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APPLYING PERFORMANCE STANDARDS TO THE AUSTRALIAN HEAVY VEHICLE FLEET

John Edgar	Director – Operations, National Road Transport Commission, PO Box 13105, LAW COURTS VIC 8010, AUSTRALIA
Hans Prem	Roads and Transport Dynamics, Suite 11, Bulleen Corporate Centre, 79 Manningham Road, BULLEEN VIC 3105, AUSTRALIA
Fiona Calvert	Manager – Strategy, National Road Transport Commission, PO Box 13105, LAW COURTS IC 8010, AUSTRALIA

ABSTRACT

In 1999 the National Road Transport Commission (NRTC) and Austroads initiated a major joint project to develop Performance Based Standards (PBS) for heavy vehicle regulation in Australia and New Zealand.

This paper discusses the principles that form the foundations of PBS and the process that will be followed in determining how vehicles can operate under the system. The benefits of moving to Performance Standards and the key issues in implementing a PBS approach are discussed.

A set of 25 proposed performance standards were developed against which the Australian heavy vehicle fleet was tested. Fifteen of these measures have been selected for further development and implementation.

This paper reviews a large body of work being undertaken over a three-year period. A number of reports published by the NRTC provide in-depth technical background on specific issues discussed here; policy principles, selecting and setting performance standards, and assessing computer simulation models. These papers maybe accessed through the NRTC Website (www.nrtc.gov.au), where more information on the wider project may also be obtained.

1. BACKGROUND

Heavy vehicles in Australia and New Zealand are regulated predominantly by prescriptive standards that evolved over a long period and often differed between States and Territories. Through the reforms progressed by the National Road Transport Commission (NRTC) many inconsistencies have been removed. Nevertheless, some remain particularly in relation to innovative approaches to solving transport needs. Modernising regulations by moving to a nationally consistent performance based approach to regulation of heavy vehicle operations is now being considered as a voluntary optional alternative to the existing prescriptive regulations.

Under a performance-based approach to regulation, standards would specify the performance required from vehicle operations rather than mandating how this level of performance is to be achieved. In Australia and New Zealand this approach to regulation has been adopted in other sectors, such as occupational health and safety and food standards, and is now well established as the approach preferred by regulatory review agencies.

The performance based standards (PBS) project seeks to align regulatory requirements more closely with the realities of how vehicles perform, how they are driven and operated, and the characteristics of the road network. It aims to improve productivity, increase safety, and to better protect the infrastructure.

Traditionally, heavy vehicles have been regulated by tightly defined prescriptive limits, such as mass and size limits, which provide little scope for innovation. This method of control is very crude, with no guarantees that vehicles meeting the current requirements do not have relatively poor performance. Many of the intrinsic safety issues such as stability, handling and controllability, high-speed tracking, and gradeability are not evaluated and are only indirectly controlled, if at all.

Under PBS, the interactions of vehicles with the roads they will be used on are taken into account more explicitly. In determining whether a specific vehicle can operate on a particular road, the vehicle's capabilities and the relevant road standards and traffic conditions can be examined jointly to decide whether the operation meets the performance standards.

A wide range of performance measures has been developed over many years of research for the evaluation of heavy vehicle performance. A key selection of these performance measures has been considered and found to be both practical and relevant for the evaluation of the Australian heavy vehicle fleet. Accident studies have found relationships between these measures and crash risk, providing a sound basis on which to set minimum performance levels for the key performance measures.

The following are the key objectives and benefits that can be attributed to a PBS approach to the regulation of heavy vehicles:

- increased productivity and innovation in vehicle design and operation
- improvements in road safety, traffic operations and asset management (infrastructure)
- a national basis for the regulation of heavy vehicles
- consistency in the application of assessment techniques that are performance based
- better matching of the capabilities of vehicles and the road system; and
- consistency in permitting local and specific-use vehicles.

In defining the project, the NRTC and Austroads established the following six inter-related phases:

Phase A:	***Performance Measures and Standards*** – identifying the appropriate performance measures and standards and surveying the performance of the current heavy vehicle fleet.
Phase B:	***Regulatory and Compliance Processes*** – establishing a regulatory system in which PBS can operate as a seamless national alternative to existing prescriptive regulations including national compliance and enforcement arrangements.
Phase C:	***Guidelines*** – preparing guidelines detailing the procedures and processes for the consistent application of PBS.
Phase D:	***Legislation*** – developing the legislative arrangements for PBS to operate as an alternative to prescriptive regulations.
Phase E:	***Case Studies*** – assembling work previously conducted and demonstrating the practical application of PBS to nationally agreed priorities.
Phase F:	***Implementation*** – putting in place the necessary legislative and administrative systems to allow PBS to operate nationally and providing the training and information to support these changes.

A number of reports have been prepared as part of Phase A of the project. These are listed in the bibliography. Together with the report Performance Characteristics of the Australian Heavy Vehicle Fleet (The Fleet Report), and the Regulatory Impact Statement, they will form the completion of Phase A of the PBS project. Phase A is the main focus of this paper.

The NRTC budget for completion of the PBS Project to the stage of final recommendations to ministers is expected to be approximately A$2 million. Additionally parts of the project are being undertaken and funded by state road agencies.

2. THE NEED FOR A PERFORMANCE-BASED APPROACH

The main reasons for investigating performance-based approaches to heavy vehicle regulation are that:

- road transport is a vital component of the Australian economy and consequently any improvements to regulation that PBS can provide are significant;
- there is continuing pressure to improve the safety and amenity of heavy vehicles;
- there is little room for further wholesale relaxation of prescriptive standards, as has occurred in the past.

The search for regulatory solutions that will support Australia's high and growing dependency on road freight is critical to improving Australians' standard of living and the nation's economic wellbeing. Large increases in the size of the road freight task are forecast (NRTC, 2001d), highlighting the importance of continued efforts to improve the overall safety, efficiency and fairness of the road transport system. It is unlikely that these trends can be maintained without the adoption of mechanisms that promote innovation and provide the flexibility for transport operators to improve productivity, where this has no detrimental impact on safety or road infrastructure. In the road transport sector this includes a more sophisticated approach to heavy vehicle regulation.

At the same time as providing for innovations in the road transport sector, governments much also meet the community's expectations for improved health, safety and quality of life (NRTC, 2001d).

The introduction of PBS is expected to:

- encourage innovation;
- provide a better match between vehicles and roads;
- increase regulatory transparency by providing a more consistent and more rational regulatory approach;
- improve performance (by providing better controls on safety and infrastructure wear); and
- improve compliance.

3. TERMS AND CONCEPTS

Performance standards specify the outcomes required of vehicle operations, but leave open the ways in which these outcomes are achieved. For example, *performance standards* might specify that a vehicle must be able to travel along the road and negotiate turns without tipping over or intruding on the road space of other road users. They might specify how well the vehicle should be able to stop and how much road wear it can cause. In comparison, *prescriptive standards* would specify the dimensions and mass of a vehicle to achieve these outcomes.

Each performance *standard* assigns a numerical limit to a *performance measure*, defining a boundary between what is acceptable and unacceptable. A performance measure quantifies how a vehicle performs for a specific circumstance or manoeuvre. The manoeuvre and the method of measuring the vehicle's performance must be specified in detail, in order for the *performance measure* to be objective.

For example, low-speed off-tracking is a performance measure for the tendency of the rear trailer or rear axle to track inside the path taken by the steering axle in low-speed turns. It is measured at a specific speed, angle of a turn and so on. Without this, comparisons between vehicles and tests would be meaningless.

4. PBS PRINCIPLES

Five principles form the basis of the policy framework for the PBS proposal. These principles, developed through a stakeholder consultation process, have been agreed by the Australian Transport Council (ATC). The ATC consists of the Australian Commonwealth, State and Territory Transport Ministers.

They are:

Principle One:

Performance-based standards will be a national system of regulating heavy vehicle safety and infrastructure impacts that operates as an alternative to existing prescriptive regulations.

- Some existing heavy vehicle regulations will continue to apply, but PBS will provide alternative controls in the main areas of mass, dimension and configuration controls.
- If an operator chooses to operate outside PBS, the relevant prescriptive standards must be satisfied.

Principle Two:

Performance standards should be matched to road and traffic conditions.

- Consequently, standards established for some performance measures will differ between a limited group of road classes, based on variations in road and traffic conditions that characterise each class of roads.
- Road authorities will determine which classification applies to the roads they manage.

Principle Three:

Compliance with performance based standards will be ensured by nationally consistent and practical methods that are based on certifying that vehicle-related features meet the performance standards and identifying simple operating conditions.

- Where warranted, vehicle operators will be required to be accredited to demonstrate that they comply with these conditions.

Principle Four:

All parties in the transport chain will be held responsible for factors in their control that ensure Performance Standards are achieved and maintained.

Principle Five:

An approval process will apply to each proposed PBS operations. Features of the approval process will be:

- Anyone should be able to apply for a vehicle, componenet or operation to be approved under the performance based standards.
- Lower cost ways of accessing the benefits of PBS must be available to smaller operators and those with fewer technical resources.
- The approval process and compliance arrangements should provide vehicle operators with the flexibility to choose at different times whether to operate under the existing prescriptive regulations or the performance based standards.
- Procedures should be incorporated to provide for mutual recognition of PBS approvals nationally.
- All performance assessors will need to be accredited to ensure their assessments are consistent and of sufficient quality.

The PBS system will apply to both general access and access to limited routes/regions. The approval process will involve:

- identifying which set of performance standards applies for the circumstances of the proposal, eg the roads to be accessed;
- assessing whether these standards are met by the proposal and identifying simple conditions to ensure they will be met on-road;
- certifying that the vehicle(s) to be used are consistent with the proposal assessed; and
- recording the approval and any operating conditions.

5. DEVELOPMENT OF PROPOSED PERFORMANCE MEASURES

As a first step in establishing an appropriate set of performance standards under a PBS approach to the regulation of heavy vehicles in Australia, the entire field of potential performance measures relevant for heavy vehicles were determined and documented (NRTC, 1999a; NRTC, 1999b). The next step in the process was to select an initial set of potential regulatory performance measures using the methodology described in (NRTC, 2000a). Several steps were used in the selection process, detailed in (NRTC, 2001a), to reduce the more than 100 potential performance measures to a set of 25 that cover safety and infrastructure related issues.

(NRTC, 2001c) provides definitions for the set of 25 potential regulatory performance measures that emerged from (NRTC, 2001a) reviewed by stakeholders (Appendix A). The report (NRTC, 2001c) also specifies an initial set of performance levels based on the review of the literature (available records) by the project team. The potential regulatory performance measures when combined with the associated performance levels lead to an initial set of potential regulatory performance standards (Appendix B). Appendix B also indicates for each measure whether physical testing or computer simulation methods are available for determining vehicle performance.

The potential regulatory performance standards that are considered to have been developed to a useable level were tested against the Australian heavy vehicle fleet using computer modelling. A set of 139 generic vehicle combinations which characterise the Australian Heavy vehicle fleet were developed for this purpose. This process and the results reported in (NRTC, 2002), the Fleet Report, are discussed below.

6. THE FLEET REPORT

6.1 Overview of the Fleet Report

The Fleet Report aimed to do two things:

- assess the performance of the existing fleet of heavy vehicles in comparison to the proposed measures; and
- review the performance standards in light of additional work, the results of the fleet assessment and stakeholder responses to previous work.

The proposed performance measures were reviewed in light of the fleet performance results from the simulations, the further findings generated by the study, and the feedback received from stakeholders. Further analysis through correlation was also undertaken The Fleet Report to reduce the total number of measures that would cover all the areas of interest to ensure safety performance was not compromised and infrastructure impacts would be acceptable.

After rigorous review, a total of twenty performance measures survived the process, which constitute the proposed final set, summarised in Table 1.

Of the twenty performance measures presented, fifteen have been developed to a stage where they are considered to be both useable and suitable for performing heavy vehicle assessments for regulatory purposes. In Table 1, the fifteen measures that are proposed to remain under consideration are presented in normal text. Those considered to be relevant but not yet developed to a stage where they can be fully implemented – requiring further research and development – are underlined and shown in italics.

Further details of the proposed set of performance standards, including details of the way in which they would be assessed and the standards to be required, are set out in Appendix C, reproduced from the Fleet Report.

In the review and evaluation process two new performance measures were proposed, Acceleration Capability and Maximum Effect Relative to Reference Vehicle (or MERRV). These are designed to replace, respectively, Intersection Clearance Time and Maximum Bridge Stress.

A number of relatively minor revisions were made to several of the performance standards, as detailed in the Fleet Report. However, a major revision was made to the performance level specification for Rearward Amplification. In its revised form it links the performance requirement to the rollover stability of the critical rear–most, roll–coupled unit — providing a very transparent and tangible safety outcome. This leads to a significantly higher proportion of the fleet meeting the rearward amplification standard, particularly for truck/trailers and road trains.

From the original set of performance measures the following two, Load Transfer Ratio and High–Speed Steady–State Offtracking, were determined to be redundant, and they were removed from further consideration. Load Transfer Ratio being highly correlated in the fleet with Static Rollover Stability, Rearward Amplification, and the interaction between the two, whereas High–Speed Steady State Offtracking and Tracking Ability were found to be highly correlated with each other, essentially providing the same information.

A comprehensive series of parametric studies was conducted on a set of mid–range vehicles, which were selected from the main set. Briefly, parameters found to be highly significant were: engine power/torque, driveline gear ratio, centre–of–gravity (CG) height, axle loads, wheelbase dimensions (trailers in particular), tyre cornering stiffness and speed. The less significant parameters included coupling rear overhang and suspension roll stiffness.

This analysis provides an indication of how vehicles can achieve additional productivity while meeting the necessary safety and infrastructure protection criteria. A table summarising these results is included as Appendix D, an extract from the Fleet Report.

For example, if an articulated vehicle needs to improve its steer tyre friction demand in order to take advantage of the productivity increases potentially available under PBS, it may be able to do so by increasing the prime mover wheelbase and decreasing drive axle group spacings. Alternatively, if an operator wishes to utilise increased axle loads, the vehicle may need to have spare 'capacity' in its current level of performance against some of the performance standards.

6.2 Further Issues to be Considered

Several performance measures were identified as requiring further development. The further issues are summarised below.

i. *Overtaking Time*: Overtaking effects needed to be considered because this is clearly a safety issue on two–lane two–way rural roads. However, additional work will be required to develop this important safety–related performance measure to a useable form. It is considered this issue could be addressed in the context of the road environment rather than as a vehicle performance issue *per se*, through the judicious use of overtaking lanes, for example. Some background material presented in The Fleet Report, builds on this notion.

ii. *Ride Quality (Driver Comfort)*: There is currently insufficient information to determine an acceptable performance level for this performance measure. Discussions with industry identified that this performance measure was important and should be retained, even if there is insufficient data at this stage to justify the setting of performance levels. Further research is required before an acceptable performance level can be determined for this measure.

iii. *Rearward Amplification*: There appear to be two interpretations by industry of the requirement of the SAE J2179 lane change test; one that correctly requires the lateral acceleration test value of ±0.15g to be achieved at the centre of the steer axle, and the other – the more common but incorrect - requiring lateral accelerations of ±0.15g to be achieved at the hauling unit CG. The second is based on the original definition of rearward amplification but it is not consistent with SAE J2179 and should not be used. The consequences of these different interpretations, while not immediately obvious, have very subtle (and potentially serious) implications, as discussed in the report. The correct version of SAE J2179 should be promoted and used.

iv. *Handling Quality (Oversteer/Understeer)*: Few fleet vehicles were found to comply with the proposed performance requirements for heavy vehicle handling. However, an estimated 20% of the fleet vehicles considered were found to possess handling qualities that are similar to those of the vehicle identified as having the worst handling in the recent study into heavy vehicle handling funded by the Federal Office of Road Safety (FORS). As the implications of this finding are potentially serious, it warrants urgent further investigation.

v. *Braking Stability in a Turn*: The standard in its present form appears to be technically feasible, and the fleet results suggest performance compliance would be high. However, before this standard can be recommended, field–testing of a range of vehicles is suggested, both to confirm the findings of the fleet analysis and to determine if there are any practical issues that may prevent the use of ABS on a much wider range of Australian fleet vehicles and operating conditions.

vi. *Gross Mass per Standard Axle Repetition*: The standard in its present form, with a performance level of 8.4t/SAR applicable to vehicles operating on granular pavements with thin surfacing, appears to be acceptable and would cover the majority of combination vehicles operating on the major part of the network. However, further research will be required for other pavement types and operating environments, including development of a suitable measure for rigid pavements.

vii. *Horizontal Tyre Forces*: During stakeholder consultation there was general agreement on the need for this, as controls on horizontal forces were seen as particularly important to develop. Further research was recommended aimed at measuring horizontal forces and stresses in pavements to confirm the predictions from the simulations.

viii. *Tyre Contact Pressure Distribution*: This standard will not proceed at this stage because further research is required before an adequate performance level can be established. In the consultation process there was general agreement of the need for this standard and support for further research aimed at developing a performance standard is therefore recommended.

6.3 Fleet Performance

Each fleet vehicle was evaluated against each of the proposed standards using the following three broad levels of route access/road environment.

- unrestricted access to the entire network (urban and arterial);
- access to major freight routes; and
- access to remote area routes.

If the vehicle met all the performance requirements for the full set of the proposed standards then its overall performance, in the context of The Fleet Report, was considered to be acceptable.

It is important to note that the analysis presented refers to a sample of representative vehicles that were taken from the Australian heavy vehicle fleet. The overall proportion of vehicles using the roads that meet the standards will depend on the numbers of each representative vehicle actually operating on the road. This aspect of the project will be analysed and considered in much greater detail in the Regulatory Impact Statement (RIS), which will also quantify in general terms the potential benefits and costs of the proposed set of performance standards.

6.4 Unrestricted Access

Around 20% of the fleet considered met the performance standards applicable to unrestricted access. Within this group, 18% of rigid trucks (18%), 47% of prime mover and semi–trailers, 22% of truck and pig/tag–trailers and 21% of truck and dog–trailers met all the performance standards. Details of the proportion of each vehicle category that met each of the performance standards for unrestricted access are shown in Appendix E, an extract from the Fleet Report.

The performance requirements that were set for gradeability (maximum grade), low–speed offtracking and acceleration capability associated with unrestricted access to all roads in Australia, could not be met by almost all the B–doubles, the B–triple, the A–double, and the A–triple and AAB–quad road trains. This was not an unexpected result, given that all these vehicles operate under access restrictions at present.

Most of the rigid trucks, buses/coaches, and various configurations of truck/trailer failed to comply with the GM/SAR performance requirement. This standard is based on a performance level of 8.4t/SAR, applicable to vehicles operating on granular pavements with thin surfacing, and appears to be acceptable, covering the majority of combination vehicles operating on the major part of the network. Consequently, these vehicles may not be able to vary from existing prescriptive mass limits, although they may be able to vary dimensions if they meet the safety-related performance standards.

Analysis of weigh-in-motion data indicates that the majority of smaller vehicles—two and three axle rigid trucks and buses —often operates empty or well below their rated legal loads. The proposed standard in its current form would therefore have little practical impact on these fleet vehicles. The exception to this would be smaller vehicles operating in high–density bulk haul applications, where vehicles may be loaded to their rated gross capacity. The low proportion of truck and pig/tag trailers meeting this standard also appears to be due to the low GM/SAR values. However, for the truck and dog–trailer combinations the low overall compliance appears to be the outcome of an unfortunate mix of only moderate performances for several measures; gradeability, static and dynamic stability as well as the infrastructure measures.

6.5 Major Freight Routes

Overall 27% of the fleet met performance standards for access to major freight routes. Details of the proportion of each vehicle category that met each of the performance standards for major freight routes are shown in Appendix F. Slightly more prime mover and semi–trailers met these requirements compared to those applying to unrestricted access, up from 47% to 53%.

For the B–doubles, 30% were found to meet the standards due to the slightly relaxed requirements on gradeability, acceleration capability and low–speed offtracking. However, gradeability (maximum grade) was the main reason for the somewhat low overall proportion of B–doubles meeting the standards. Reducing the gradeability requirement from 20% to 16% would significantly improve the overall proportion of B–doubles meeting the standards, raising it from 30% to 70%.

It would also increase the proportion of A–doubles meeting these standards to 83%, and elevate the overall proportion of the fleet meeting the standards from 27% to 41%. However, The Fleet Report states that the 20% gradeability performance requirement for major freight route access is based on current practice and that it should be retained.

6.6 Road Train Routes

On road train routes the performance measures controlling vehicle access were found to be the static and dynamic stability measures and the infrastructure/pavements measures. Overall 42% of current vehicles were able to meet these standards. This increase is due mainly to more of the fleet vehicles being able to meet the low-speed longitudinal and directional performance standards. Details of the proportion of each vehicle category that met each of the performance standards for road train routes are shown in Appendix G.

For the A-triple and AAB-quad road trains, the three measures having the greatest influence on the proportion of the vehicles meeting the standards are rearward amplification, high-speed transient offtracking and horizontal tyre forces.

6.7 Route-Specific Access

The Fleet Report suggests there is little scope at present for relaxing the performance levels for these three key measures—namely, rearward amplification, high–speed transient offtracking and horizontal tyre forces—and improvements in performance to achieve the desired safety outcomes would need to come from design–specific changes. Alternatively, route–specific performance levels for the key measures could be determined based on the prevailing local conditions and applied by the Road Agency.

It is important to also note that route specific requirements may be different to the generic set of conditions assumed in the analysis of the generic fleet vehicles. For specific, or tightly managed, applications the precise conditions on the route/environment will be well defined in most cases.

Also, for operations on some routes it may not be necessary to apply all the standards, and a selection of applicable measures may be able to be made by the Road Agency, together with a set of route and operation specific performance levels. These can be adjusted to suit the specific application.

6.8 Conclusions from the Fleet Report

The attached tables from the report provide the basis for the conclusions discussed above. From the information, it can be concluded:

- Large numbers of existing vehicles already meet the performance standards proposed for unrestricted access to the entire road network.

- A greater number of existing vehicles meet the requirements proposed for operation on either major freight routes or remote area routes.
- The study of parametric effects indicates a range of design features that, with adjustment, will enable new or modified vehicles to meet the standards.

Analysis of the costs and benefits of retaining each proposed performance measure has not been completed at the time of writing. It is expected the implementation costs of some measures will exceed the benefits in terms of productivity and safety; these performance measures will not be used.

The NRTC expects a number of existing vehicles to be able to operate in the PBS regime without modification, and many more should meet the performance standards with some design changes. The operator of these vehicles could have access to productivity gains at minimum cost.

7. COMPARISON OF MODELLING SYSTEMS

The initial potential performance standards were tested against the Australian heavy vehicle fleet as mentioned in chapter 6. The performance of the heavy vehicle fleet will be primarily determined using computer-based modelling techniques.

Some stakeholders have expressed the concern that performance predictions from computer-based modelling packages may not be reliable and may substantially differ with software packages and with the computer simulation practitioners that use them. Given that PBS is intended to encourage and foster innovation in road transport, and that computer-based modelling is expected to play a central role in both the development and initial demonstration of innovative vehicles, the concerns that were expressed by stakeholders needed to be addressed promptly and as a priority.

A report "Comparison of Modelling Systems for Performance-Based Assessments of Heavy Vehicles" addresses these concerns and, additionally, resolves calibration issues associated with computer-based modelling in a way that is transparent and open to scrutiny. This is an essential step in building stakeholder confidence in the use of computer-based modelling and in its application to the regulation of heavy vehicles in Australia using performance based standards. The report is on the NRTC Website.

Computer-based models of two vehicles were created in the course of this project by two Consultants using three separate computer-based modelling packages; ADAMS, UMTRI's constant velocity Yaw/Roll program and AUTOSIM. Comprehensive input datasets were developed for a non-descript B-double and a non-descript truck/trailer. The same datasets were supplied to each Consultant and identical simulations were performed using the same test manoeuvres comprising a pulse steer, step steer, standards SAE lane change and a low-speed 90 degree turn.

Time histories of a wide range of variables from the simulations were compared as well as numeric values from a selection of performance measures. For the more stable of the two vehicles models, the B-double, the time histories from the pulse steer and step steer simulations were almost indistinguishable showing excellent agreement between all three modelling packages. Agreement in the outputs from the simulations in all manoeuvres was generally better than 10% for the performance measures considered. These were marginally influenced by the characteristics of the steer controller in the lane change manoeuvre though agreement was still generally better than 10%.

The truck/trailer model, representing a less stable and dynamically more active vehicle compared to the B-double, produced larger but acceptable amounts of variation between simulations in the pulse and step steer simulations and low-speed 90^0 turn. However, in the SAE lane change the differences between the models were much too large as a result of the greater deviations in the path followed. To achieve acceptable agreement in the lane change manoeuvre between models a deviation from the desired path not greater than $\pm$30mm is required and is recommended. This is significantly less than the current recommended tolerance of $\pm$150mm specified by the Society of Automotive Engineers (SAE).

Simulations that provide a direct measure of only the vehicle responses to precisely defined steer inputs generally lead to more consistent results than simulations that require steer controllers and closed loop path following. When there is a choice, open loop manoeuvres should be selected in preference to closed loop manoeuvres that require the use of steer controllers.

8. REGULATORY AND COMPLIANCE PROCESSES

Phase B forms the second major part of the PBS Project, addressing regulatory and compliance issues. The objective of Phase B – Regulatory and Compliance Processes is to establish a regulatory system in which performance based standards can operate as a seamless national alternative to existing prescriptive regulations, utilising common national compliance and enforcement arrangements. While PBS is to be an optional alternative to the current regulations, it will rely on many of the same mechanisms and processes used to administer the existing prescriptive rules. The regulatory and compliance systems needed to implement the nationally agreed performance standards are being designed with this in mind.

To date five Phase B reports have been published dealing with a selection of specific aspects of the issues in establishing PBS as an optional, nationally consistent alternative to the current prescriptive regulations on mass, dimension and configuration.

9. COMPARISON OF BENEFITS AND COSTS

At the time of writing a Regulatory Impact Statement (RIS) is being prepared to assess the costs and benefits of the proposed set of performance standards. The purpose of the RIS is to analyse the policy impacts of the range of technical proposals discussed in this paper. This comprehensive analysis addresses fleet, operational and infrastructure issues such as:

- Composition of the fleet
- Potential PBS vehicles
- Take up rate
- Vehicle replacement savings
- Productivity improvements
- Costs of the PBS standards
- Assessment costs
- Additional vehicle construction costs
- Savings in pavement costs
- Additional vehicle operating costs

Preliminary indications from work on the RIS suggest net present values between about A$100 million and A$300 million depending on cost scenarios.

This RIS will be completed by April 2002. A further RIS will then be undertaken on options for assessment, compliance and enforcement processes.

10. SUMMARY AND CONCLUSIONS

This paper has outlined the structure and technical development of a major project to implement performance standards in Australia on a national basis. At the time of writing the development of the technical proposals has been largely completed. Assessment of the Australian heavy vehicle fleet against each of the proposed performance standards indicates that safety and productivity gains can achieved with resulting net economic benefits. Therefore, the NTRC is progressing to put in place a comprehensive performance-based alternative to the heavy vehicle mass and dimension regulatory system currently used in Australia. The project is now moving from technical development to implementation.

Implementation of agreed performance standards will primarily use computer-based modelling techniques. Work undertaken to compare computer models and the means of using them indicates that the specifications for the use of models require special attention in order to ensure consistent results. International standardisation on some aspect of heavy vehicle computer simulation modelling would be an advantage to all agencies and practitioners who use these methods

Some areas of heavy vehicle performance, for which would be desirable to have performance standards as part of a comprehensive performance-based regulatory system, have not yet been sufficiently developed for use in a regulatory environment. Some other potential performance measures would require broader industry support than is currently the case. These areas suggest opportunities for research to develop new or enhance performance measure and to achieve a more international agreement.

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TABLES & FIGURES

Table 1 – Summary of Proposed Final Set of Performance Measures

#	Performance Measures
	SAFETY RELATED
	Longitudinal Performance (Low Speed)
1	Startability
2	Gradeability
3	Acceleration Capability
	Longitudinal Performance (High Speed)
4	*Overtaking Time*
5	Tracking Ability on a Straight Path
6	*Ride Quality (Driver Comfort)*
	Directional Performance (Low Speed)
7	Low–Speed Offtracking
8	Frontal Swing
9	Tail Swing
10	Steer Tyre Friction Demand
	Directional Performance (High Speed)
11	Static Rollover Threshold
12	Rearward Amplification
13	High–Speed Transient Offtracking
14	Yaw Damping Coefficient
15	*Handling Quality (Understeer/Oversteer)*
16	*Braking Stability in a Turn*
	INFRASTRUCTURE RELATED
	Pavements
17	Gross Mass per Standard Axle Repetition
18	Horizontal Tyre Forces
19	*Tyre Contact Pressure Distribution*
	Bridges
20	Maximum Effect Relative to Reference Vehicles

APPENDICES

APPENDIX A – INITIAL SET OF PERFORMANCE MEASURES

#	POTENTIAL PERFORMANCE MEASURE	DEFINITION
1	Static roll stability	The steady-state level of lateral acceleration that a vehicle can sustain during turning without rolling over.
2	Rearward amplification	Degree to which the trailing unit(s) amplify or exaggerate lateral motions of the hauling unit.
3	Load transfer ratio	The proportion of vertical load imposed on the tyres on one side of a vehicle unit that is transferred to the other side of the vehicle unit during a standard lane change manoeuvre.
4	High-speed transient offtracking	The lateral distance that the last-axle on the rear trailer tracks outside the path of the steer axle in a sudden evasive manoeuvre.
5	High-speed steady-state offtracking	The lateral distance that the last-axle on the rear trailer tracks outside the path of the steer axle in a high-speed steady turn.
6	Yaw damping	The rate at which "sway" or yaw oscillations of the rearmost trailer decay after a short duration steer input at the hauling unit.
7	Tracking ability on a straight path	Amount of variation in the lateral position of the trailing unit (last trailer) measured relative to the path or track followed by the hauling unit (rigid truck or prime mover).
8	Braking stability (in a straight line)	The vehicle's ability to stay within a traffic lane under heavy braking on a straight path.
9	Braking stability (in a turn)	Amount of loss of control when braking in a turn.
10	Handling quality (understeer/oversteer)	No change
11	Low-speed offtracking	Maximum distance that the rear axle of a vehicle or combination tracks inside the path taken by the steering axle in a low speed turn.
12	Frontal swing	The maximum lateral displacement between the path of the front outside corner of the vehicle (or vehicle unit) and the outer edge of the front-outside steered wheel of the hauling unit during a small-radius turn manoeuvre at low speed.
13	Tail swing	The maximum lateral distance that the outer rearmost point on a vehicle moves outwards, perpendicular to its initial orientation, when the vehicle commences a small-radius turn at low speed.
14	Friction demand (steer tyres in corner)	The maximum friction level demanded of the steer tyres of the hauling unit in a tight-radius turn at low speed.
15	Ride quality	The level of vibration that a vehicle's driver is exposed to during a working shift that leads to reduced comfort and decreased proficiency, and contributes to fatigue.
16	Startability	The maximum uphill gradient, expressed as a percentage, on which the vehicle is capable of starting forward movement from rest.
17	Gradeability	The maximum uphill gradient, expressed as a percentage, on which the vehicle can climb at a specified constant speed.
18	Intersection clearance time	The time taken for the rear of the vehicle to clear a given intersection (either straight through or turning) with the vehicle starting from rest with its front immediately behind the intersection stop line.
19	Overtaking time	The time taken for another vehicle to safely overtake the vehicle.
20	Payload mass per ESA	*This measure replaced by:* Gross Mass per Standard Axle Repetition The Gross Mass (GM) of a heavy vehicle divided by the Standard Axle Repetitions (SARs) applied to the pavement by a single pass of the vehicle.

#	POTENTIAL PERFORMANCE MEASURE	DEFINITION
21	Horizontal tyre forces	Degree to which horizontal forces are applied to the pavement, primarily in a low-speed turn and at constant speed on uphill grades, by the tyres of multi-axle groups (drive-axle group tyres in particular) and the effect on remaining pavement life.
22	Tyre contact pressure distribution	The maximum local vertical stress under a tyre's contact patch for a given vertical tyre load and tyre inflation pressure.
23	Upper bound on axle/axle-group load	*These two performance measures have been replaced by the performance measure Gross Mass per Standard Axle Repetition (refer above under #20).*
24	Upper bound on GVM/GCM	
25a	Bridge Loads (Axle spacing mass schedule)	*These two measures have been combined into the following single performance measure:*
25b	Critical design vehicle (bridges)	Maximum Bridge Stress The maximum stress that a bridge can sustain under repeated loading without incurring damage.

APPENDIX B – INITIAL SET OF PERFORMANCE STANDARDS

PERFORMANCE MEASURE	TEST SPECIFICATION	PERFORMANCE LEVEL	TEST METHOD Physical Testing	Calculation or Computer-Based Modelling
SAFETY RELATED				
Longitudinal Performance (Low Speed)				
Startability	Ability to commence forward motion on specified grade.	• Not less than 15% for unrestricted access to the entire network; • Not less than 10% for arterials and major freight routes; and • No less than 5% for remote areas.	✔	✔
Gradeability	Ability to maintain forward motion on specified grade.	1) Low-Speed Environment (maximum grade that the vehicle can climb at any speed) Unrestricted access to the entire network: 25% Urban roads of higher standard: 20% Urban roads in remote areas: 8% 2) High-Speed Environment (minimum speed on a 1% gradient) Unrestricted access to the entire network: 80km/h Remote areas: 50km/h	✔	✔
Intersection Clearance Time	Time required travelling a distance of 50m starting from rest to clear an intersection on a road with no grade. If location specific then suitable test conditions required.	No more than 12s for unrestricted access to the road network; No more than 15s for arterials and major freight routes; No more than 25s for routes designated for long combination vehicles. (May be location specific and require a separate performance level).	✔	✔
Longitudinal Performance (High Speed)				
Overtaking Time	Test specifications specific to road and traffic conditions.	Specific to delay caused to other road users, which in turn is dependent on route characteristics and traffic volumes. Table 2 in the body of the report provides a guide for various road classes.	✔	✔
Tracking Ability on a Straight Path	Traverse 1000m road segment at two test speeds (60 and 90km/h), road roughness in each wheelpath 4.0m/km IRI (±0.4m/km) and average cross-slope 4% (±0.4%). Vehicle laden.	Specified in terms of required lane width. If route specific requirement do not exist then the following is proposed: In the range 3.1 to 3.5m for urban arterials; no greater than 3.5m on rural and regional roads; in the range 3.5 to 3.7m on national highways and freeways; no greater than 3.7m in remote areas.	✔	✔

PERFORMANCE MEASURE	TEST SPECIFICATION	PERFORMANCE LEVEL	TEST METHOD Physical Testing	Calculation or Computer-Based Modelling
Ride Quality	Traverse 1000m road segment at two test speeds (100 and 60km/h), road roughness in each wheelpath 4.0m/km IRI (±0.4m/km). Vehicle laden and unladen.	Performance level required. However, vehicles can be compared on a relative basis using the procedures outlined in British Standard BS 6841, or International Standard ISO 2631, to estimate the frequency weighted RMS vibration.	✔	✔
Braking Stability on a Straight Path	As required by and specified in ADR35/01.	The ability to stay within a 3.5m wide lane.	✔	✔
Directional Performance (Low Speed)				
Low-Speed Offtracking	Centre of steer axle to follow a path comprising a straight entry segment that is tangent to a 11.25m radius 90° circular arc followed by a straight exit segment. Vehicle speed is 10km/h.	Maximum width of the swept path: 5m for local roads, 7.4m for arterial roads, 10.1m for major freight routes, and 13.7m for road train areas.	✔	✔
Frontal Swing	Same as for low-speed offtracking	Not greater than 1.5m for unrestricted access to the entire road network.	✔	✔
Tail Swing	Same as for low-speed offtracking	Not greater than 0.5m.	✔	✔
Steer Tyre Friction Demand in a Low-Speed Turn	Same as for low-speed offtracking	No greater than 80% of the maximum available tyre/road friction. Table 4 in the body of the report provides friction values for a range of surfaces.	not yet demonstrated	✔
Directional Performance (High Speed)				
Static Rollover Threshold	Procedures defined in SAE J2180 (see Society of Automotive Engineers, 1993a). If by computer-based modelling then 100m radius circular path, centre of steer-axle follows path, test speed slowly increased from 60km/h until rollover occurs.	For road tankers and buses at least 0.40g, for all other heavy vehicles at least 0.35g.	✔	✔
Rearward Amplification	Procedures defined in SAE J2179. Lane change manoeuvre - test speed 88km/h, 1.46m lateral displacement, 61m manoeuvring length, 0.15g peak lateral acceleration (see Society of Automotive Engineers, 1993).	Not greater than 2.0	✔	✔
Load Transfer Ratio	Same as for rearward amplification.	Not greater than 0.6. Where maximum speed is less than 75km/h a load transfer ratio not greater than 0.75 may be considered acceptable on a provisional basis.	not yet demonstrated	✔

PERFORMANCE MEASURE	TEST SPECIFICATION	PERFORMANCE LEVEL	TEST METHOD Physical Testing	 Calculation or Computer-Based Modelling
Yaw Damping	Application of a 3.2° (half sine) steer angle pulse at the road wheel over a 0.1s period, test speed 100km/h.	Not less than 0.15	✔	✔
High-Speed Transient Offtracking	Same as for rearward amplification	Not greater than 0.8m	✔	✔
High-Speed Steady-State Offtracking	393m radius circular path, test speed 100km/h, centre of steer-axle follows path.	No greater than 0.3m for unrestricted access to the entire network; no greater than 0.5m for arterials and major freight routes; and no greater than 0.7m for low-volume roads in remote areas.	✔	✔
Handling Quality (Understeer/Oversteer)	As specified in El-Gindy, Woofrooffe and White (1991), or equivalent. Vehicle speed of 100km/h, the understeer coefficient, K_u, is evaluated over the range 0.15g to 0.3g.	Three-point measure. First point (evaluated at $a_y = 0.15$) $0.5 < K_u < 2.0$ deg/g; second point (transition from understeer to oversteer) $a_y > 0.2$g; third point (evaluated at $a_y = 0.3$) K_u > critical understeer coefficient.	✔	✔
Braking Stability in a Turn	As specified in US FMVSS 121. The vehicle is stopped from an initial speed of 48.3km/h or 75 percent of the maximum drive through speed, whichever is less, on a 152.4m radius curve with a wet surface having a peak friction coefficient of 0.5. Both laden and unladen conditions considered.	The vehicle, when stopped four consecutive times, must stop at least three times within a 3.66m wide lane.	✔	✔
INFRASTRUCTURE RELATED				
Pavements				
Gross Mass per Standard Axle Repetition	Laden vehicle, pavement type and configuration specific.	For granular pavements with thin surfacings 8.3t/SAR for all heavy vehicles.	-	✔
Horizontal Tyre Forces	Same as for low-speed offtracking, and separately on uphill grades of 2% and 5%	Pavement wear for PBS vehicle for a particular freight task no greater than for the same task being performed by current common vehicles.	not yet demonstrated	✔
Tyre Contact Pressure Distribution	Laden vehicle, travel speed up to 100km/h.	Further research required to establish a performance level.	✔	not yet demonstrated
Bridges				
Maximum Bridge Stress	Representative loads imposed on the bridge by the proposed vehicle.	A load factor of at least 1.8 for general heavy vehicles. For vehicles carrying indivisible loads a suitable load factor remains to be determined.	✔	✔

APPENDIX C – EXTRACT FROM FLEET REPORT – SUMMARY OF PROPOSED PERFORMANCE STANDARDS

#	PERFORMANCE MEASURE	TEST SPECIFICATION	PERFORMANCE LEVEL
1	Startability	Ability to commence forward motion on specified grade.	• Not less than 15% for unrestricted access to the entire network; • Not less than 10% for arterials and major freight routes; and • No less than 5% for remote areas.
2	Gradeability	Ability to maintain forward motion on specified grade.	1) Low–Speed Environment (max. grade that the vehicle can climb at any speed) Unrestricted access to the entire network: 25% Arterials: 20% Remote areas: 8% 2) High–Speed Environment (min. speed on a 1% gradient) Unrestricted access to the entire network: 70km/h Remote areas: 60km/h
3[b]	Acceleration Capability	Ability to accelerate either from rest or to increase speed (no grade).	Performance requirement for unrestricted access, access to arterials and major freight routes, and access to road train routes, as specified in the distance/time charts shown in Fig 4(a) of Section 5.3.1.3 of main body of the report.
4[a]	*Overtaking Time*	*To be addressed in the context of the road environment rather than as a vehicle performance issue – as detailed in Section 5.3.2.1 of main body of report.*	*Specific to delay caused to other road users, which in turn is dependent on route characteristics and traffic volumes. Further work required as detailed in Section 5.3.2.1 of main body of report.*
5	Tracking Ability on a Straight Path	Traverse a 1000m road–segment at a test speed of 100km/h (or the highest speed attainable), road roughness in each wheelpath of at least 4.0m/km IRI and an average cross–slope of at least 3.0%. Vehicle laden.	Specified in terms of required lane width. If route specific requirements do not exist then the following is proposed: In the range 3.1 to 3.5m for urban arterials; no greater than 3.5m on rural and regional roads; in the range 3.5 to 3.7m on national highways and freeways; no greater than 3.7m in remote areas.
6[a]	*Ride Quality (Driver Comfort)*	*Traverse 1000m road segment at two test speeds (100 and 60km/h), road roughness in each wheelpath at least 4.0m/km IRI and an average cross–slope of at least 3.0%. Vehicle laden and unladen.*	*Performance level required. However, vehicles can be compared on a relative basis using the procedures outlined in British Standard BS 6841, or International Standard ISO 2631, to estimate the frequency weighted RMS vibration.*
7	Low–Speed Offtracking	Centre of steer axle to follow path on straight approaches to a 11.25m radius 90° circular arc. Vehicle speed is 10km/h.	Maximum width of the swept path: 5m for local roads, 7.4m for arterial roads, 10.1m for major freight routes, and 13.7m for road train areas.
8	Frontal Swing	Same as for low–speed offtracking	Not greater than 1.5m for unrestricted access to the entire road network.

#	PERFORMANCE MEASURE	TEST SPECIFICATION	PERFORMANCE LEVEL
9	Tail Swing	Same as for low–speed offtracking	For unrestricted access to the entire road network not greater than 0.35m on both approaches to the turn.
10	Steer Tyre Friction Demand	Same as for low–speed offtracking	No greater than 80% of the maximum available tyre/road friction. Only applicable to hauling units that feature tri–axles on the drive group.
11	Static Rollover Threshold	Procedures defined in SAE J2180 (see Society of Automotive Engineers, 1993a). If by computer–based modelling then 100m radius circular path, centre of steer–axle follows path, test speed slowly increased from 60km/h until rollover occurs.	Dangerous goods vehicles and buses: at least 0.40g, All other heavy vehicles at least 0.35g.
12	Rearward Amplification	Prescribed–path lane–change manoeuvre as defined in SAE J2179 (Society of Automotive Engineers, 1993b), or in accord with ISO 14791.	Rearward amplification no greater than 5.7 times the static rollover threshold of the rearmost roll–coupled unit.
13	High–Speed Transient Offtracking	Same as for rearward amplification	Not greater than 0.8m
14	Yaw Damping	Application of a 3.2° (half sine) steer angle pulse at the road wheel over a 0.1s period. Test speed 100km/h or maximum attainable. Alternatively, in accord with ISO 14791.	Not less than 0.15 for unrestricted access. For road trains at lower test speeds not less than defined by Eqn (3) in Section 5.3.4.4 of this report.
15[a]	*<u>Handling Quality (Understeer/Oversteer)</u>*	*As specified in El-Gindy, Woodrooffe and White (1991), or equivalent. Vehicle speed of 100km/h, other speeds may need to be considered. The understeer coefficient, K_{us} is evaluated up to a lateral acceleration of 0.3g.*	*Further follow–up work is highly recommended as detailed in the main body of the report. Fleet vehicles identified as potentially having poor handling quality also should be assessed.*
16[a]	*<u>Braking Stability in a Turn</u>*	*As specified in FMVSS 121.*	*In accord with FMVSS 121. Appears to be technically feasible but further work required as detail in Section 5.3.4.8 of the main body of the report.*
17	Gross Mass per Standard Axle Repetition	Laden vehicle, pavement type and configuration specific.	For granular pavements with thin surfacings no less than 8.4t/SAR for all heavy vehicles. Further work is required to establish suitable performance levels for other pavement types and operating environments.
18	Horizontal Tyre Forces	Same as for low–speed offtracking, and separately (if applicable) on uphill grades of 2% and 5%	Pavement wear for PBS vehicle for a particular freight task no greater than 1.8 times damage caused by conventional vehicles performing the same task.
19[a]	*<u>Tyre Contact Pressure Distribution</u>*	*Laden vehicle, travel speed up to 100km/h.*	*Further work is required to establish a suitable performance level.*

#	PERFORMANCE MEASURE	TEST SPECIFICATION	PERFORMANCE LEVEL
20[b]	Maximum Effect Relative to Reference Vehicle	Range of representative bridges considered (generic or route specific).	Bending moments and shear forces to be no greater than the moments and forces induced in the bridge by Austroads BAG Reference Vehicles. On routes that are not satisfactory for BAG vehicles, the worse case legal vehicle operating on that route shall be used as the reference vehicle. For vehicles transporting indivisible freight, reference loads to be determined by the relevant Road Agency.

Notes:

a) These are considered essential but require further research and development.

b) "*Acceleration Capability*" and "*Maximum Effect Relative to Reference Vehicles*" are designed to replace, respectively, "*Intersection Clearance Time*" and "*Maximum Bridge Stress*".

APPENDIX D – EXTRACT FROM FLEET REPORT – BROAD SUMMARY OF PARAMETRIC EFFECTS

Performance Measure		Parameter: Increase Engine Power/Torque	Increase Driveline Gear Ratio	Increase CG Height	Increase Axle Loads	Longer Prime Mover Wheelbase	Longer Trailer Wheelbase	Longer Dolly Wheelbase	Increase Number of Articulation Points	Increase Axle Group Spread	Increase Coupling Rear Overhang	Increase Suspension Roll Stiffness	Increase Tyre Cornering Stiffness	Increase Front Overhang	Increase Rear Overhang	Decrease Speed
Startability			+		–											
Gradeability	a) Maximum Grade	+	+		–											
	b) Speed on 1% Grade	+	/–													
Acceleration Capability																
Tracking Ability on a Straight Path				–	–								+			+
Low–Speed Offtracking						–	–		+							
Frontal Swing						–								–		
Tail Swing															–	
Steer Tyre Friction Demand						+				–						
Static Rollover Threshold				–												
Rearward Amplification							+		–				+			+
High–Speed Transient Offtracking				–	–		+						+			+
Yaw Damping Coefficient				–			+						+			+
GM per SAR																
Horizontal Tyre Forces		–			–					–						
Max. Effect Relative to Ref. Vehicles					–	+	+									

Key to Descriptors:

++	Denotes a significant positive effect on performance
+	Denotes a moderate positive effect
blank	Little or no influence
–	Moderate negative effect
– –	Significant negative effect

APPENDIX E – EXTRACT FROM FLEET REPORT – FLEET VEHICLE COMPLIANCE FOR UNRESTRICTED ACCESS TO ENTIRE NETWORK (URBAN AND ARTERIAL) (%)

#	Vehicle Class	Startability (%)	Gradeability (Max. Grade) (%)	Gradeability (Max. Speed on 1%Grade) (km/h)	Acceleration Capability (s)	Tracking Ability (m)	Low-Speed Offtracking (m)	Frontal Swing (m)	Tail Swing (m)	Steer Tyre Friction Demand (%)	Static Rollover Threshold (g)	Rearward Amplification (–)	High-Speed Transient Offtracking (m)	Yaw Damping Coefficient (–)	Gross Mass per SAR (t/SAR)	Horizontal Tyres Forces (–)	Max. Effect Relative to Ref. Vehicle (%)	**OVERALL (%)**
		Performance Levels																
		15	**25**	**70**	**12**	**3.1**	**7.4**	**1.5**	**0.35**	**80**	**0.35**	**5.7**	**0.80**	**0.15**	**8.4**	**1.8**	**95**	**-**
17	rigid trucks	100	100	100	100	100	100	100	100	100	71	100	100	100	18	29	100	**18**
6	buses/coaches	100	100	100	100	100	100	100	100	100	100	100	100	100	-	83	100	**-**
43	prime–mover and semi–trailer	100	67	100	98	100	95	100	100	100	79	100	100	100	72	93	100	**47**
23	B–double	100	-	100	35	100	4	100	100	100	78	100	100	100	78	100	100	**-**
1	B–triple	100	-	100	-	100	-	100	100	100	100	100	100	100	100	100	100	**-**
9	truck and pig/tag–trailer	100	78	100	100	100	100	100	100	100	56	56	56	100	22	89	100	**22**
14	truck and dog trailer	100	79	100	93	100	100	100	100	100	86	50	71	93	71	79	93	**21**
12	A–double	100	-	100	-	100	8	100	100	100	92	92	83	100	100	100	92	**-**
12	A–triple road train	-	-	25	-	100	-	100	100	100	75	17	8	83	100	92	100	**-**
2	AAB–quad road train	-	-	-	-	100	-	100	100	100	100	50	-	100	100	50	-	**-**
139	**entire fleet**	**90**	**50**	**92**	**68**	**100**	**64**	**100**	**100**	**100**	**79**	**83**	**83**	**98**	**65**	**84**	**97**	**<u>20</u>**

APPENDIX F – EXTRACT FROM FLEET REPORT – FLEET VEHICLE COMPLIANCE FOR ACCESS TO MAJOR FREIGHT ROUTES (%)

#	Vehicle Class	Startability (%)	Gradeability (Max. Grade) (%)	Gradeability (Max. Speed on 1%Grade) (km/h)	Acceleration Capability (s)	Tracking Ability (m)	Low–Speed Offtracking (m)	Frontal Swing (m)	Tail Swing (m)	Steer Tyre Friction Demand (%)	Static Rollover Threshold (g)	Rearward Amplification (–)	High–Speed Transient Offtracking (m)	Yaw Damping Coefficient (–)	Gross Mass per SAR (t/SAR)	Horizontal Tyres Forces (–)	Max. Effect Relative to Ref. Vehicle (%)	**OVERALL (%)**
	Performance Levels	**10**	**20**	**70**	**15**	**3.5**	**10.1**	**1.5**	**0.35**	**80**	**0.35**	**5.7**	**0.80**	**0.15**	**8.4**	**1.8**	**80**	**-**
17	rigid trucks	100	100	100	100	100	100	100	100	100	71	100	100	100	18	29	100	**18**
6	buses/coaches	100	100	100	100	100	100	100	100	100	100	100	100	100	-	83	100	**-**
43	prime–mover and semi–trailer	100	86	100	100	100	100	100	100	100	79	100	100	100	72	93	100	**53**
23	B–double	100	39	100	100	100	100	100	100	100	78	100	100	100	78	100	100	**30**
1	B–triple	100	-	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**-**
9	truck and pig/tag–trailer	100	100	100	100	100	100	100	100	100	56	56	56	100	22	89	100	**22**
14	truck and dog trailer	100	93	100	100	100	100	100	100	100	86	50	71	93	71	79	93	**21**
12	A–double	100	-	100	100	100	100	100	100	100	92	92	83	100	100	100	92	**-**
12	A–triple road train	100	-	25	-	100	8	100	100	100	75	17	8	83	100	92	100	**-**
2	AAB–quad road train	50	-	-	-	100	-	100	100	100	100	50	-	100	100	50	100	**-**
139	**entire fleet**	**99**	**65**	**92**	**90**	**100**	**91**	**100**	**100**	**100**	**79**	**83**	**83**	**98**	**65**	**84**	**99**	**27**

APPENDIX G – EXTRACT FROM FLEET REPORT – FLEET VEHICLE COMPLIANCE FOR ACCESS TO ROAD TRAIN ROUTES (%)

#	Vehicle Class	Startability (%)	Gradeability (Max. Grade) (%)	Gradeability (Max. Speed on 1%Grade) (km/h)	Acceleration Capability (s)	Tracking Ability (m)	Low–Speed Offtracking (m)	Frontal Swing (m)	Tail Swing (m)	Steer Tyre Friction Demand (%)	Static Rollover Threshold (g)	Rearward Amplification (–)	High–Speed Transient Offtracking (m)	Yaw Damping Coefficient (–)	Gross Mass per SAR (t/SAR)	Horizontal Tyres Forces (–)	Max. Effect Relative to Ref. Vehicle (%)	**OVERALL (%)**
	Performance Levels	**5**	**8**	**60**	**25**	**3.7**	**13.7**	**1.5**	**0.35**	**80**	**0.35**	**5.7**	**0.80**	**0.15**	**8.4**	**1.8**	**75**	**-**
17	rigid trucks	100	100	100	100	100	100	100	100	100	71	100	100	100	18	29	100	**18**
6	buses/coaches	100	100	100	100	100	100	100	100	100	100	100	100	100	-	83	100	**-**
43	prime–mover and semi–trailer	100	100	100	100	100	100	100	100	100	79	100	100	100	72	93	100	**53**
23	B–double	100	100	100	100	100	100	100	100	100	78	100	100	100	78	100	100	**70**
1	B–triple	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**100**
9	truck and pig/tag–trailer	100	100	100	100	100	100	100	100	100	56	56	56	100	22	89	100	**22**
14	truck and dog trailer	100	100	100	100	100	100	100	100	100	86	50	71	93	71	79	93	**21**
12	A–double	100	100	100	100	100	100	100	100	100	92	92	83	100	100	100	92	**83**
12	A–triple road train	100	100	100	100	100	100	100	100	100	75	17	8	83	100	92	100	**-**
2	AAB–quad road train	100	100	100	100	100	100	100	100	100	100	50	-	100	100	50	100	**-**
139	**entire fleet**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**79**	**83**	**83**	**98**	**65**	**84**	**99**	**<u>42</u>**