum of the axle group mass limits (either for GML or HML) significant productivity gains are possible. Table 1 shows approximate potential productivity increases, which will vary with the individual tare mass increases for different manufacturers and different applications.

The reference to *existing* in Table 1 relates to vehicles that already require a twin-steer to cater for a truck mounted crane. As can be seen, potential productivity gains are large for these vehicles.

Table 1: Potential Productivity Improvements by Summing Axle Group Limits

Configuration	Potential gain in gross mass	Approximate increase in tare mass	Approximate potential payload gain	
General Mass Limits			mass	percentage
A223	5.0 tonnes	1.5 tonnes	3.5 tonnes	13%
A223 (existing)	5.0 tonnes	nil	5.0 tonnes	> 20%
B2233	5.0 tonnes	1.5 tonnes	3.5 tonnes	9%
Higher Mass Limits				
A223	5.5 tonnes	1.5 tonnes	4.0 tonnes	13%
A223 (existing)	5.5 tonnes	nil	5.5 tonnes	> 20%
B2233	5.5 tonnes	1.5 tonnes	4.0 tonnes	9%

2.1.2 Cost

There will be three cost penalties for the productivity gain of using a twin-steer prime mover – increased capital cost, increased registration cost and increased operating cost.

The capital cost penalty is likely to be in the order of $25,000 to $30,000. Registration cost under the national registration scheme for a twin-steer prime mover (8x4) is $4,845 compared to a traditional single steer (6x4), which is $3,744, an annual penalty of $1,101.

Increased operating costs will arise from increased fuel for the greater gross mass and increased maintenance and tyre costs for the additional steering axle. It is expected that these additional operating costs will be in the order of 2% to 4%.

Industry advice, however, is that incurring increased costs would be a commercial decision and likely to be offset by the productivity gain.

2.1.3 Gaining maximum load on the twin-steer axle group

With a load of uniform density on a semi-trailer, it could be difficult to achieve full axle weights on a twin-steer. Transferring payload to a twin-steer axle group requires longer king pin leads (the distance that the centreline of the fifth wheel is ahead of the centreline of the tandem drive axle group). King pin leads would need to be of the order of 600 mm to 900 mm to achieve close to full axle masses. While truck manufacturers and operators do not see these long leads as a problem, they can affect the vehicle dynamics and require particular attention to swing clearances. One possible implication from inability to load to full mass on the twin-steer is that operators could seek to place freight on the prime mover directly behind the cabin. Again there may be impacts on vehicle dynamics.

The various effects on dynamics will be investigated in the PBS assessments.

2.1.4 Availability of road friendly twin-steer groups

While it is expected that air suspensions for twin-steers would meet the performance requirement of a road friendly suspension, initial indications are that the softer leaf spring suspensions usually found on existing steer axles might also meet a road friendly test similar to that prescribed in VSB 11. If this were the case, the choice of road friendly twin-steer vehicles would be quite broad.

The range of air suspended twin-steer axle groups in Australia is extremely limited at this time. Some truck manufacturers have air suspended twin-steer groups manufactured overseas but do not at this time make these suspensions generally available on the Australian market. Some truck manufacturers do not manufacture a prime mover with an air suspended twin-steer, even overseas. However, manufacturers would be expected to meet any demand if an increase in the allowable load made road friendly twin-steer axle groups more attractive.

2.1.5 Interchangeability

The longer king pin leads, heavier loads on king pins and attention to swing clearances will require specific attention to the design of the semi-trailer, with consequent implications for interchangeability of semi-trailers. While specifically designed semi-trailers could be towed behind standard single steer prime movers, subject to complying with overall vehicle combination length limits, it is unlikely that normal semi-trailers could be utilised with twin-steer prime movers with long king pin leads. For standard semi-trailers, the fifth wheel would need to be located close to the centre of the drive tandem and obtaining optimal loads on a twin-steer prime mover using standard semi-trailers will not be possible without the additional load on the prime mover mentioned above. However, standard semi-trailers could be used with reduced mass.

2.1.6 Suitability for long haul transport

Over the years, various objections have been raised to the use of twin-steer prime movers on long haul operations due to tyre wear considerations. However, no concerns were raised by manufacturers or operators as to the suitability of modern twin-steer prime movers for longer haul transport tasks with their enhanced vehicle and suspension designs.

2.2 Regulatory Issues

2.2.1 Vehicle manoeuvrability and general access potential

A twin-steer vehicle is, as a general rule, less manoeuvrable and has a larger swept path than a single steer vehicle. This reduction in manoeuvrability arises mainly because of the larger effective wheelbase of a twin-steer. Improvements in the maximum wheel "cut", or steering angle, over the last 10 or 20 years has reduced the swept path for twin-steer vehicles. Industry stakeholders did not view a slightly larger swept path as an operational difficulty.

However, it is possible that road agencies may not grant a twin-steer prime mover and semi-trailer combination with increased mass the right of general access. South Australia will not grant vehicles in excess of 42.5 tonnes the right of general access. Granting general access is a significant policy issue that will need to be resolved by jurisdictions if the sum of axle masses is to be granted.

The PBS analysis to be undertaken during this project will determine if the twin-steer vehicles meet PBS low speed offtracking requirements.

2.2.2 Accreditation

Vehicles under the HML regime approved in some jurisdictions must be accredited if a vehicle operating under HML is equipped with a tri-axle group. The main reason for this approach is to limit potential for additional damage to bridges.

Twin-steer prime mover and semi-trailer combinations under GML would, if permitted, operate at a GCM of 47.5 tonnes. This GCM is of a similar magnitude to the mass permitted for some truck and dog trailer combinations, which do not require accreditation. Any such twin-steer vehicles would operate under an approved axle spacing mass schedule that is formulated to protect the bridge stock. It does not seem necessary to require these vehicles to be accredited.

Twin-steer articulated vehicles operating at HML will gross in the region of 51 tonnes if fitted with a tri-axle group. Heavier B-double combinations at HML would most likely be fitted with tri-axle groups. Operators of both combinations at HML would need to be accredited under present policy arrangements.

A twin-steer prime mover and a tandem semi-trailer combination operating at HML would gross up to 45.5 tonnes and would not be fitted with a tri-axle group. Axle group mass limits are similar to truck and trailer combinations that do not require accreditation.

Therefore, the requirement for accreditation for twin-steer vehicles should reflect the current arrangements of other vehicles.

2.2.3 OH&S issues associated with using truck mounted cranes

In general, any manual loading and unloading of vehicles would be aided by a truck mounted crane. A number of vehicles are already equipped with truck mounted cranes. Cranes with a greater lifting capacity already require a twin-steer because of the tare mass of the crane.

A gross mass of at least 47.5 tonnes for twin-steer articulated vehicles will certainly facilitate the provision of truck mounted cranes. However, in practice the additional take-up is likely to be small because of the associated tare mass disadvantages as well as the capital cost. One factor that may favour truck mounted cranes is the difficulty of achieving full axle weights for general operation as noted above and therefore the provision of a crane may not be seen as reducing payload. In other words, a small truck mounted crane could be added and bring the twin-steer up to its allowable load, using standard semi-trailers with a uniform density load.

2.2.4 Legislative issues

Two legislative changes will need to be made if the sum of axle mass limits for twin-steer prime movers is to be adopted. The national Road Transport Reform (Mass and Loading) Regulations do not provide for single articulated combinations to exceed 42.5 tonnes. The mass of this combination is limited to 42.5 tonnes and the axle spacing mass schedule does not extend beyond 42.5 tonnes.

In relation to the axle spacing mass schedule, it is understood that agreement has been reached between jurisdictions to include in the Mass and Loading Regulations an axle spacing mass schedule for vehicles between 42.5 tonnes and 50 tonnes. If agreement to permit single articulated vehicles to exceed 42.5 tonnes is reached, the Regulations could be amended without difficulty.

Of perhaps greater significance is that VSB 11 does not provide a means to certify as road friendly axles fitted with single tyres. Appendix 1 to VSB 11 requires that all axles be fitted with dual tyres, apart from a six tyred tandem. Changes would need to be made to VSB 11 if a road friendly twin-steer is to be certified.

2.3 Issues for the Regulatory Impact Statement

The Regulatory Impact Statement (RIS) that will be prepared later in the project will consider the costs and benefits of the possible changes outlined in this Discussion Paper. Included in the analysis will be:

- the reduction in vehicle kilometres due to a higher payload capacity;
- pavement effects resulting from the higher axle masses;
- benefits arising from increased mass; and
- increased capital and operating costs.

Other issues that will be canvassed will include the potential reduction in Occupational Health & Safety (OH&S) claims resulting from mounted cranes providing mechanical loading/unloading of goods and the possibility of attaching a safety harness for manual loaders working on top of laden vehicles.

Of critical importance in determining the costs and benefits of the various proposals will be estimates of the numbers of vehicles that would operate under any new arrangement, i.e. the take-up estimates. It is probable that take-up will vary with different industries, with the higher take-up in containers and tippers and the lower take up in general freight. It is expected that the take-up rate will be the same for GML vehicles as for HML vehicles but of course the number of HML vehicles is much lower than GML. Take-up in this case refers to the use of the vehicle, not the construction, as many vehicles may be able by construction to operate at HML limits but are not able to do so because of access limitations.

Comments are invited on the likely take-up estimates given in Table 2.

Table 2: Proposed take-up percentage by industry segment

Industry segment	percent	Industry segment	percent
Agriculture	2	Grain	8
Mining	10	Petrol	8
Manufacturing	2	Bulk Liquid	5
Construction	2	Logs	5
Wholesale/retail	2	Food	2
Livestock	0	Waste	0
Mineral	10	General Freight	2
Car	0	Parcels	0
Quarry	5	Containers	10

It is proposed to sum benefits over 10 years at a discount rate of 5%. Take-up will build in an even progression over four years.

An issue for the RIS is the treatment of options. Alternatives that will be investigated include the following options:

1. the Base Case – status quo or current regulations;
2. allowing the sum of axle mass limits at GML;
3. allowing the sum of axle mass limits at HML at present HML limits; and
4. allowing the sum of axle mass limits at HML with an increased twin-steer limit if fitted with a road friendly suspension.

These options are not mutually exclusive, as Option 2 could be coupled with either Option 3 or Option 4. It appears that the best approach would be to analyse each of options 2, 3 and 4 against the base case (Option 1), as this approach allows summing of results for either Option 3 or Option 4 with Option 2.

3. POTENTIAL TWIN-STEER MASS LIMIT

This Section deals with establishing the potential mass limit for twin-steer axle groups fitted with road friendly suspensions.

3.1 Mass Limits Review Approach

The Mass Limits Review (MLR) used road wear reduction factors (RWRF) to allow for the effects of road friendly suspension systems on road wear, as detailed in NRTC (1996a). Two factors were taken into account in calculating the RWRF – load sharing between axles within an axle group and dynamic load variations above and below the static wheel force due to road surface unevenness. Table 3 below is reproduced from NRTC (1996c) and shows the relevant factors for different axle groups.

Table 3: MLR dynamic load road wear factors – road classes associated with high-speed zones

Axle group	Tyre fitment	Load sharing		Dynamic load		Road friendly road wear reduction factor
		NON-RFS	RFS	NON-RFS	RFS	
Single axle	Single tyres	-		1.04	1.04	1.00
Single axle	Dual tyres	-		1.25	1.06	1.18
Tandem axle on prime mover	Dual tyres	1.01	1.01	1.36	1.06	1.28
Tandem axle on trailer	Dual tyres	1.03	1.00	1.245	1.06	1.21
Tandem axle	Dual & single tyres	1.03	1.00	1.245	1.06	1.21
Triaxle	Dual tyres	1.06	1.01	1.245	1.06	1.23

Source: Table 1*a* of NRTC (1996c)

NRTC (1996b) included another table which had lower dynamic load factors to recognise that dynamic wheel loads are reduced in lower speed zones. The final RWRF used arose from the recognition that much of the travel occurs in high-speed zones and that some conservatism should be applied to results.

The final RWRF used in the MLR are shown in Table 4.

Table 4: RWRFs used in the Mass Limits Review

Axle group (all dual tyres)	RWRF
single axle	1.15
tandem axle (drive axle)	1.25
tandem axle (non-drive axle)	1.20
triaxle	1.20

Source: NRTC (1996a)

In relation to *single steer axles,* the MLR concluded (NRTC 1996b, page 108):

> It is not appropriate to distinguish between road friendly and non road friendly suspensions on steering axles. All freight vehicle steering axles have relatively soft leaf springs with controlled friction and hydraulic dampers fitted.

The only difference therefore would be with load sharing. No specific twin-steer data is available from the NSW load sharing survey (NRTC 1996b). Softer springs traditionally have lower load sharing and consequently the value for non-RFS load sharing was increased to 1.05. The row shown in Table 5 could be added to Table 3 for high-speed zones.

Table 5: Suggested factors for twin-steer axle groups

Axle group	Tyre fitment	Load sharing		Dynamic load		Road friendly road wear reduction factor
		NON-RFS	RFS	NON-RFS	RFS	
Tandem axle (non-drive)	Single tyres	1.05	1.00	1.04	1.04	1.05

The result using the equivalent MLR methodology would therefore be a RWRF of 1.05.

It should be noted that this value may be conservative. Using the formulae given in NRTC (1996c) to calculate the difference in road wear for an allowable 10% variation compared to a 5% variation (see Section 3.3 below) gives a RWRF of 1.2.

3.2 Progress since the Mass Limits Review

The original research for the OECD Divine Project was the basis for the values used in the MLR (NRTC 1996b) and was adapted for the context of Australian trucks and roads. However, the final report of the Project (OECD 1997) whilst providing some information, was not definitive. No additional research has been conducted to throw further light on the road friendliness of suspensions.

Nevertheless, there is disagreement about the road wear reduction effects of road friendly suspensions. The opinions of experts vary as to the extent of the advantages to pavements of these particular suspension types. However, in this analysis, the only difference between the suspensions is a more stringent load sharing requirement (see Section 3.3 below) and therefore the outcome should not be controversial.

3.3 Present single steer axle load

The present allowable load on a single steer axle with single tyres is 6 tonnes[1]. Some sections of industry, particularly the Truck Industry Council representing truck manufacturers, have been lobbying for an increase in the allowable single steer axle load. Manufacturers point to the variety of factors that are under discussion to improve the safety and environmental performance of trucks, including front under-run protection systems (FUPS) and new ADRs directed at lowering noise and gaseous emissions. Manufacturers suggest that these developments will increase the steer axle load. However, for the purposes of this project, it will be assumed that the 6 tonne single steer axle load will remain for the immediate future.

Given a limit of 6 tonnes on a single steer axle with single tyres, the maximum that could be placed on two such axles is 12 tonnes. However, a limit of 12 tonnes would imply perfect load sharing. The definition of a load sharing suspension system in the Australian Vehicle Standards Rules (AVSRs) includes a requirement as follow:

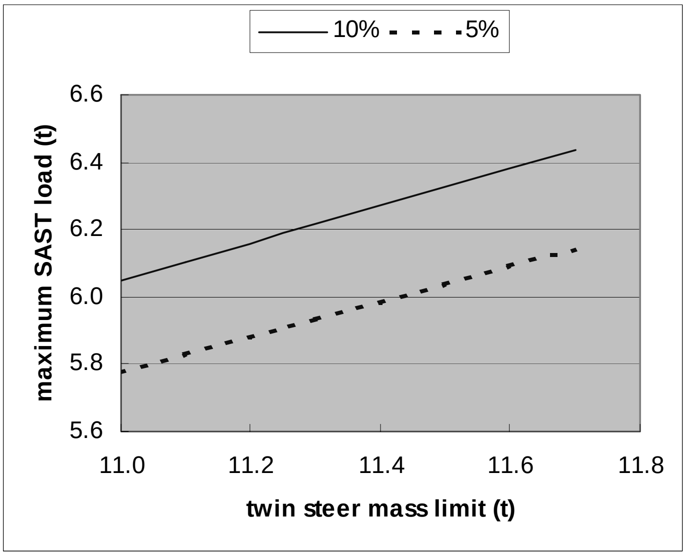
> ***load-sharing suspension system*** means an axle group suspension system that:
>
> (a) is built to divide the load between the tyres on the group so that no tyre carries a mass over 10% more than the mass that it would carry if the load were divided equally; and
>
> (b) has effective damping characteristics on all axles of the group.

[1] single steer axles on road trains are permitted more than 6 tonnes if fitted with wide single tyres.

In Vehicle Standards Bulletin No. 11 (VSB 11) relating to certification of road friendly suspension systems the 10% requirement above has been reduced to 5%. An illustration of the maximum loads for a single axle with single tyres (SAST) that could occur under 10% and 5% variation rules for various twin-steer masses is shown in Figure 1.

It can be seen that the present 11 tonne axle group limit provides that one of the axles could, with a 10% variation in load sharing, reach 6.05 tonnes. With a 5% allowance, the same level is provided at a maximum twin-steer mass of 11.5 tonnes.

Figure 1: Effect of 5% and 10% variation in nominal share of a twin-steer group mass



3.4 Comparable increases under MLR

Increases arising from the MLR for other axle groups were:

- tri-axle with dual tyres – from 20 tonnes to 22.5 tonnes (12.5%);
- tandem axle with dual tyres – from 16.5 tonnes to 17 tonnes (3%); and
- 6 tyred tandem (tandem with dual and single tyred axles) – from 12 tonnes to 13 tonnes (8.3%).

The main reasons for restricting the increase for the tandem axle with dual tyres were:

- concerns with the possible effects on short span bridges;
- to increase the ratio between the tri-axle limit and the tandem axle limit to improve the dynamic performance of a 6 axle articulated vehicle; and
- that the single axle limit of 9 tonnes restricted the ability to increase the limit beyond 17 tonnes (allowing for a 5% variation in load).

In the latter situation, a 5% variation around the nominal axle load of 8.5 tonnes for each axle of a road friendly tandem gives a maximum single axle load of 8.93 tonnes.

3.5 Establishing a twin-steer group mass limit

The upper limit for the allowable mass on a load sharing twin-steer axle group is restricted by the maximum of 6 tonnes on a single axle with single tyres and the road wear reduction factor for a road friendly twin-steer. The indicative load from both these restrictions is 11.5 tonnes.

It is concluded, therefore, that the mass limit for a road friendly twin-steer axle group that should be investigated by this project is 11.5 tonnes.

This prospective limit would provide an increase of 4.5%, about the same as the road wear reduction value based on the MLR methodology. An increase of 4.5% would be comparable to the increase of 3% granted under the MLR to tandem axles with dual tyres and below comparable increases for tri-axles and 6 tyred tandem axles.

4. ISSUES WITH PBS ASSESSMENTS

This Section discusses some issues relating to the PBS assessments to be undertaken later in the project.

4.1 Issues with PBS assessments against infrastructure standards

Both the Pavement Vertical Loading and Bridge Loading standards have been approved by ATC, but there were caveats attached to some approvals. However, in the interim until the PBS project is completed there is a clear understanding that these standards can be used as a basis for permit assessments and case studies.

The approved standards are:

Pavement Vertical Loading
Measure: Degree to which vertical forces are applied to the pavement.
Level: The Average Road Wear Per Axle Group (SARs/AG) shall not exceed the level calculated for a vehicle with the same number of rigid parts and the same number of axles on each rigid part as is permitted by prescriptive (or equivalent) regulations.

Bridge Loading
Measure: The maximum effect on a bridge measured relative to a reference vehicle.
Level: Bending moments and shear forces shall be no greater than the moments and forces induced in the bridge by representative Austroads Bridge Assessment Group (ABAG) configured vehicles with axle group loadings set at GML or HML as appropriate for the road class or route.

4.1.1 Pavement Vertical Loading standard

Appendix C of the PBS Phase A Regulatory Impact Statement contained a more detailed listing of "*Rules*" to apply to the Pavement Vertical Loading standard. In this Discussion Paper, all "*Rules*" apart from the *Measure* and *Level* given above will be termed *Supplementary Rules*. These Supplementary Rules are critical for the assessment of PBS vehicles and it is proposed that these Supplementary Rules be used in this project, even though it is recognised that some changes are possible.

The Supplementary Rules state:

> the SARs/AG methodology is not intended to apply to Higher Mass Limits (HML) at this stage

In this project, VicRoads has requested a PBS assessment of all mass limit approaches, including HML. Two possible means can overcome this conundrum:

- use a road friendly factor to reduce the HML loads to GML loads and enable comparison; or
- conduct a separate assessment comparing the relevant reference vehicle at HML to the twin-steer vehicles also at HML.

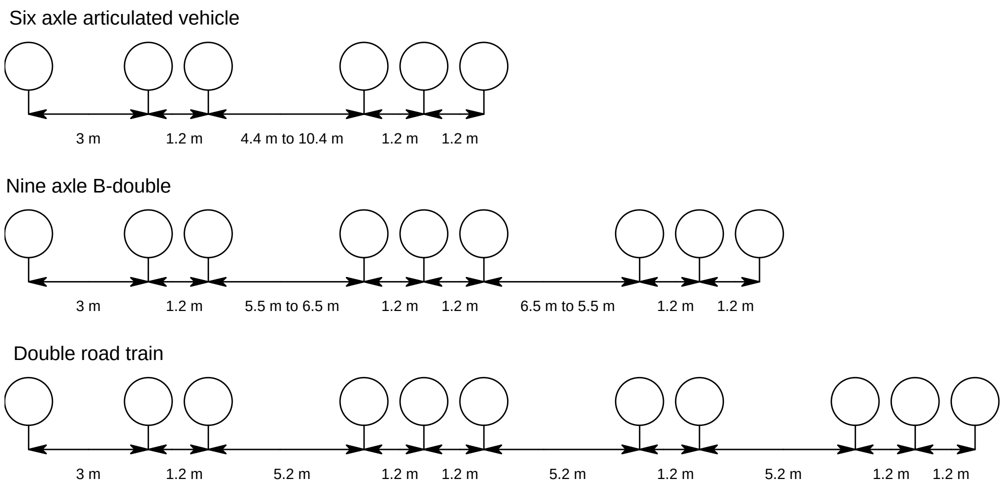
To overcome the controversial issue of using road friendly factors, it is proposed to use reference vehicles at HML even though this is not an approved PBS approach.

4.1.2 *Bridge Loading standard*

The approved Bridge Loading standard, known as the Maximum Effect Relative to Reference Vehicle (MERRV), uses the reference vehicle approach to make compare bridge loading effects.

The dimensions of the ABAG reference vehicles are shown in Figure 2 below.

Figure 2: Dimensions of the ABAG reference



Axle group loads are either GML or HML as appropriate and therefore there are no issues in using HML.

In this project, only six-axle articulated vehicles and a B-double will be assessed.

However, no Supplementary Rules have been developed, let alone adopted, to assist with the PBS bridge assessment. The Supplementary Rules would provide details of bridges to be assessed. In other words, should the assessment be made only for simply supported bridges or for both simply supported bridges and bridges that are continuous for live loads?

As this is a general approach, route specific bridges are not appropriate.

Proposed approach

It is proposed that the assessments be made on the following bridges:

- simply supported spans – from 6 metres to 50 metres in 2 metre increments; and
- continuous spans – 2 equal spans, with span lengths from 8 metres to 50 metres in 2 metre increments

4.1.3 *Other infrastructure PBS standards*

The remaining two infrastructure standards, Pavement Horizontal Loading and Tyre Pressure Distribution, are prescriptive at this time.

The Pavement Horizontal Loading Standard is the degree to which horizontal forces are applied to the pavement and specifies requirements for steerable axles in multi-axle groups and a minimum number of driving axles for a given gross mass.

The Tyre Contact Pressure Distribution standard is the maximum local vertical stress under a tyre's contact patch for a given vertical load type and tyre inflation pressure. The existing prescriptive requirements relating to maximum pressure is to be retained and applied to PBS vehicles.

Therefore, assessment against these two standards is not relevant.

4.2 Issues with PBS assessments against safety standards

Of the sixteen safety performance standards, the following twelve are considered to be applicable to this project because vehicle performance in each will be directly influenced by mass limit increases and possible modifications to dimensions:

- startability
- gradeability
- acceleration capability
- tracking ability on a straight path
- low speed swept path
- frontal swing
- tail swing
- steer tyre friction demand
- static rollover threshold
- rearward amplification
- high speed transient offtracking
- yaw damping coefficient

The *ride quality (driver comfort)* and *handling quality (understeer/oversteer)* standards will not be considered in this project because performance levels have not yet been established and further work is required to progress these standards.

The requirements of the performance standard *directional stability under braking* has several deemed-to-comply provisions, including use of anti-lock braking systems, and any complying vehicle is likely to use these deemed to comply provisions.

The remaining standard, *overtaking time,* relies on traffic volumes of particular roads and is therefore route specific.

Therefore, assessments will be made against only the twelve PBS safety standards identified above.

4.3 Mass of vehicles to be assessed

The three different mass limit approaches that will be the main focus of the investigations in this project are given in Table 6.

Table 6: Mass of vehicles to be assessed

	mass limits				
	twin-steer	**drive**	**trailer 1**	**trailer 2**	**gross mass**
Single articulated vehicles					
Sum of axle weights	11.0 t	16.5 t	20.0 t		47.5 t
Sum of present Higher Mass Limits	11.0 t	17.0 t	22.5 t		50.5 t
Sum of Higher Mass Limits with increased twin-steer axle mass	11.5 t	17.0 t	22.5 t		51.0 t
B-doubles					
Sum of axle weights	11.0 t	16.5 t	20.0 t	20.0 t	67.5 t
Sum of present Higher Mass Limits	11.0 t	17.0 t	22.5 t	22.5 t	73.0 t
Sum of Higher Mass Limits with increased twin-steer axle mass	11.5 t	17.0 t	22.5 t	22.5 t	73.5 t

4.4 Configurations

The assessments will be done on five different configurations that are considered the most common and practical for use with twin-steer prime movers. The basis for the selection of these configurations is given below.

The most common body types in the fleet are:

- flat top;
- van;
- curtain;
- temperature controlled;
- tipper;
- tanker;
- stock;
- car;
- skel; and
- jinker.

Body types, industries and commodities that are potential candidates for use of twin-steer prime movers are:

Body type	Industry	Commodity	Comment
Flat top	Building/construction	Bricks	Primarily urban operation with a truck mounted crane a useful addition
Flat top	Building/construction	Pipes, rails etc	Primarily urban operation with a truck mounted crane a useful addition
Flat top	Containers	Containers	Primarily urban operation but could be longer distance from rural areas. Could facilitate the use of side-loader operations.
Flat top	General freight	General Freight	Mostly medium to long distance
Van	General freight	General Freight	Mostly longer distance
Temp controlled	Food	Food	Mostly longer distance
Tipper	Building/construction/ mining	Quarry products	Largely urban but mining is longer distance
Tanker	Petrol/bulk liquid	Petrol	Combination of urban and longer distance
Skel	Containers	Containers	Primarily urban operation but could be longer distance from rural areas
Jinker	Logs	Logs	Rural operations

The flat top, van and temperature controlled bodies in the general freight and food industries are likely to be similar in output for the PBS assessment. The brick cartage or pipes are logical candidates for use of a truck mounted crane.

Therefore, pending consultations, it is intended to use five of the following six configurations as 7 axle articulated vehicles in the PBS assessment. At this stage, it appears that the jinker would be left out, but comment is invited on this issue.

Body type	**Commodity**
Flat top	Bricks
Van	General Freight
Tipper	Quarry products
Tanker	Petrol
Skel	Containers
Jinker	*Logs*

For the B-double configuration, it is intended to use a tanker body type.

It is intended to assess the general freight vehicle with a standard semi-trailer and some freight on the prime mover.

4.5 Dimensions

Dimensions of the candidate vehicles to be assessed will be finalised after consultations on the body types. However, some general issues are relevant.

The axle spacing mass schedules (ASMS) for general access vehicles (at GML) will be based on the nationally agreed formulae:

- up to 42.5 tonnes, M = 3L + 12.5; and
- from 42.5 tonnes to 50 tonnes, a formula of M = L + 32.5 tonnes.

For restricted access B-doubles, the schedule is based on the formulae:

- up to 46.5 tonnes, M = 3L + 12.5; and
- from 46.5 tonnes to 62.5 tonnes, a formula of M = 1.5L + 29.5 tonnes.

A minor change for B-doubles allows for the full 62.5 tonnes to be achieved with an overall axle spacing of 21 metres rather than the 22 metres required by the formula. In addition, a clear space rule applies to B-doubles.

A twin-steer single articulated vehicle therefore requires an overall axle spacing of 15 metres to achieve a gross mass of 47.5 tonnes. This is both achievable and practical.

The B-double formula for GML stops at 62.5 tonnes and therefore does not cater for the twin-steer B-double at 67.5 tonnes. To overcome this difficulty, the Category 2 road train formula, which extends to 110 tonnes and is identical to the second part of the B-double formula, could be used for the twin-steer B-doubles. However, even if the Category 2 formula was used, the overall axle spacing of the B-double would need to exceed 25 metres, which is not possible with a maximum allowable length of the B-double set at 26 metres by the project.

It is proposed, therefore, that the overall axle spacing be the maximum possible within the 26 metre limit, somewhere in the region of 23 metres. However, the present minimum of 18 metres (allowing 56.5 tonnes) from the leading drive axle to the rear axle will be retained.

5. INITIAL RESULTS

Some initial analysis has taken place on the two infrastructure standards of pavement vertical loading and bridge loading. The results are provided in this section.

5.1 PBS Pavement Vertical Loading analysis

5.1.1 Introduction

The pavement vertical loading performance *level* is Average SARs per Axle Group. SARs stands for Standard Axle Repetitions and is very similar to ESAs (Equivalent Standard Axles). SARs per axle group (SARs/AG) is calculated by:

$$\text{SARs per Axle Group} = \sum(L/L_{eq})^n/N_{ag} \qquad (2)$$

where L is the load on the axle group;
L_{eq} is the equivalent load on the axle group for a single SAR;
N_{ag} is the number of axle groups in the vehicle or combination; and
n is the selected damage exponent, in this case 12.

The maximum SARs per axle group for a PBS vehicle is that for an equivalent vehicle loaded to statutory limits (the reference vehicle), subject to limits in the *Supplementary Rules* on the maximum SARs/AG below.

Gross mass range	**Maximum SARs/AG**	
	3 axle groups	**more than 3 axle groups**
Greater than 42.5 tonnes to 55.5 tonne	4.88	3.66
Greater than 55.5 tonnes to 70 tonnes	not applicable	4.29

Therefore, the SARs per axle group for an A223 must not exceed 4.88 and for a B2233 must not exceed 4.29.

L_{eq} values used in this analysis were:

single axle (single tyres)	tandem axle (single tyres)	tandem axle (dual tyres)	triaxle (dual tyres)
5.4 t	9.18 t	13.8 t	18.5 t

5.1.2 Findings

The results of the analysis are given in Table 7 below.

Table 7: Results of the pavement vertical loading analysis (GML)

ID		**Axle group masses (t)**				**Gross mass**	**total SARs**	**Number axle gps**	**SAR/AG**
		steer	**drive**	**trailer 1**	**trailer 2**				
Single articulated									
1	A123	6.0	16.5	20.0		42.5	14.6	3	4.88
2	A223	11.0	16.5	20.0		47.5	20.8	3	6.94
3	A223	10.03	15.75	21.63		47.41	14.6	3	**4.87**
B-doubles									
4	B1233	6.0	16.5	20.0	20.0	62.5	17.2	4	4.29
5	B2233	11.0	16.5	20.0	20.0	67.5	23.4	4	5.84
6	B2233	10.0	15.6	21.1	21.1	67.8	17.1	4	**4.29**

Each vehicle incorporating a twin-steer exceeds the maximum SARs/AG as detailed in the Supplementary Rules. In particular, at General Mass Limits (GML), the vehicles (ID # 2 and 5) are significantly in excess of the allowable levels of 4.88 and 4.29 respectively (ID # 1 and 4). The maximum SARs/AG levels can be reduced to the maximum allowable by reducing the loads on the twin-steer (ID # 3 and 6).

Even though not a PBS measure but simply a comparison for the purposes of this project, the HML values show the same result as outlined in Table 3 below.

Table 8: Results of the pavement vertical loading analysis (HML)

ID		Axle group masses (t)				Gross mass	total SARs	Number axle gps	SAR/AG
Single articulated									
7	A123	6.0	17.0	22.5		45.5	26.2	3	8.74
8	A223	11.5	17.0	22.5		51.0	39.3	3	13.09
9	A223	10.53	16.53	22.71		49.77	26.2	3	**8.73**
B-doubles									
10	B1233	6.0	17.0	22.5	22.5	68.0	36.7	4	9.18
11	B2233	11.5	17.0	22.5	22.5	73.5	49.8	4	12.44
12	B2233	10.0	16.1	23.0	23.0	72.1	36.7	4	**9.18**

Therefore, maximum gross mass for an A223 to meet the PBS pavement vertical loading standard is in the region of 47.4 tonnes with reduced steer axle and drive axle mass.

5.2 Bridge loading

A MERRV PBS Level 1 comparison was undertaken for the ABAG A123 and a typical A223, both at GML loads. The A223 used in these examples has an overall axle spacing of 15.6 metres, greater than the 15 metre minimum required of the axle spacing mass schedule.

Figure 3 shows the ratio midspan moments for simply supported spans from 12 metres to 50 metres. The ratio is the moment for the A223 divided by the moment for the ABAG A123, so that a ratio of greater than 1 means the A223 has a greater midspan moment than the ABAG vehicle. The ratio exceeds 1 for spans greater than 40 metres and less than 14 metres, the latter where the twin steer has a significant effect.

Figure 3: Ratio of A223 to ABAG A123 – midspan moment for simply supported spans (PBS Level 1)

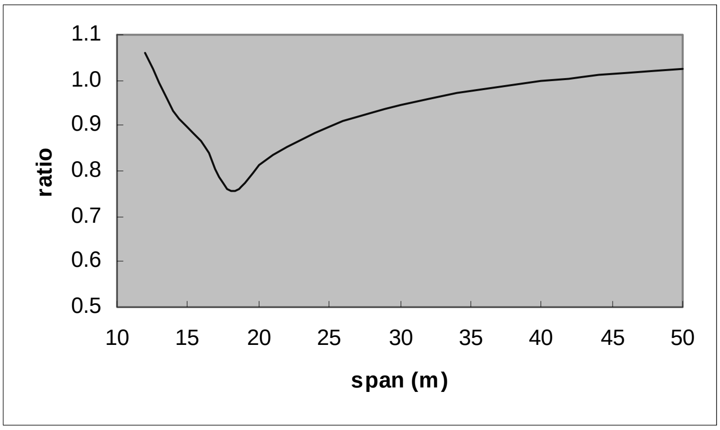
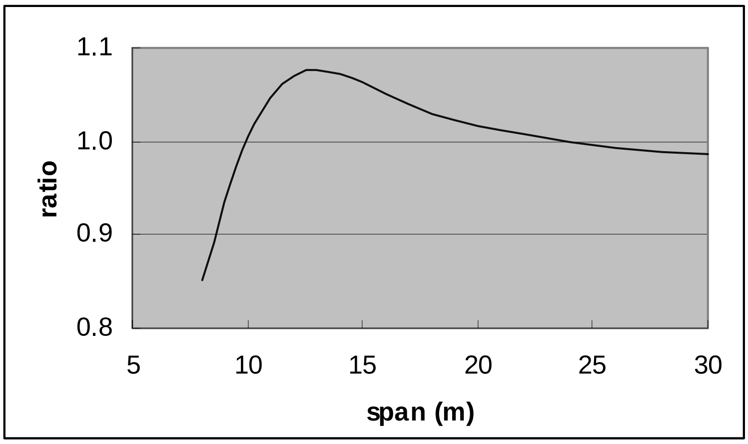


Figure 4 shows the same comparison, this time for the maximum negative moment for a bridge continuous for live load over 2 equal spans. The ratio exceeds 1 for spans between 10 and 22 metres, with a maximum of 1.07 for the 12 and 14 metre spans.

Figure 4: Ratio of A223 to ABAG A123 – maximum negative moment for 2 span continuous bridges (PBS Level 1)



Note: results to 30 m spans shown only at this time

A preliminary conclusion is that the MERRV analysis is conservative for Level 1. In both cases, the A223 is longer than required by the L + 32.5 formula but fails the MERRV standard.

6. SUMMARY AND MAIN ISSUES

The Twin-steer Axle Mass Limits Project aims to establish the axle mass limits for twin-steer prime mover and semi-trailer combinations, considering the safe operation of the vehicle, the impact on infrastructure and operational practicality.

Three different approaches will be examined in the project:

- allowing the sum of axle mass limits at General Mass Limits;
- allowing the sum of axle mass limits at Higher Mass Limits at present limits; and
- allowing the sum of axle mass limits at Higher Mass Limits with an increased twin-steer limit if fitted with a road friendly suspension.

These approaches will be compared with the base case of the present regulations, which restrict twin-steer prime mover and semi-trailer combinations to 42.5 tonnes.

Comments are invited on this Discussion Paper. Comments are particularly sought on the main issues examined in this Paper, as listed below:

Industry Issues

Productivity

If twin-steer vehicles were permitted to operate at the sum of the axle group mass limits (either for GML or HML) significant productivity gains, of about 13% for most single articulated vehicles but up to 20% for existing twin-steer prime mover and semi-trailer combinations, are possible.

Availability of road friendly Twin-Steer groups

The range of air suspended twin-steer axle groups in Australia is extremely limited at this time. However, initial indications suggest that existing multi-leaf steel spring suspension used on steer axles might meet road friendly performance requirements.

Industry comment on this issue is particularly important.

Cost

There will be three cost penalties for the productivity gain of using a twin-steer prime mover – increased capital cost (of the order of $25,000), increased registration cost (about $1,100) and increased operating cost (about 2% to 4%). However, operators would make a commercial decision on the use of twin-steer vehicles if greater mass were permitted.

Gaining maximum load on the twin-steer axle group

With a load of uniform density on a semi-trailer, it could be difficult to achieve full axle weights on a twin-steer. King pin leads would need to be of the order of 600 mm to 900 mm to achieve close to full axle masses. It is possible that moves would be made to place freight on the prime mover, which may have a number of implications.

Interchangeability

The longer king pin leads, heavier loads on king pins and attention to swing clearances will require specifically designed semi-trailers to gain full productivity advantages, with consequent implications for interchangeability of semi-trailers and prime movers.

Suitability for long haul transport

No concerns to date have been raised by manufacturers or operators as to the suitability of modern twin-steer prime movers for longer haul transport tasks.

Regulatory Issues

Vehicle manoeuvrability and general access potential

Improvements in the maximum wheel “cut”, or steering angle, over the last 10 or 20 years has reduced the swept path for twin-steer vehicles. Industry stakeholders to date have not viewed the slightly greater swept path an operational difficulty.

Accreditation

Any requirement for accreditation for twin-steer vehicles should reflect the current arrangements of other vehicles.

OH&S issues associated with using truck mounted cranes

In general, any manual loading and unloading of vehicles would be aided by a truck mounted crane. Cranes could also be used to attach safety harnesses for driver loading and unloading. However, in practice the additional take-up is likely to be small because of the associated tare mass disadvantages as well as the capital cost.

Legislative issues

Two legislative changes will need to be made if the sum of axle mass limits for twin-steer prime movers is to be adopted, but the changes could be implemented without difficulty. The changes that would be necessary would allow single articulated combinations to exceed 42.5 tonnes and provide for an axle spacing mass schedule to extend beyond 42.5 tonnes.

However, VSB 11 does not provide a means to certify as road friendly axles fitted with single tyres. Appendix 1 to VSB 11 requires that all axles be fitted with dual tyres, apart from a six tyred tandem. Changes would need to be made to VSB 11 if a road friendly twin-steer is to be certified.

Issues for the Regulatory Impact Statement

Of critical importance in determining the costs and benefits of the various proposals will be estimates of the numbers of vehicles that would operate under any new arrangement i.e. the take up estimates.

Comments are invited on the likely take-up estimates given in Table 2 on page 7.

An issue for the RIS is the treatment of options. Alternatives that will be investigated include the following options:

1. the Base Case – status quo or current regulations;
2. allowing the sum of axle mass limits at GML;
3. allowing the sum of axle mass limits at HML at present HML limits; and
4. allowing the sum of axle mass limits at HML with an increased twin-steer limit if fitted with a road friendly suspension.

These options are not mutually exclusive, as Option 2 could be coupled with either Option 3 or 4. It appears that the best approach would be to analyse each of Options 2, 3 and 4 against the base case (Option 1), as this approach allows summing of results for either Option 3 or Option 4 with Option 2.

Potential twin-steer group mass limit for groups fitted with road friendly suspensions

Section 3 outlined the basis for determining a potential mass limit for twin-steer axle groups fitted with road friendly suspension systems. The upper limit for the allowable mass on a load sharing twin-steer axle group is restricted by the maximum of 6 tonnes on a single axle with single tyres and the road wear reduction factor for a road friendly twin-steer.

It appears that the mass limit for a road friendly twin-steer axle group that should be investigated by this project is 11.5 tonnes.

PBS Assessments

Standards

Section 4 outlined some issues with the assessment of vehicles against the PBS infrastructure and safety standards.

In the case of the Pavement Vertical Loading standard, it is intended to follow the Supplementary Rules detailed in the PBS Phase A Regulatory Impact Statement. In the case of the Bridge Loading Standard, no Supplementary Rules exist and some issues arise as to how the assessment will be undertaken.

The assessment of the safety standards will be made against twelve of the standards, excluding ride quality, handling quality, directional stability under braking and overtaking time. The first two standards are not completely developed, directional stability under braking would be met using deemed-to-comply provisions and, in the case of overtaking time, the standard is route specific.

Mass and Configurations

It is proposed that the masses of the vehicles to be assessed will be:

	mass limits				
	twin-steer	**drive**	**trailer 1**	**trailer 2**	**gross mass**
Single articulated vehicles					
Sum of axle weights	11.0 t	16.5 t	20.0 t		47.5 t
Sum of present Higher Mass Limits	11.0 t	17.0 t	22.5 t		50.5 t
Sum of Higher Mass Limits with increased twin-steer axle mass	11.5 t	17.0 t	22.5 t		51.0 t
B-doubles					
Sum of axle weights	11.0 t	16.5 t	20.0 t	20.0 t	67.5 t
Sum of present Higher Mass Limits	11.0 t	17.0 t	22.5 t	22.5 t	73.0 t
Sum of Higher Mass Limits with increased twin-steer axle mass	11.5 t	17.0 t	22.5 t	22.5 t	73.5 t

Pending consultations, it is intended to use five of the following six configurations as 7 axle articulated vehicles in the PBS assessment. At this stage, it appears that the jinker body type will be left out, but comment is invited on this issue.

Body type	**Commodity**
Flat top	Bricks
Van	General Freight
Tipper	Quarry products
Tanker	Petrol
Skel	Containers
Jinker	*Logs*

It is proposed that the one B-double will be a tanker body. It is also proposed that the general freight vehicle will be assessed with additional freight immediately behind the driver cabin.

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