Performance-Based Standards Scheme – the Standards and Vehicle Assessment Rules

November 2022

National Transport Commission

PBS Scheme – The Standards and Vehicle Assessment Rules

These Rules were made by the National Transport Commission on 30 July 2007, and were approved by the Australian Transport Council on 3 October 2007. This version of the Rules includes amendments that were consented to by the Australian Transport Council on 7 November 2008.

National Heavy Vehicle Regulator

Amendment Summary		
Version Number	Date	Nature of amendment
1.03	January 2020	Amendment to increase frontal swing limit per ministerial approval.
2.01	November 2022	Introduction of ministerial approved generic tyre approach.

ISBN: (To be allocated)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

PART 1 – INTRODUCTORY MATTERS

1. Purpose of these Rules

The purpose of these Rules is to specify –

(a) the Performance Based Standards that must be met for a vehicle to be eligible to participate in the Performance Based Standards Scheme; and

(b) the methods of assessment and the procedures for assessment that must be used by assessors to determine if those Standards are met in any particular case.

2. The Standards to be met

(1) To be eligible to participate in the Scheme, a vehicle must meet –

(a) all of the infrastructure standards set out in Appendix A; and

(b) all of the safety standards set out in Appendix C.

(2) In general, a vehicle meets those standards for the purposes of the Scheme if either –

(a) the design of the vehicle is assessed in accordance with these Rules as having a high probability of meeting all of those standards, and it is established that the vehicle was built according to that design; or

(b) the vehicle is assessed in accordance with these Rules as meeting all of those standards.

3. Exempt prescriptive provisions

(1) If a vehicle is eligible to participate in the Scheme, it may be exempted from any of the following provisions that are incompatible with its design –

(a) any of the following provisions of the Australian Vehicle Standards that are

incompatible with its design – the *Heavy Vehicle (Mass, Dimension and Loading) National Regulation* prescribed as vehicle standards under section 34 of Schedule 2 of the *Heavy Vehicle (Vehicle Standards) National Regulation* –

(i) section 3 of Schedule 6 (Length—general)

(ii) section 4 of Schedule 6 (Length—trailers)

(iii) section 5 of Schedule 6 (Length—rear overhang)

(iv) section 6 of Schedule 6 (Length—trailer drawbars)

(v) section 7 of Schedule 6 (Width)

(vi) section 8 of Schedule 6 (Height);

(vii) clause 66 (Width); and

(b) the *Heavy Vehicle (Vehicle Standards) National Regulation*—

(i) section 29(b) and (c) of Schedule 3 (Attachment of couplings and drawbar eyes on road trains)

(ii) section 31 of Schedule 3 (Tow coupling overhang on road trains).

(c) ADR 43 prescribed as vehicle standards under section 2 of Schedule 1 of the *Heavy Vehicle (Vehicle Standards) National Regulation* –

(i) clauses 6.1.1 and 6.2.1 (total length)

(ii) clause 6.2.2 (drawbar length)

(iii) clauses 6.1.2 and 6.2.3 (rear overhang)

(iv) clauses 6.1.3 and 6.2.4 (height)

(v) clauses 6.1.5 and 6.2.6 (overall width)

(vi) clause 9.4 (retractable axle), other than to the extent it requires a vehicle to comply with clause 6.1.4, 6.1.6, 6.2.5 or 6.2.7;

(c) clause 5.2 (Tow coupling overhang) of ADR 62 prescribed as a vehicle standard under section 2 of Schedule 1 of the *Heavy Vehicle (Vehicle Standards) National Regulation*

(d) clause 5.1 (Tow coupling location) of ADR 63 prescribed as a vehicle standard under section 2 of Schedule 1 of the *Heavy Vehicle (Vehicle Standards) National Regulation*;

A reference in subsection (1) to a clause of an ADR is a reference to—

(a) the version of the clause applying to the heavy vehicle as a vehicle standard; and

(b) if another clause was superseded by the clause (including with modification or because of a renumbering of the ADR) and a version of the superseded clause applies to the heavy vehicle as a vehicle standard—the version of the superseded clause applying to the heavy vehicle as a vehicle standard; and

(c) if the clause is omitted and remade (with or without modification) or renumbered and a version of the clause as remade or renumbered applies to the heavy vehicle as a vehicle standard—the version of the clause as remade or renumbered applying to the heavy vehicle as a vehicle standard.

PART 2 – RULES FOR ASSESSORS

Division 1 – General duty and overview

4. General duty

An assessor assessing a vehicle design or a vehicle for the purposes of the Scheme must comply with all of the requirements set out in these Rules.

5. Overview of the assessment process

(1) To conduct an assessment of a vehicle design or a vehicle for the purposes of the Scheme, the assessor must assess the design or vehicle against the requirements of the standards by means of numerical modelling or testing conducted in accordance with Division 2.

(2) If the assessor is of the opinion that the design or vehicle will, or does, meet the standard or standards in respect of which the modelling or testing was conducted to the extent required by these Rules, he or she must –

(a) identify and record the vehicle physical characteristics of the design or vehicle in accordance with Division 3; and

(b) conduct, if thought necessary, one or more risk sensitivity analyses of the design or vehicle in accordance with Division 4; and

(c) consider whether to recommend any national operating conditions in respect of the design or vehicle in accordance with Division 5; and

(d) determine from which of the prescriptive requirements listed in rule 3 the design or vehicle will need exemption; and

(e) issue any certificate required by Division 6.

6. Non-complying vehicle not to be certified

If the assessor determines that a vehicle design or vehicle will not, or does not, meet one or more of the standards to the extent required by these Rules, and is not likely to be eligible for approval under rule 33A or 33B of the *Performance Based Standards Scheme: Review Panel Business Rules*, he or she must not issue a certificate in relation to the vehicle.

Division 2 – Modelling and testing procedures

7. [Reserved]

8. Assessment procedures for safety standards

(1) To assess a vehicle design or a vehicle against a safety standard specified in Appendix C, the assessor must carry out modelling or testing in accordance with any requirements for Test Specification in Appendix C, unless another Appendix expressly provides for another specification, and –

(a) if the assessment is undertaken by numerical modelling, the procedures in Appendix E must also be followed;

(b) if the assessment is undertaken by testing, the procedures in Appendix F must also be followed.

(2) If a vehicle is to be field tested and the assessor is responsible for organising that testing, he or she must ensure that a site manager is on site before any testing starts, and that the site manager remains on site during the whole of the field testing programme. The assessor may also be the site manager.

8A. Assessment procedures for generic tyre data

(1) All vehicle designs or vehicles assessed against the safety standards on or after 1 March 2023 must be carried out in accordance with the Test Procedure specified in Appendix N.

(2) To assess a vehicle design or a vehicle against the safety standards, the assessor must carry out modelling in accordance with the Test Procedure specified in Appendix N, unless another Appendix expressly provides for another specification.

(3) All existing PBS Vehicle Approvals issued prior to 1 December 2022:

(a) are still valid and deemed to comply with Appendix N

(b) do not require reassessment

(c) all administrative changes to PBS Vehicle Approvals captured under 8A (3)(a) will be updated by the NHVR, at its discretion, when a Vehicle Approval holder seeks to amend a Vehicle Approval.

(4) All PBS Design Approvals issued prior to 1 March 2023:

(a) are still valid and deemed to comply with Appendix N

(b) do not require reassessment.

Division 3 – Vehicle physical characteristics

9. Required vehicle physical characteristics must be recorded

(1) As part of the assessment process, the assessor must complete the Vehicle Certification Information (Appendix G) for the vehicle design.

(2) The assessor must ensure that the Vehicle Certification Information sets out a complete description of the vehicle physical characteristics that a vehicle built to the design must have to enable the vehicle to meet the standards.

(3) The assessor may refer, in an entry in the Vehicle Certification Information for a design, to drawings or other information, provided the link is clearly identifiable, and the drawings or other information are attached to the Information.

10. Specific requirements concerning the recording of vehicle physical characteristics

(1) The assessor must comply with the requirements of this rule in completing the Vehicle Certification Information (Appendix G).

(2) For each trailer, semi-trailer or dolly proposed in a design, the assessor must identify the vehicle physical characteristics for each separate vehicle unit, and must also identify the position of the vehicle unit in the proposed combination.

(3) The assessor must specify all dimensions as a maximum, a minimum, or as a maximum and a minimum (i.e. a range).

(4) The assessor must specify the vehicle physical characteristics in a way that allows the characteristics to be checked using one or more of the following methods –

(a) physically checking the vehicle by straightforward measurements taken by a certifier;

(b) checking by a simple visual inspection of components by a certifier (for instance, this could involve confirming the make, model and serial number of specific components such as the chassis, engine or transmission, or of entire suspension assemblies or individual suspension components (shock absorbers, airbags, springs, and the like), tyres, and other features or components that are considered to be risk sensitive);

(c) checking by a certifier by sighting written documents from service providers (these could include other assessors not involved with the specific assessment), manufacturers or component suppliers/testers.

(5) If vehicle physical characteristics cannot be specified using one or more of the methods in subrule (4), the assessor must specify a reasonable way for a certifier to check the characteristic.

Division 4 –Sensitivity testing

11. Parameter sensitivity testing

(1) This Division applies if it appears to the assessor that, in respect of either a design feature or an operating factor, there is a significant risk that a vehicle built to the design being assessed by the assessor may not perform as designed as a result of off-baseline variations in the characteristics of a relevant critical component, sub-assembly or load.

(2) The assessor must undertake a parameter sensitivity analysis in relation to the design’s compliance with the standard or standards in respect of which the risk arises with a view to determining whether or not it may be necessary to take steps to control the risk (such as by the imposition of one or more operating conditions).

12. General requirements

(1) If a parameter sensitivity analysis is undertaken, the assessor must list risk sensitive parameters and the off-baseline variation used (%) in the same form as is shown in Appendix H or Appendix I, as the case may be.

(2) If there is more than one trailer, semi-trailer or dolly proposed in a design, the assessor must identify the relevant risk sensitive parameters for each separate vehicle unit, and must also take into account the position of each vehicle unit in the proposed combination.

13. Sensitivity testing of vehicle design features

(1) This rule applies if an assessment of risk sensitive parameters that relate to vehicle design features is undertaken.

(2) The risk sensitive parameters that should be considered in an initial sensitivity analysis for particular safety standards are set out in Appendix H. The parameters listed are not intended to be all-inclusive, and there may be other parameters that the assessor chooses to consider in response to any unique features of a design. By the same token, nothing in this Division requires the assessor to conduct a sensitivity analysis for a parameter in respect of a particular application if the assessor considers that the parameter is not significant (in a practical sense) to that application.

(3) The baseline figure the assessor must use in conducting a sensitivity analysis in respect of a standard, or an aspect of a standard, is –

(a) in the case of numerical modelling, the performance achieved in respect of that standard, or aspect, as recorded in Table 36; or

(b) in the case of physical testing, the result or reference in respect of that standard, or aspect, as recorded in Table 55.

(4) A sensitivity analysis must consider off-baseline variations in parameter values caused by –

(a) the following known variations –

(i) expected variations due to manufacturing tolerances;

(ii) expected variations in the performance characteristics of like components sourced from the same or different suppliers;

(iii) expected in-service variations due to normal wear and tear; and

(b) other known variations.

(5) If variations in parameter values are not known or cannot be reasonably estimated, they are to be taken to be ±20% of the baseline values.

(6) The assessor must recalculate the performance of the vehicle design with respect to the standard using the maximum value of the off-baseline variation range, and then must repeat the calculation using the minimum value of the off-baseline variation range.

(7) The assessor must identify a parameter as a risk sensitive parameter if he or she determines that an off-baseline variation produces a change in the value of the standard outcome of not less than 2.0%.

14. Sensitivity testing of vehicle operating factors

(1) This rule applies if an assessment of risk sensitive parameters that relate to vehicle operating factors is undertaken.

(2) The risk sensitive parameters that should be considered in an initial sensitivity analysis for particular safety standards are set out Appendix I. The parameters listed are not intended to be all-inclusive, and there may be other parameters that the assessor chooses to consider.

(3) The assessment must be carried out in a manner similar to that required for vehicle design features in rule 13.

(4) The sensitivity analysis must consider the likely largest in-service variations, and where variations are unknown, then the variation is to be taken to be ±20% of the baseline values.

15. How risk sensitive parameters are to be ranked

(1) Risk sensitive parameters must be ranked as specified in Table 1.

Table 1. Ranking of risk sensitive parameters

Ranking	Percentage change in numerical value of safety standard
1	20.0% or more
2	2.0% or more but less than 20.0%

(2) The initial rankings shown in Appendix H and in Appendix I are indicative only. Actual rankings can vary from one vehicle design to another and will depend on specific design features, operating conditions and the commodity transported.

Division 5 – Recommendations on conditions

16. Assessor must consider whether national operating conditions desirable

(1) After conducting any testing required by Division 4, the assessor must –

(a) complete items 1 – 3 of Appendix J; and

(b) in the light of that information and the results of the testing, consider whether to recommend that the vehicle, or a vehicle built to the design, assessed by him or her should be made subject to one or more operating conditions once it begins to operate; and

(c) if he or she considers that one or more operating conditions should be imposed, list that condition, or those conditions, in item 5 of Appendix J.

(2) In considering whether to recommend the imposition of operating conditions, the assessor must have regard to the *Performance Based Standards: Guidelines for Determining National Operating Conditions*, as approved by the Australian Transport Council from time to time.

Division 6 – Certificates of compliance

17. Certifying compliance with individual standards

(1) If an assessor has assessed a vehicle design in relation to a standard and is of the opinion that a vehicle built to that design will meet the standard, he or she must issue a certificate in the form of Appendix L to that effect.

[*Subrule (2) was deleted as a consequence of an amendment consented to by the ATC on 7 November 2008*.]

(3) If an assessor has assessed a vehicle in relation to a standard and is of the opinion that it meets the standard, he or she must issue a certificate in the form of Appendix L to that effect.

(4) Despite subrules (1) and (3), an assessor need not issue a certificate in the circumstances described in those sub-rules if the person who commissioned the assessment asks him or her not to issue the certificate.

(4) In issuing a certificate under subrule (1) or (3), the assessor must ensure that the certificate includes all the information required by Appendix L, and that there is attached to the certificate any attachment required by Appendix L.

(5) The assessor may issue a certificate in respect of more than one standard if he or she is accredited to conduct assessments on the additional standard or standards, but only a primary assessor may issue a certificate in relation to all the standards.

18. Certifying a vehicle design/vehicle – primary assessors

(1) If a primary assessor has assessed a vehicle design and is of the opinion that a vehicle built to that design will meet all of the standards, he or she must issue a certificate in the form of Appendix K to that effect.

[*Subrule (2) was deleted as a consequence of an amendment consented to by the ATC on 7 November 2008*.]

(3) If a primary assessor has assessed a vehicle and is of the opinion that it meets all of the standards, he or she must issue a certificate in the form of Appendix K to that effect.

(4) Despite sub-rules (1) and (3), a primary assessor need not issue a certificate in the circumstances described in those sub-rules if the person who commissioned the assessment asks him or her not to issue the certificate.

18A. Certifying an alternatively complying vehicle design/vehicle – primary assessors

(1) If a primary assessor has assessed a vehicle design and is of the opinion that a vehicle built to that design will not meet all of the standards, but that it is likely that the design is eligible for approval under rule 33A or 33B of the *Performance Based Standards Scheme: Review Panel Business Rules*, he or she must issue a certificate in the form of Appendix M to that effect.

(2) If a primary assessor has assessed a vehicle and is of the opinion that it does not meet all of the standards, but that it is likely that it is eligible for approval under rule 33A or 33B of the *Performance Based Standards Scheme: Review Panel Business Rules*, he or she must issue a certificate in the form of Appendix M to that effect.

(3) Despite sub-rules (1) and (2), a primary assessor need not issue a certificate in the circumstances described in those sub-rules if the person who commissioned the assessment asks him or her not to issue the certificate.

19. General requirements concerning completion of certificates

(1) In issuing a certificate, the assessor must comply with any procedures that have been specified by the Panel.

(2) Before signing a certificate, the assessor must ensure that all the information required by the certificate form has been inserted into, or is attached to, the certificate.

20. Retention of documents

(1) The assessor must retain for at least 5 years –

(a) all documents relating to numerical modelling recorded by him or her in accordance with Appendix E; and

(b) all documents relating to field testing recorded by him or her in accordance with Appendix F.

(2) The assessor must retain and maintain any other documents relating to assessments conducted by him or her that he or she is required by the Panel to keep and maintain, and must do so in accordance with the directions of the Panel.

(3) The assessor must make available to the Panel, or a representative of the Panel, on request any document that he or she is required to retain under this rule.

PART 3 – AMENDMENT OF THESE RULES

21. Amendment of these Rules

(1) These Rules may only be amended by the National Transport Commission –

(a) with the consent of the Australian Transport Council; or

(b) in the case of an amendment that is of an administrative or non-controversial nature, with the unanimous consent of the Transport Agency Chief Executives.

(2) A reference in any document to these Rules as approved by the ATC from time to time is to be read as including any amendments consented to by TACE under subrule (1)(b).

PART 4 – INTERPRETATIVE MATTERS AND REFERENCES

22. Definitions of general terms

In these Rules, unless the contrary intention appears –

assessor means a person accredited to assess vehicle designs and vehicles for the purposes of the Scheme;

certificate means the certificate set out in Appendix K or L;

combination vehicle means a group of vehicles consisting of a motor vehicle connected to 1 or more vehicles;

hauling unit means the motor vehicle that provides the primary means of motive power for a combination vehicle;

infrastructure standard means a standard set out in Appendix A;

least favourable load condition means the loading condition that will produce the worst case result, either under the maximum laden mass, in the unladen condition or in some other loading condition, including consideration of asymmetry of loading if the vehicle is designed to operate with an asymmetric load and partial loading if the vehicle is a road tanker;

maximum axle or axle group mass means the maximum mass on each axle or axle group at which a vehicle would be authorised to operate if it were to be permitted to operate under the Scheme;

maximum laden mass means the maximum gross mass at which a potential vehicle would be authorised to operate if it were to be permitted to operate under the Scheme;

Network Classification Guidelines means the *Performance Based Standards Scheme: Network Classification Guidelines*, as approved by the Australian Transport Council from time to time;

Performance Based Standards Road Classification Level means the level of access to the road network as defined in the *Network Classification Guidelines*;

performance level means the performance level specified in relation to a particular standard in Appendix A or C;

primary assessor means an assessor who takes primary responsibility for the assessment of a vehicle design, or vehicle, and who is accredited to issue a certificate in the form of Appendix G;

safety standard means a standard set out in Appendix C;

Scheme means the Performance Based Standards Scheme;

site manager means the person responsible for the organisation of the field testing on the test site and for conducting the field testing in a safe manner;

standard means an infrastructure standard or a safety standard;

trailing unit means a unit generally without motive power that is towed or meant to be towed but does not include a hauling unit that is being towed;

vehicle includes the equipment fitted to, or forming part of, the vehicle;

vehicle physical characteristic means –

(a) a dimension; or

(b) a component of a vehicle including but not limited to its tyres, suspension, engine, couplings, brakes or control system, including an emissions control system;

vehicle unit means any rigid part of a combination vehicle.

23. Reference provisions

(1) A reference in these Rules to a vehicle is to be read as including a reference to a combination vehicle, unless the contrary intention appears.

(2) A reference in the appendices to a vehicle is to be read as including a reference to a vehicle design if the context requires or permits.

24. Technical terms

(1) The reference *Society of Automotive Engineers* (1976) must be used as the source of technical terms used in the Appendices as they relate to vehicle dynamics terminology.

(2) It is possible that the exact term used in the appendices is not the same as in the reference, but if the term being defined has the same general meaning as a term in the reference, the definition in the reference must be used.

(3) Any dispute about the definition of a technical term is to be determined by the Panel.

(4) Unless there is a conflict with a term defined in the reference, the following definitions of other technical terms apply:

auxiliary brakes mean engine brakes, exhaust brakes and retarders but not the service brakes for the vehicle;

crossfall means the slope of a road surface such that there is a difference in elevation of the left and right wheel paths;

International Roughness Index means the measure of road roughness as defined by the World Bank (also described as IRI);

percentage grade means 100 times the change-in-height divided by the (horizontal) distance over which the height change occurs;

roll-coupled means the joining of vehicle units such that roll motion is transferred from one vehicle unit to the next vehicle unit either ahead or behind, usually by means of a fifth wheel;

roll-coupled unit means a series of vehicle units that are roll-coupled;

swept width means the width of traffic lane required to accommodate all lateral motions of the tyres of a vehicle during straight-line travel;

test length means the section of pavement between the start of testing and the end or finish mark used for testing;

upgrade means the slope of a road surface such that elevation increases as a vehicle travels in the forward direction.

25. Diagrams

(1) A diagram in these Rules is part of these Rules.

(2) A diagram of something is an illustrative example of the thing, but does not represent its dimensions or the dimensions of any part of it.

26. Notes

A note in these Rules is part of these Rules.

27. Examples

(1) An example (whether or not in the form of a diagram) in these Rules is part of these Rules.

(2) If these Rules include an example of the operation of a provision of these Rules –

(a) the example is not exhaustive; and

(b) the example may extend the meaning of the provision; and

(c) the example does not limit the meaning of the provision unless the contrary intention appears.

28. References to documents

(1) References used in these Rules are as follows –

(a) Australian Design Rules. *Australian Design Rules for Motor Vehicles & Trailers (3rd edition)*, being national standards for the purposes of the Motor Vehicle Standards Act 1989 (Commonwealth);

(b) Austroads 2004. *Heavy vehicle mass – measurement adjustment and breakpoints. Guidelines for the physical measurement of heavy vehicle mass*. Stage 1 report. Austroads project RUM.HV.C.035 (Draft). Austroads: Sydney NSW;

(c) ECE R13V9, Annex 13, Appendix 2 Cl. 1.1.4;

(d) International Standards Organisation ISO 14791:2000. *Road vehicles – heavy commercial vehicle combinations and articulated buses – lateral stability test methods*. ISO, Geneva, Switzerland;

(e) McLean, J.R. and Hoffman, E.R. (1971). *Analysis of Drivers' Control Movements.* Human Factors, 13(5), pp407-418. Human Factors and Ergonomics Society, Santa Monica, California;

(f) McLean, J.R. and Hoffman, E.R. (1973). *The Effects of Restricted Preview on Driver Steering Control and Performance*. Human Factors, 15(4), pp421-430. Human Factors and Ergonomics Society, Santa Monica, California;

(g) Sayers M W, Gillespie T D and Paterson W D O, 1986. Guidelines for conducting and calibrating road roughness measurements. World Bank Technical Paper no. 46. World Bank, Washington D.C;

(h) Society of Automotive Engineers (1976). *Vehicle Dynamics Terminology*. SAE Recommended Practice J670e, Society of Automotive Engineers: Warrendale, PA, United States of America;

(i) Society of Automotive Engineers (1993a). *A Test for Evaluating the Rearward Amplification of Multi-Articulated Vehicles.* SAE Recommended Practice J 2179. Society of Automotive Engineers: Warrendale, PA, United States of America;

(j) Society of Automotive Engineers (1993b). *Steady-state Circular Test Procedure for Trucks and Buses*. SAE Recommended Practice J 2181, Society of Automotive Engineers: Warrendale, PA, United States of America;

(k) Society of Automotive Engineers (1998). *A Tilt Table Procedure for Measuring the Static Rollover Threshold for Heavy Trucks.* SAE Recommended Practice J 2180, Society of Automotive Engineers: Warrendale, PA, United States of America;

(m) Standards Australia AS/NZS 4602:1999 *High visibility safety garments*. Standards Australia, Homebush, NSW;

(n) Standards Australia AS 1742.3:2002, *Manual of uniform traffic control devices, Part 3 – traffic control devices for works on roads*. Standards Australia, Homebush, NSW;

(o) Standards Australia AS/NZS 4360:2004, *Risk management*. Standards Australia, Homebush, NSW;

(p) Tyre and Rim Association of Australia, 2004. *Standards Manual*. Tyre and Rim Association of Australia: Hawthorn, Vic.

(2) A reference to any of these documents is to be read as a reference to the document as amended from time to time, unless a contrary intention appears.

APPENDIX A: THE INFRASTRUCTURE STANDARDS

A1 PAVEMENT VERTICAL LOADING (INTERIM STANDARD)

A1.1 Purpose and Intent

(a) Purpose

The purpose of the pavement vertical loading standard is to limit the stress on the pavement layers below the surface of the road.

(b) Intent

The basis of the standard is to limit individual axle group[1] loads to those that presently apply under:

- General Mass Limits[2] (GML);
- Concessional Mass Limits[3] (CML); or
- Higher Mass Limits[4] (HML).

Total gross mass is not limited by this standard, but may be limited indirectly by the Bridge Loading standard and the safety standards. The *Network Classification Guidelines* presently limit General Access vehicles to a gross mass of 50 tonnes.

Jurisdictions reserve the right to refuse access to their road network, or to exclude vulnerable assets from a vehicle's access arrangements, if they have a reasonable concern that the vehicle's intended operation would cause unacceptable pavement wear, until such time as a pricing regime that fully recovers the pavement wear costs of PBS and other high productivity vehicles is operational.

Whilst a full cost-recovery mechanism is not expected to be available before mid-2008, jurisdictions may consider permitting operators to participate in incremental pricing trials that are programmed to commence in early 2008. In embracing such an approach, the requirements of local governments should be considered.

A1.2 Definition

The axle group loads for a PBS vehicle shall not exceed the maximum permitted on the route/network for commercial[5] heavy vehicles (refer to *Intent* above for detail). Axle group types are limited to present prescriptive configurations[1].

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[1] As defined in the Australian Design Rules or otherwise permitted by a jurisdiction (e.g. tandem axle group). Note that the listings of exempt prescriptive provisions on page 1 of this document do not provide for exemptions to be sought for axle configuration at this time.

[2] As per Table 1 of Schedule 1 of the National Transport Commission (Road Transport Legislation – Mass and Loading Regulations) Regulations 2006.

[3] See NTC web site (www.ntc.gov.au).

[4] See NTC web site (www.ntc.gov.au).

[5] Heavy vehicles other than special purpose vehicles and those operating under indivisible load notices and permits.

A1.3 Requirements

An assessor must state that a proposed vehicle meets the standard and that the vehicle will only use the routes/network for which the specified axle group mass limits apply.

Vehicles operating under CML or HML axle loads are, by default, subject to the operating conditions that are normally applied to prescriptive CML and HML vehicles, such as mass management accreditation and certified road-friendly suspensions (in the case of HML).

A2 PAVEMENT HORIZONTAL LOADING

A2.1 Purpose and intent

(a) Purpose

The purpose of this standard is to regulate road wear by limiting the impact on the surface of road pavements of:

- the horizontal tyre forces of a multi-axle group when turning; and
- the tractive tyre forces of the drive axle or axles when a vehicle participating in the Scheme is starting or climbing an upgrade.

(b) Intent

The horizontal forces imposed on a pavement are the longitudinal tyre forces caused by braking and by the drive axle or axles when a vehicle starts, accelerates or climbs an uphill grade and the lateral or side forces that are generated by multi-axle groups during a turning manoeuvre.

A vehicle's tractive capability, its axle loads, axle spacing, and its low-speed offtracking influence the horizontal forces. Road-related effects such as horizontal and vertical geometry, grade and surface characteristics (tyre/road friction) also contribute to the horizontal forces that can be generated. The horizontal forces are of a concern in areas where significant turning, traction or braking is expected. However, to be consistent with road safety objectives, the limitation of braking forces is not feasible under this standard.

Traditionally, wear of surfacings has not been treated separately from pavement wear, and has been implicitly assumed to be part of the wear attributed to fourth power Equivalent Standard Axles (ESAs). However, there are growing concerns that the horizontal forces generated by heavy vehicles are causing excessive surface wear for bituminous chip-seal pavements and asphalt pavements. Horizontal forces have a direct influence on pavement wear and are particularly important for bituminous chip-seal pavements in areas of road-train operation.

It is the intention that this standard will eventually be performance-based. However, until further work has been undertaken to develop a suitable performance standard, a prescriptive requirement has been adopted.

A2.2 Definition

The degree to which horizontal forces are applied to the pavement surface, primarily in a low-speed turn, during acceleration and on uphill grades.

A2.3 Requirements

In relation to axle groups:

- for tandem axle groups with an axle spacing of more than 2 metres, at least one axle must be steerable; and
- for axle groups with three or more axles and a spread of greater than 3.2 metres, all axles beyond the 3.2 metre spread must be steerable.

In relation to driving axles:

- all driving axles in a drive axle group must distribute tractive forces, such that the maximum difference in tractive force between any two driving axles in the group is not greater than 10% of the total tractive force delivered by the drive axle group; and
- a vehicle or combination having one or two driving axles is not permitted when the gross mass of the vehicle or combination exceeds the relevant limit in Table 2.

Table 2. Maximum gross mass permitted with one or two driving axles

Performance Based Standards Road Class	Maximum gross mass for one driving axle (tonnes)	Maximum gross mass for two driving axles (tonnes)
Level 1	35	70
Level 2	45	85
Level 3	45	110
Level 4	45	150

A3 TYRE CONTACT PRESSURE DISTRIBUTION

A3.1 Purpose and intent

(a) Purpose

The purpose of this standard is to restrict road wear by setting minimum tyre widths and by limiting the local contact pressure between the tyre and the road within the tyre contact patch.

(b) Intent

The forces and moments acting between the tyre and the roadway are transmitted to the pavement through an area of contact referred to as the tyre contact patch. There is sufficient evidence to confirm that the distribution of pressure or contact stresses (force per unit area) within the tyre contact patch may be non-uniform and that it is influenced by the following parameters:

- load supported by the tyre;
- tyre inflation pressure;
- tyre size (diameter and width);
- construction (bias or radial ply);
- tread pattern;
- speed;

- whether the tyre is following a straight or curved path; and
- whether the tyre is free-rolling, braking or transmitting tractive forces.

Each of these factors will have some effect on the area and shape of the contact patch, as well as the distribution of pressure within it.

Traditional design and evaluation of pavements assumes the vertical (or normal) contact pressure between the tyre and the roadway is uniformly distributed over a contact area that is circular. While this approach may be adequate for relatively thick (>75mm) asphalt surfacing and base layers, it would be highly inaccurate for thinner layers subjected to non-uniform tyre contact stresses (De Beer, 1996a). Further, recent research suggests that the damage to the chip-seal surfacing increases in proportion to the maximum tensile strain raised to the fifth power (Prem et al, 2000); this means that doubling the tensile strain would increase damage by a factor of 32. Horizontal tensile strains resulting from non-uniform contact stress distributions can be up to 100% higher when compared to those from uniform stress distributions, indicating the potential for premature failure (De Beer, 1996a).

Australia's sealed rural road network consists predominantly of bituminous chip-sealed granular pavements. The performance and wear of these thin pavements is directly influenced by the distribution of pressure within the tyre contact patch and the shape of the patch (i.e. the tyre width).

Until further work can quantify the impacts of tyre patch shape, maximum tyre pressure and tyre pressure differentials, a prescriptive requirement has been adopted.

A3.2 Definition

The minimum tyre width that is allowed, and the maximum pressure and pressure variation that is applied to the road surface by a single-tyre or pair of tyres in a dual tyred set.

A3.3 Requirements

Existing prescriptive requirements relating to minimum tyre width and maximum pressure have been retained and applied to vehicles participating in the Scheme.

A4 BRIDGE LOADING

A4.1 Purpose and Intent

(a) Purpose

To limit the maximum effect on a bridge to that which is acceptable to the bridge owner[6].

(b) Intent

The protection of bridges is primarily an infrastructure issue but becomes a safety issue when a bridge component fails or an entire bridge collapses. The bridge loading standard addresses the issue of bridge strength and ensures that a vehicle in the Scheme does not induce effects on bridge structures that exceed accepted limits as specified by the bridge owner.

[6] Bridge owner – the person who has the ultimate authority to determine whether or not a PBS vehicle can use the bridge.

A4.2 Definition

The effects caused by a vehicle in the Scheme on any bridge on the route/network requested shall be limited by either of the following methods ('tiers'). Note that each successive tier may allow greater gross mass and may reduce the extent of network access.

Tier 1 **General Access or Restricted Access**

Must meet the bridge formulae listed in Section A4.5.

Tier 2 **Special Access**

Must not cause more effects than those caused by existing commercial[7] vehicles acceptable to the bridge owner.

Tier 3 **Specific Link Access**

Approval by the owners of the bridges to use all of the bridges on a specific link based on detailed individual bridge assessment.

A4.3 Requirements

Tier 1 Assessors must demonstrate that proposed vehicle designs satisfy the appropriate bridge formulae.

Tier 2 Assessment must be undertaken by a prequalified bridge engineer[8]. The engineer must demonstrate that the vehicle will not cause bridge effects that exceed acceptable limits for the bridges on the network/route/link proposed for use by the vehicle.

Tier 3 This assessment should be undertaken by the bridge owner. Some authorities may be prepared to accept assessment by a prequalified bridge engineer using the authorities' bridge data.

A4.4 Commentary

Many heavy vehicles[9] are not approved for general access to the Australian road network. This is because Australian bridges vary considerably in design strength and structural condition; many were designed for much lighter trucks than are the norm today and some are in a degraded condition. As a consequence access for vehicles that do not meet the General Access bridge formulae is limited, due to excessive effects in some older and weaker bridges. Timber bridges are an example of typical bridges that restrict general access to only the smaller and lighter heavy vehicles.

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[7] Heavy vehicles other than special purpose vehicles and those operating under indivisible load notices and permits. Details can be obtained from the relevant road authority.

[8] Contact the Chief Bridge Engineer in the relevant road authority to obtain the names of prequalified bridge engineers. It may be the case that a road authority chooses to totally retain this role.

[9] Heavy Vehicle - A two-axle vehicle with the minimum axle spacing greater than 3.2 m, or a three- or more-axle vehicle configured at least with two axle groups (excluding short vehicles towing vehicles, e.g. trailer, caravan, boats, etc.). Also defined by Austroads as a Class 3 or higher classification vehicle. (Source: Draft Austroads Glossary of Terms: Pavement Technology, Asset Management and Heavy Vehicles)

Some vehicles in the Scheme will meet general access requirements and others will not. However there will be some vehicles in the Scheme that cause bridge effects that are only acceptable on limited networks such as Higher Mass Limits or high bridge strength links. These vehicles will only be granted access to these networks or routes as approved by bridge owners.

Vehicles in the Scheme may also be subject to stringent compliance regimes with penalties in place for non-compliance. These will be set by the Performance Based Standards Review Panel and road and bridge owners. There may be a requirement in some cases for vehicle tracking and prospectively an approved on-board mass measurement system.

A4.5 Bridge Formulae (Tier 1)

The minimum distance, L (metres), between the extreme axles of any two axle groups—for a given total gross mass, M (tonnes), on the axles within that distance—is controlled by the relevant bridge formula. The absolute minimum internal distance allowed between any two axle groups is 2.5 m. Existing clear space rules apply to minimum clear distances between axle groups on B-doubles.

For vehicles operating under the Concessional Mass Limits scheme, axle groups are to be treated as though they are laden to General Mass Limits. Higher Mass Limits vehicles will only have access to portions of the road and bridge network that the jurisdiction considers to be suitable for Higher Mass Limits vehicles.

Access to the PBS Level 1 road network

$M = 3L + 12.5$ for $M <= 42.5$ t; and

$M = L + 32.5$ for $M >= 42.5$ t

Access to the PBS Level 2 road network

$M = 3L + 12.5$ for $M <= 46.5$ t; and

$M = 1.5L + 29.5$ for $M >= 46.5$ t

Access to the PBS Level 3 and Level 4 road networks

$M = 3L + 12.5$ for all M

APPENDIX B: [RESERVED]

APPENDIX C: THE SAFETY STANDARDS

This Appendix specifies the safety standards that must be met by a vehicle to enable it to participate in the Scheme. The safety standards are:

Table 3. Safety Standards

C1. STARTABILITY

C1.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk associated with starting on grade by ensuring that a vehicle participating in the Scheme has adequate starting capability on grades.

(b) Intent

A vehicle participating in the Scheme must be capable of starting on the steepest grade it has to negotiate on the nominated route when operating at its maximum allowed gross mass, otherwise it can become a safety risk and an inconvenience to other road users.

A combination vehicle that is stopped on a grade beyond its capability will either require that its units be separated and moved or require the use of heavy haulage equipment to move it to a location where it can restart.

C1.2 Definition

(a) Summary statement

The ability to commence forward motion on specified upgrade.

(b) Detailed statement

When operating at maximum laden mass, a vehicle participating in the Scheme must be able to commence and maintain steady forward motion from a standing start on a pavement section of specified upgrade. Momentary reverse motion (downhill) at commencement, associated with the release of brakes and clutch engagement, or similar, is acceptable provided uphill forward motion is subsequently achieved and maintained.

C1.3 Measure

(a) Performance value

The maximum upgrade on which forward motion is commenced and maintained must be measured and reported as the achieved performance value, in units of percentage grade[10], rounded down to the nearest whole number.

(b) Performance levels

Table 4. Startability performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	At least 15%
Level 2	At least 12%
Level 3	At least 10%
Level 4	At least 5%

[10] Percentage grade is defined to mean 100 times the change-in-height divided by the (horizontal) distance over which the height change occurs. A grade of 100% corresponds to a grade line of 1:1 or 45º incline, a grade of 10% would be 1:10, or a 5.7º incline.

C1.4 Test specification

(a) Test load

The vehicle being assessed must be loaded to its maximum laden mass. Each tyre on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyre. Each tyre must be inflated to a pressure within the range as specified by the vehicle and/or tyre manufacturer.

(b) Test conditions

The full length of the vehicle being assessed must be on an upgrade appropriate to the road classification level. The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

From a standing start on a slope having an upgrade not less than the specified grade, the vehicle being assessed must commence and maintain steady forward motion. Steady forward motion on the specified grade is achieved when the vehicle's speed is either constant or increasing for a distance of at least 5 metres.

(d) Test method

Numerical modelling (computer-based simulation) or field-testing.

C2: GRADEABILITY

C2.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk associated with travel on grade by ensuring that a vehicle participating in the Scheme has the capability to maintain acceptable speeds on upgrades.

(b) Intent

When operating at the maximum allowable gross mass, vehicles participating in the Scheme must be able to maintain a specified minimum speed on upgrades. This is desirable in order to minimise traffic congestion or delays to other vehicles travelling in the same direction. Further, heavy vehicles travelling on grade that impede traffic are known to increase accident rates on two lane rural highways (Khan et al, 1990).

Gradeability is applicable to all heavy vehicle operations – in urban, rural/regional and remote areas – and to all vehicles participating in the Scheme. In addition to safety considerations and concerns, gradeability also influences vehicle productivity, route selection and access.

The vehicle-related factors that determine startability also influence gradeability. However, a vehicle may be designed to maximise startability at the expense of its gradeability performance (geared low). Similarly, if optimised for gradeability it may not meet the startability requirement. For this reason both startability and gradeability must be within acceptable limits for a vehicle participating in the Scheme.

PART (A) MAINTAIN MOTION

C2.2 Definition

(a) Summary statement

The ability to maintain forward motion on specified upgrade.

(b) Detailed statement

When operating at maximum laden mass, a vehicle participating in the Scheme must be able to maintain steady forward motion on a pavement section of specified upgrade. An initial change in speed associated with the transition from the approach to the upgrade is acceptable, provided steady forward motion can be maintained on the upgrade.

C2.3 Measure

(a) Performance value

The maximum upgrade on which steady forward motion is maintained must be measured and reported as the achieved performance value, in units of percentage grade rounded down to the nearest whole number.

(b) Performance levels

Table 5. Gradeability - Part (a) Maintain Motion performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	At least 20%
Level 2	At least 15%
Level 3	At least 12%
Level 4	At least 8%

C2.4 Test specification

(a) Test load

The vehicle being assessed must be loaded to its maximum laden mass. Each tyre on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyre. Each tyre must be inflated to the pressure as specified by the vehicle and/or tyre manufacturer.

(b) Test conditions

Same as for startability. Additionally, the upgrade must be of sufficient length to allow steady forward motion to be established. The full length of the vehicle being assessed must be on the upgrade. The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

With the vehicle being assessed in forward motion on a slope having an *upgrade* not less than the specified grade, it must maintain steady forward motion. Steady forward motion is achieved when the vehicle's forward speed on the upgrade is either constant or increasing for a distance of at least 5 metres.

(d) Test method

Numerical modelling (computer-based simulation) or field-testing.

PART (B) MAINTAIN SPEED

C2.5 Definition

(a) Summary statement

The ability to maintain a minimum speed on a specified upgrade.

(b) Detailed statement

When operating at maximum laden mass, a vehicle participating in the Scheme must be able to maintain a specified minimum speed on a pavement section having an upgrade of not less than 1%. An initial change in speed associated with the transition from the approach to the upgrade is acceptable, provided the specified minimum speed is maintained on the upgrade.

C2.6 Measure

(a) Performance value

The minimum sustained steady speed must be measured and recorded as the achieved performance value, in units of km/h rounded down to the nearest whole number.

(b) Performance levels

Table 6. Gradeability - Part (b) Maintain Speed performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	At least 80 km/h
Level 2	At least 70 km/h
Level 3	At least 70 km/h
Level 4	At least 60 km/h

C2.7 Test specification

(a) Test load

The vehicle being assessed must be loaded to its *maximum laden mass*. Each tyre on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyre. Each tyre must be inflated to the pressure as specified by the vehicle and/or tyre manufacturer.

(b) Test conditions

The full length of the vehicle being assessed must be on an upgrade. The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

With the vehicle being assessed in forward motion on a slope having an upgrade of not less than 1%, steady forward motion must be maintained at a speed at least equal to the specified minimum speed. Steady forward motion is when the forward speed of the vehicle on the upgrade is either constant or increasing for a period of at least 5 seconds.

(d) Test method

Numerical modelling (computer-based simulation) or field-testing.

C3: ACCELERATION CAPABILITY

C3.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk associated with travel through intersections and rail crossings by specifying minimum times for a vehicle participating in the Scheme to accelerate from rest, to increase speed, and travel specified distances.

(b) Intent

Acceleration capability is of primary concern to long or slow vehicles and addresses issues associated with intersection clearance times and rail level crossings. Heavy vehicles that require long times to accelerate to speed will take too long to clear intersections or railway level crossings, causing congestion and delays to through traffic, as well as posing a threat to safety if sight distances are inadequate. At an unsignalised intersection the probability of finding a gap in opposing traffic decreases as the size of the gap required increases. Signalised intersections operate on phase times that, where possible. should permit most heavy vehicles to clear the intersection in the allocated time.

Acceleration capability has an effect on the productivity of heavy vehicles in urban traffic, the capacity of the intersection and traffic congestion.

C3.2 Definition

(a) Summary statement

The ability to accelerate either from rest or to increase speed on a road with no grade.

(b) Detailed statement

When operating at maximum laden mass, a vehicle participating in the Scheme must be able to accelerate from rest, and travel 100 m on a road with no grade within a specified time.

C3.3 Measure

(a) Performance value

The time taken to travel the distance of 100 metres must be reported as the achieved performance, to the nearest 0.1 second.

(b) Performance levels

Table 7. Acceleration capability performance levels

Performance Based Standards Road Class	Time To Travel 100m Free Rest (secs)
1	20
2	23
3	26
4	29

C3.4 Test specifications

(a) Test load

The vehicle being assessed must be loaded to its maximum laden mass. Each tyre on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyre. Each tyre must be inflated to the pressure as specified by the vehicle and/or tyre manufacturer.

(b) Test conditions

The full length of the vehicle being assessed must be on a site with zero grade throughout the test (except for assessment by testing – see Appendix F). The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

From a standing start the vehicle being assessed must accelerate, changing through the gears as required, over a distance of at least 100 metres.

The point of commencement of acceleration should be taken as the moment forward motion starts.

(d) Test method

Numerical modelling (computer-based simulation) or field-testing.

C4: OVERTAKING PROVISION

The requirements for Overtaking Provision have been moved to the *Network Classification Guidelines* as a key component of classifying the heavy vehicle freight network. This allows the standard to be applied to the Performance Based Standards network without diminishing the intent of the standard, whilst improving the process for the assessment of individual applications.

To assist in the application of the *Network Classification Guidelines*, the maximum vehicle lengths for each road class are as set out below. For heavy vehicles participating in the Scheme that wish to gain access to a specific network level but exceed the maximum permitted length for that level, an individual route assessment will need to be carried out.

Table 8. Network classification by vehicle length

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

* General Access is subject to a 50 tonne gross mass limit, posted local restrictions and restrictions or limitations specified by the jurisdiction.

C5: TRACKING ABILITY ON A STRAIGHT PATH

C5.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk associated with lane width and lateral clearance by ensuring that a vehicle participating in the Scheme remains within its traffic lane when travelling at high speed on straight roads with uneven surfaces.

(b) Intent

When the hauling unit of a heavy vehicle follows a straight path along a section of road, it is both a practical requirement and necessary for safe operation that the rear of the vehicle follows with adequate fidelity and tracks within a specified lane width. Vehicles that require more lane width than is available present a risk to safety and the infrastructure when crossing the centre-line when being overtaken or passed, and when leaving the pavement seal causing edge break-off and aggravating shoulder drop. If large enough and the conditions sufficiently adverse, shoulder drop can initiate a rollover.

In practice, each trailer in a combination vehicle will undergo small lateral excursions from the path of its lead unit as it responds to the driver’s steering actions, road surface unevenness and other external disturbances, such as cross winds. The ability of the trailing units to faithfully track along the same path as the hauling unit is referred to as tracking ability. Tracking ability depends on a range of vehicle-related factors, including: number of trailers and the location and type of coupling between them (turntable or pintle hitch); alignment of axles; suspension geometry (roll and bump steer effects); tyre cornering stiffness; vehicle length; and speed.

C5.2 Definition

(a) Summary statement

The total swept width while travelling on a straight path, including the influence of variations due to crossfall, road surface unevenness and driver steering activity.

(b) Detailed statement

When operating at least favourable load condition and travelling along the specified straight path on a section of pavement having the specified unevenness and cross-slope characteristics, the total swept width of the vehicle being assessed in the specified test must be no greater than the specified value.

C5.3 Measure

(a) Performance value

The total swept width of the vehicle being assessed must be measured and reported over the specified test section as the achieved performance value, expressed in units of metres, rounded up to the nearest 0.1metre The swept width at any point along the straight path is the length of the straight-line segment intersecting all the path trajectories, measured in the ground plane and perpendicular to the direction of travel, as shown in Figures 1 to 3. For single unit and combination vehicles, the swept width along the path must be determined from the path trajectories of the outermost paths scribed in the ground plane by the vertical projections of the outermost reference point, or points of all vehicle units. The number of reference points must ensure that the swept width is measured to the defined accuracy. The reference points must be selected when the vehicle is on a flat level surface. Where there is a choice of more than one reference point at any particular location, such as along the vertical outside corner of the front or rear of a vehicle unit, the outermost point nearest to the ground must be selected.

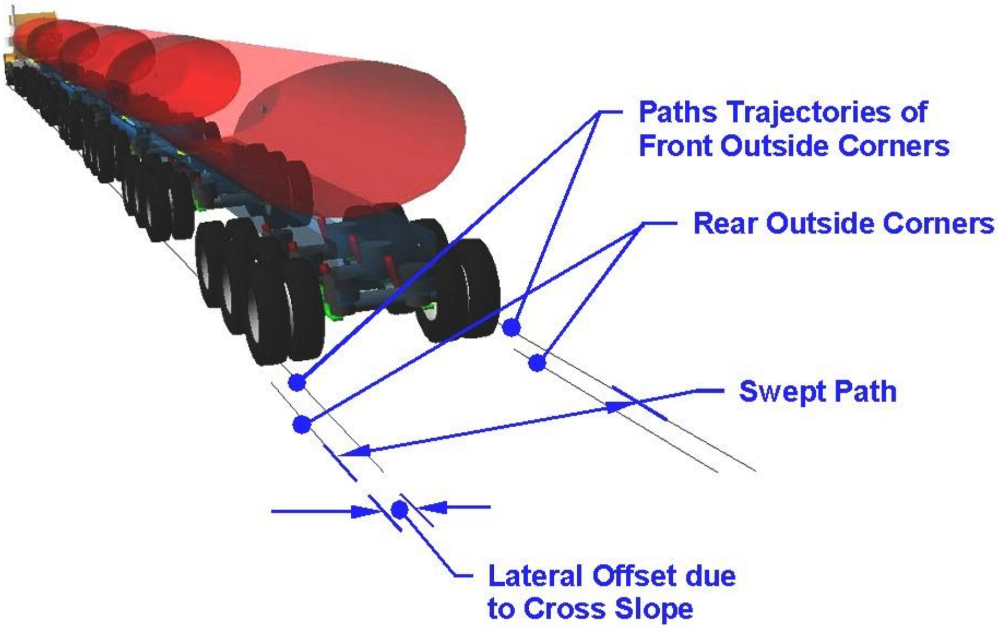

Figure 1. Perspective view illustration of front and rear outside-corner path trajectories and swept width in the tracking ability on a straight path test.

* Note that the path trajectories of only 4 points are shown in the above example.)

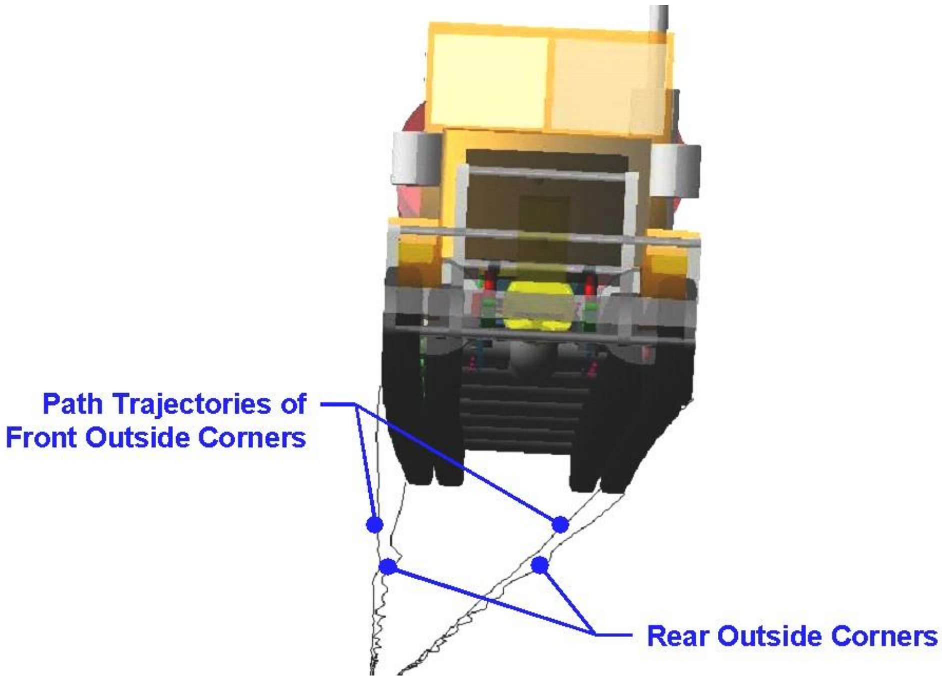

Figure 2. Underside perspective view illustration showing typical characteristics of the path trajectories and offsets due to cross slope.

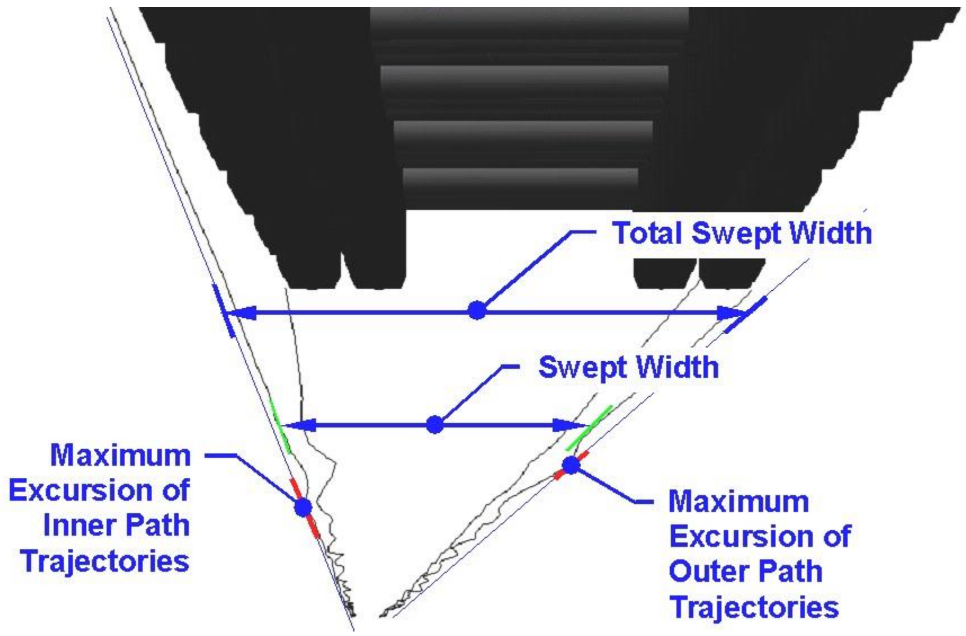

Figure 3. Close-up underside perspective view illustration showing both the swept width envelope and Total Swept Width from the 4 path trajectories defined in Figures 1 and 2.

(b) Performance levels

Table 9. Tracking ability performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	Not greater than 2.9 m
Level 2	Not greater than 3.0 m
Level 3	Not greater than 3.1 m
Level 4	Not greater than 3.3 m

If the assessment is undertaken by numerical modelling, a test road conforming to the test conditions will be supplied to the assessor so that all assessments are undertaken under equal conditions. However, to allow for variations in computer models, the 99th percentile of the measured swept width will be accepted as meeting the performance level. With assessment by testing, a risk exists that one or two major bumps on the test section will not provide a reasonable test of the ability of the vehicle being assessed to meet the standard and again the 99th percentile of the measured swept width will be accepted as meeting the performance level.

C5.4 Test specification

(a) Test load

The vehicle being assessed must be loaded to the least favourable load condition. The maximum laden mass and the corresponding maximum axle group loads must not be exceeded. For standard test conditions, the tyres on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyres, and have no less than 100 km of running. Tyres must be inflated to pressures as specified by the vehicle and/or tyre manufacturer.

(b) Test conditions

The road pavement test section must be at least 1000 metres long and the surface must have an overall unevenness level in each wheel path of not less that 3.8 m/km IRI (International Roughness Index). The unevenness level in each wheel path reported every 100 m must be not less than 3.0 m/km IRI. The entire test section must have an average crossfall, falling to the left when viewed in the direction of travel, of not less than 3.0%. The average crossfall must have a crossfall standard deviation of not less than 1.0%.

For the numerical modelling, a standard set of road profiles will be supplied to the assessor. The standard profiles are taken from the work performed for Austroads described in Prem et al (1999). The profiles were used in the Performance Based Standards fleet analysis project that developed this and other standards (NRTC, 2002).

(c) Test procedure

The vehicle being assessed must traverse a road segment not less than 1000 metres long at a travel speed not less than 90 km/h. The vehicle must be driven in a normal manner at the specified speed while as closely as possible following a straight path that is either defined specifically for the task, such as a contrasting line, or by existing pavement edge line or centreline markings.

(d) Test method

Numerical modelling or field-testing. If performed by numerical modelling, as noted above a test road conforming to the test conditions specified above will be supplied by the Panel to the assessor.

C6: RIDE QUALITY (DRIVER COMFORT)

C6.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting driver whole-body vibration especially on uneven roads where travel speeds are high and vibration levels are expected to be significant.

(b) Intent

The effect of whole-body vibration on heavy vehicle drivers is an important road safety and occupational health and safety issue for the road transport industry. Short-term exposure to high-intensity vibration can have adverse effects on motor processes and the sensory system (limb movements, sensing and response to motion, vision, and hearing) that can impair the driver's ability to control the vehicle. This type of vibration can also lead to acute injuries. Further, long-term exposure to occupational whole-body vibration poses a health risk that can lead to chronic injuries associated with the back and abdominal regions of the human body.

While there appears to be a connection between whole-body vibration and driver comfort and health, vibration has been observed both to improve and to reduce proficiency. This may be because it fatigues or arouses or, because of increased task difficulty, motivates. These effects cannot be reliably predicted at present.

Ride vibration is influenced by a variety of factors, including vehicle load, suspension and tyre characteristics, prime mover wheelbase, seat location (fore-aft and height), seat transmissibility characteristics, road surface unevenness, speed, kingpin lead and trailer characteristics.

C6.2 Definition, measure and test specification

This standard has yet to be defined. Its three main components (a performance measure, a test procedure from which to obtain the performance measure and a performance level, or levels, to be satisfied) are not able to collectively be defined to an acceptable level of robustness at this time based on current research.

There are three (very similar) recognised standards[11] for assessing whole-body vibration that could form the basis of defining the performance measure and performance level(s), but at this point in time there has yet to be developed a suitable test procedure from which to obtain measurements. It is important that the severity of the test procedure is at a level that allows good-performing vehicles to pass the standard and disallows poor-performing vehicles from passing the standard. Setting the severity at too low a level will potentially allow all vehicles to pass the standard, regardless of their performance. Conversely, setting the severity at too high a level may potentially disallow all vehicles.

The NTC has initiated a project to finalise this standard in its 2007/2008 work programme. A proposal will be submitted to the Australian Transport Council for approval in 2008 following consultation with industry and Transport Agency Chief Executives.

[11] Australian Standard 2670, British Standard 6841, International Standard 2631

C7: LOW-SPEED SWEPT PATH

C7.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk associated with turns at intersections by limiting the road space required by a vehicle participating in the Scheme when making low-speed turns.

(b) Intent

When a long vehicle makes a low-speed turn at an intersection, the rear of the vehicle will follow a path that is inside the path taken by the front of the vehicle. This is known as low-speed offtracking. A high value of offtracking is undesirable because the vehicle, sweeping a wider path, will require more road space for turning than may be available. This may cause the vehicle to encroach into adjacent or opposing lanes, collide with parked or stopped vehicles, damage roadside furniture, endanger pedestrians, or the rear wheels may climb the kerb or fall off the edge of the pavement.

C7.2 Definition

(a) Summary statement

The maximum width of the swept path in a prescribed 90º low speed turn.

(b) Detailed statement

When operating at maximum laden mass and unladen, the maximum width of the swept path of a vehicle participating in the Scheme in the prescribed 90º turn performed at a speed of no more than 5 km/h must be no greater than the specified value.

C7.3 Measure

(a) Performance value

The maximum width of the swept path must be measured and reported as the achieved performance value, in units of metres rounded up to the nearest 0.1 metre. The maximum width of the swept path is the maximum distance, SPW_{max}, between the outer and inner path trajectories of the swept path envelope of the vehicle being assessed in the specified low-speed turn, shown in Figures 5 and 6. The maximum distance, SPW_{max}, is the straight-line segment intersecting both trajectories perpendicularly to their respective tangents at the intersection points. The swept path must be determined from the path trajectories of: 1) the outermost path scribed in the ground plane by the vertical projection of the furthest forward or outside point, or points, on the vehicle on the outside of the turn; and 2) the innermost path scribed in the ground plane by the vertical projection of the point, or points, on the vehicle on the inside of the turn. The above is summarised in Figures 4 to 6.

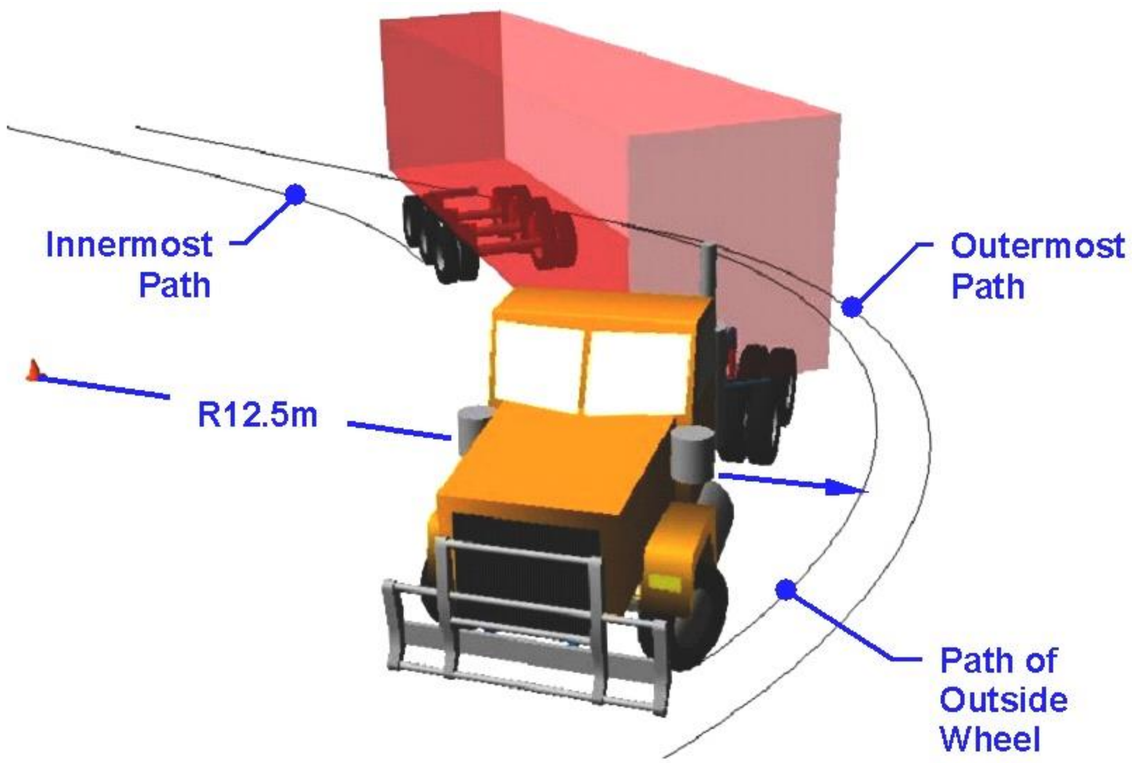

Figure 4. Perspective view illustration of vehicle partway through the Performance Based Standards low-speed turn showing path trajectories.

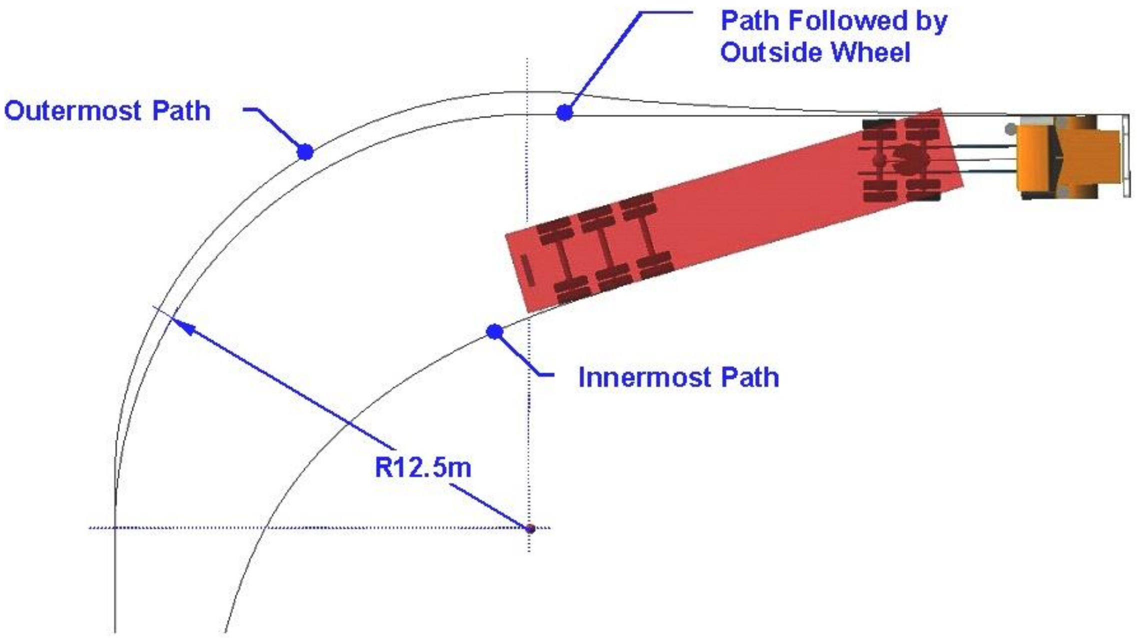

Figure 5. Plan view illustration of path trajectories that define the vehicle's swept path in the Performance Based Standards low-speed turn.

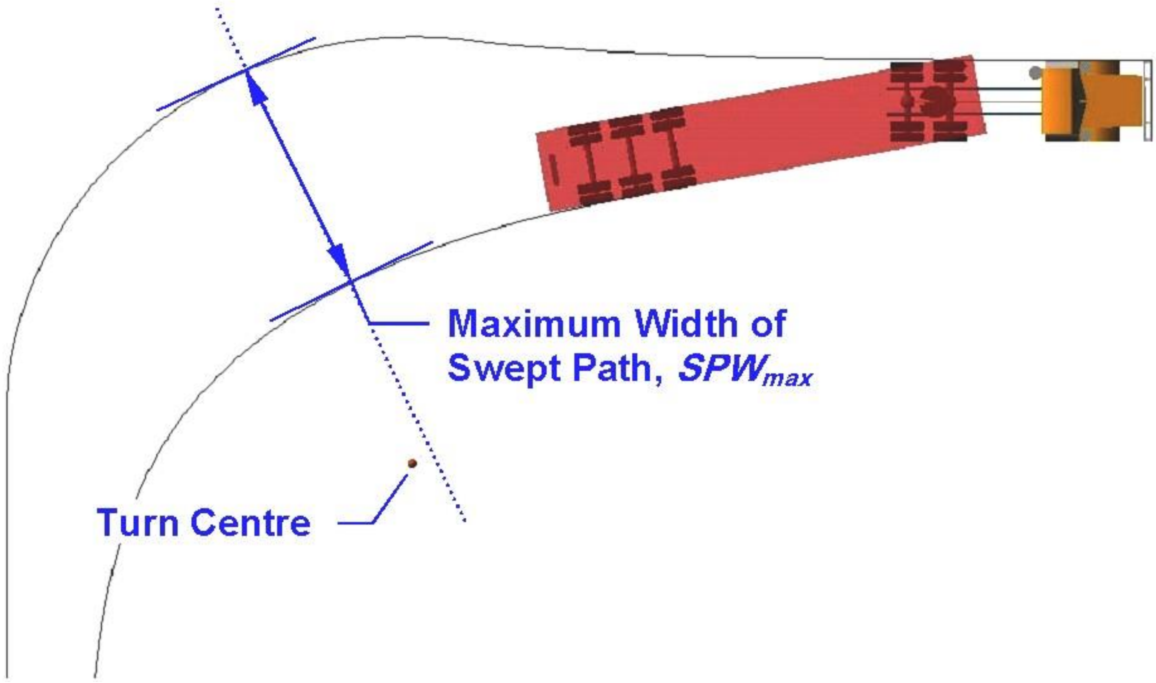

Figure 6. **Plan view illustration of Maximum Width of Swept Path, SPW_{max}. Note that the line perpendicular to both path trajectories (shown dotted in the illustration) does not necessarily pass through the turn centre.**

(b) Performance levels

Table 10. Low speed swept path performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	No greater than 7.4 m
Level 2	No greater than 8.7 m
Level 3	No greater than 10.6 m
Level 4	No greater than 13.7 m

C7.4 Test specification

(a) Test load

The vehicle being assessed must be tested fully laden and unladen. When fully laden it must be loaded to its maximum allowed gross mass and the corresponding maximum allowed axle group loads must not be exceeded. For the purposes of measuring swept path, mirrors and signalling devices are ignored.

(b) Test conditions

The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

The vehicle being assessed must be driven through the specified turn, unladen and laden, at a speed no greater than 5 km/h. The path of the specified turn that the driver will use to guide the vehicle must comprise straight tangent approaches to a 90º circular arc of 12.5 metre radius. The approaches to the turn must be of sufficient length to ensure:

(i) the entire vehicle is straight at the point where the 90º turn is commenced; and

(ii) at the conclusion of the turn the vehicle travels far enough into the straight exit segment to record the maximum width of the swept path.

The driver must ensure the entire vehicle is straight at the commencement of the turn (within 0.1 metre of the entry approach tangent). In the turn the driver must steer the vehicle along the specified path. The vehicle must be steered such that the vertical projection in the ground plane of the outer most point on the outer tyre sidewall nearest to the ground[12], on the forward most outside steered-wheel, follows the specified path as illustrated in Figure 5. Using the above point as a reference, the driver must steer the vehicle along the specified path and maintain a lateral distance error between the reference point and the specified path not greater than 50 millimetres.

(d) Test method

Numerical modelling (computer-based simulation) or field-testing.

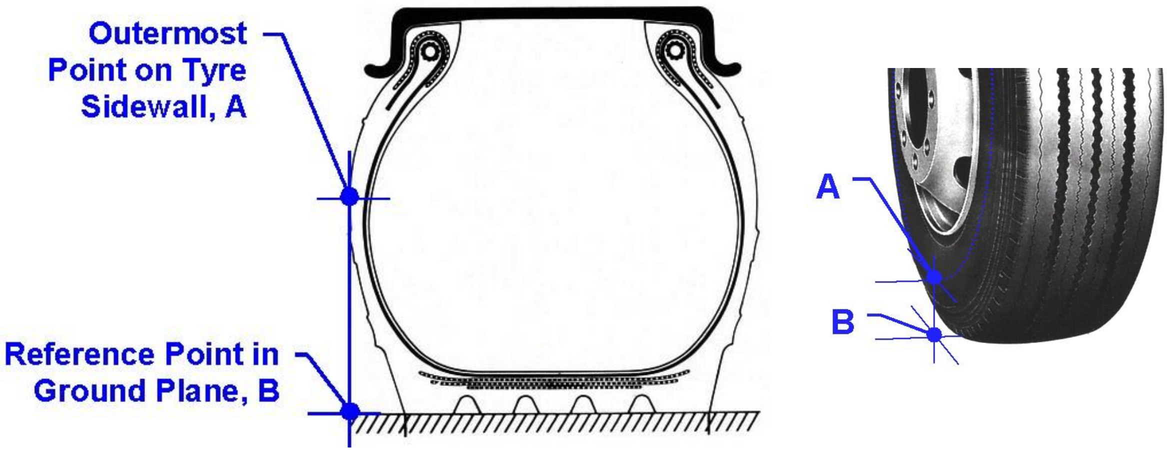

Figure 7. Illustration of outside wheel reference point.

[12] This represents the outermost point on the tyre sidewall – including tyre bulge due to deflection – which is most likely to come into contact first with the kerb in a shallow angle strike.

C8: FRONTAL SWING

C8.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting the road space requirement of a vehicle participating in the Scheme when making a tight turn at low speed.

(b) Intent

In a low-speed turn the front overhang of the hauling unit (rigid truck, prime mover, bus and coach) will generally cause the path of the front outside corner to track outboard the path of the front outside steered wheel. This behaviour is known as frontal swing. A large amount of frontal swing is undesirable because the vehicle will require more road (and/or kerbside) space for turning than may be available. In some situations this may cause the vehicle to encroach into adjacent or opposing lanes, interfere with roadside objects, collide with parked or stopped vehicles, endanger pedestrians, or require reversing the vehicle in the middle of a turn.

In addition to the above, on the exit side of the turn, the path of the front outside corner of a semi-trailer with large front overhang may track outboard of the path of the front outside corner of the hauling unit. For these vehicles, the road space and safety implications are similar to those for the hauling unit described above.

Both of these aspects of frontal swing are controlled by this standard, and they are important in situations where a vehicle operates in an environment and traffic situations where tight turns are frequently required to be performed.

Part A of frontal swing tested by this performance measure specifically addresses issues related to the hauling unit. The second and third components (Parts B and C) of the frontal swing performance measure, which deal with the semi-trailer(s), are both measured on the exit side of the turn and perpendicular to the exit path. These relate to the distance the semi-trailer front outside corner tracks outside the path of the front outside corner of the unit ahead of it (prime mover or converter dolly); on a prime mover the front outside corner is the primary reference that the driver sees, knows and will use (assisted by side mirrors) to establish adequate clearance between the vehicle and road and/or kerbside objects adjacent to the path of the turn, to prevent collisions or conflicts. Part B controls the maximum of the difference between the two paths. It is referred to as the Maximum of Difference between frontal swing-out values, or frontal swing MoD. Part C of the measure, referred to as the Difference between the Maximum frontal swing-out values, or frontal swing DoM, places an upper limit on maximum swing-out of the front outside corner of the semi-trailer measured relative to the maximum swing-out of the prime mover.

The key parameters that influence frontal swing are the amount of front overhang forward of the steer axle, and for semi-trailers the amount of overhang forward of the kingpin. For a fixed amount of front-overhang, longer-wheelbases will generally increase frontal swing.

PART (A) RIGID TRUCKS, PRIME MOVERS, BUSES AND COACHES

C8.2 Definition

(a) Summary statement

The maximum width of the frontal swing swept path in a prescribed 90º low-speed turn.

(b) Detailed statement

When operating at the maximum laden mass and unladen, the maximum width of the frontal swing swept path of a vehicle participating in the Scheme in a prescribed 90º low-speed turn performed at the specified speed must be no greater than the specified value.

C8.3 Measure

(a) Performance value

The maximum width of the frontal swing swept path must be measured and reported as the achieved performance value, in units of metres rounded up to the nearest 0.01 metre The maximum width of the frontal swing swept path is the maximum distance, FS_{max}, between the outer and inner path trajectories of the frontal swing swept path envelope of the vehicle being assessed in the specified low-speed turn. The maximum distance, FS_{max}, is the straight-line segment intersecting both trajectories perpendicularly to their respective tangents at the intersection points. The swept path must be determined from the path trajectories of:

(i) the outermost path scribed in the ground plane by the vertical projection of the furthest forward or outside point, or points, on the vehicle on the outside of the turn; and

(ii) the path scribed in the ground plane of the outer most point on the outer tyre sidewall nearest to the ground, on the forward most outside steered-wheel.

The above is summarised in Figure 8.

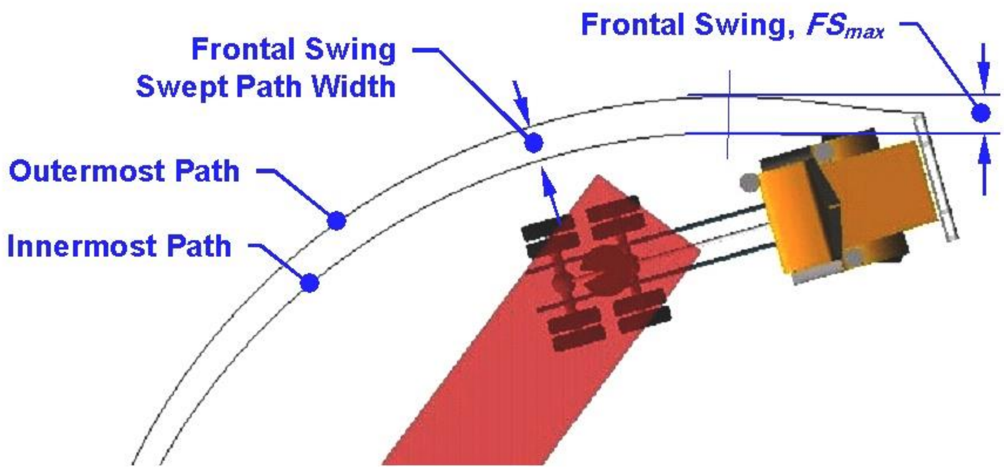

Figure 8. Illustration of path trajectories in the Performance Based Standards low-speed turn of Part A of the frontal swing performance measure. For this measure the innermost path is the path followed by the outside front wheel.

(b) Performance levels

Table 11. Frontal swing performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1 Level 2 Level 3 Level 4	For rigid trucks and prime movers no greater than 0.85 m, for buses and coaches no greater than 1.5 metres.

C8.4 Test specification

(a) Test load

Same as for low-speed swept path.

(b) Test conditions

Same as for low-speed swept path.

(c) Test procedure

Same as for low-speed swept path.

(d) Test method

Same as for low-speed swept path.

PART B: SEMI-TRAILERS, MAXIMUM OF DIFFERENCE (*MoD*)

C8.5 Definition

(a) Summary statement

The maximum of the difference between the frontal swing-out distances between adjacent vehicle units in a prescribed 90º low-speed turn.

(b) Detailed statement

When operating at the maximum laden mass and unladen, the maximum of the difference between the frontal swing-out distances of adjacent vehicle units, one of which is a semi-trailer of a vehicle participating in the Scheme, when measured relative to the exit tangent of the prescribed 90º low-speed turn performed at the specified speed, must be no greater than the specified value.

C8.6 Measure

(a) Performance value

The maximum of the difference between the frontal swing-out distances of adjacent vehicle units, referred to as frontal swing MoD, must be measured and reported as the achieved performance value, in units of metres rounded up to the nearest 0.01 metre The difference between the frontal swing-out distances must be determined from the path trajectories of the outermost path scribed in the ground plane by the vertical projection of the furthest forward or outside point, or points, on each of two adjacent vehicle units, one of which is a semi-trailer. Frontal swing MoD is the maximum value of the straight-line segment intersecting both trajectories perpendicular to the low-speed turn exit tangent, as shown in Figures 9 to 12. If the frontal swing-out of the second vehicle unit is less than the frontal swing-out of the first vehicle unit throughout the entire turn then frontal swing MoD is not applicable and must be recorded as "not applicable".

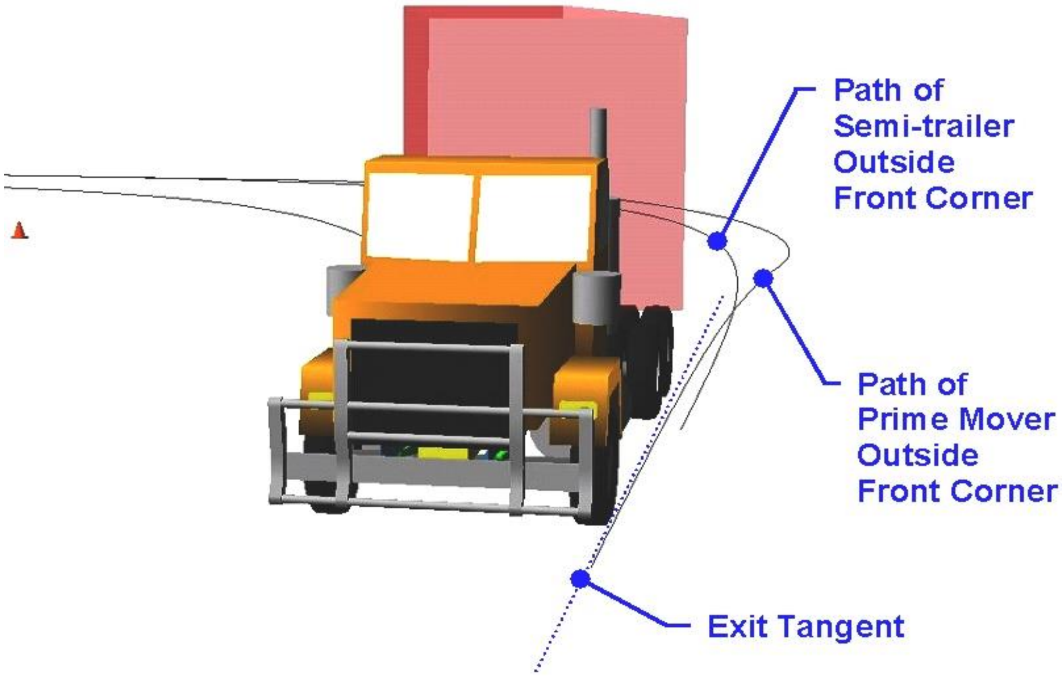

Figure 9. Perspective view illustration of path trajectories partway through the Performance Based Standards low-speed turn for Parts B and C of frontal swing MoD and DoM performance measures.

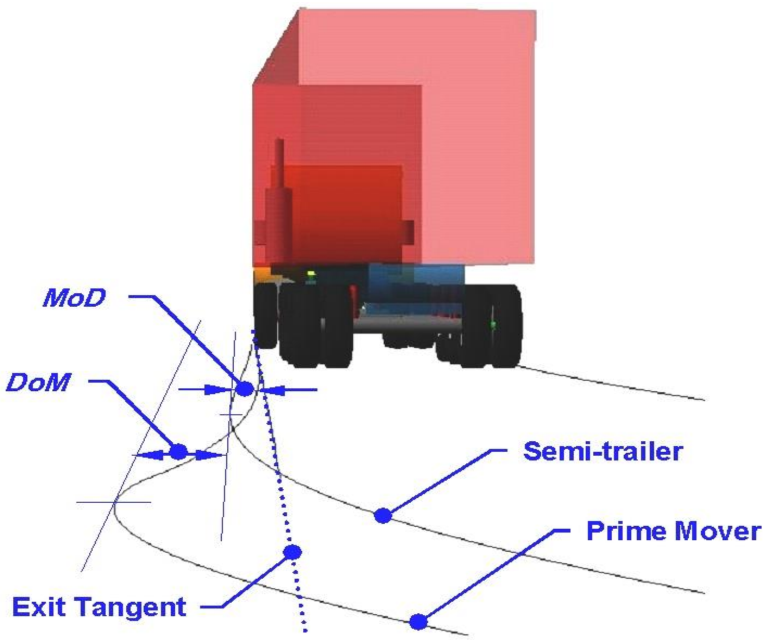

Figure 10. Perspective view illustration of Parts B and C of the frontal swing MoD and DoM performance measures looking along the exit

tangent during the final stages of the low-speed turn.

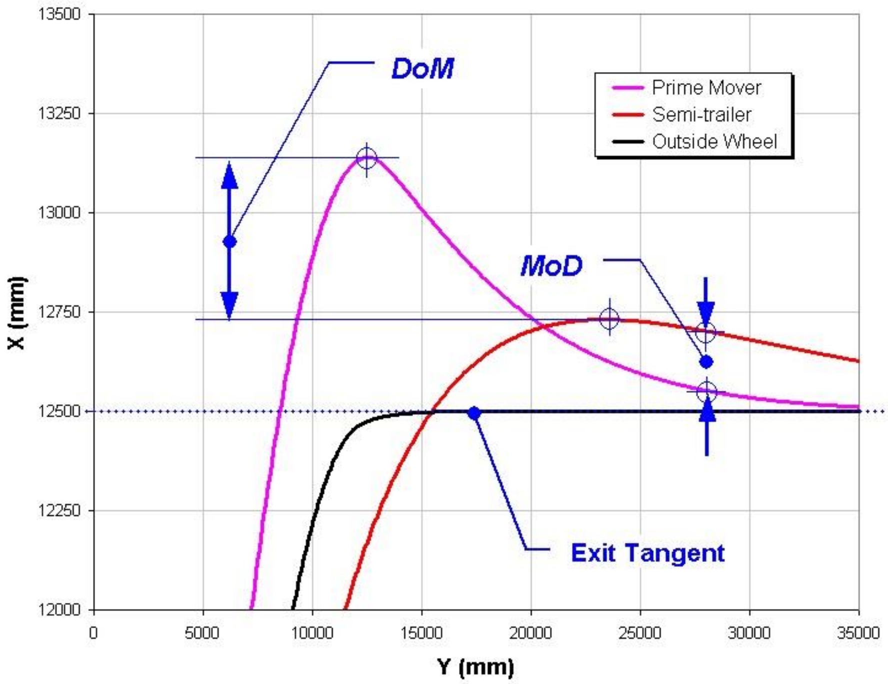

Figure 11. Further detail on the Parts B and C frontal swing DoM and MoD performance measures. Note that the vertical (X) axis scale is exaggerated.

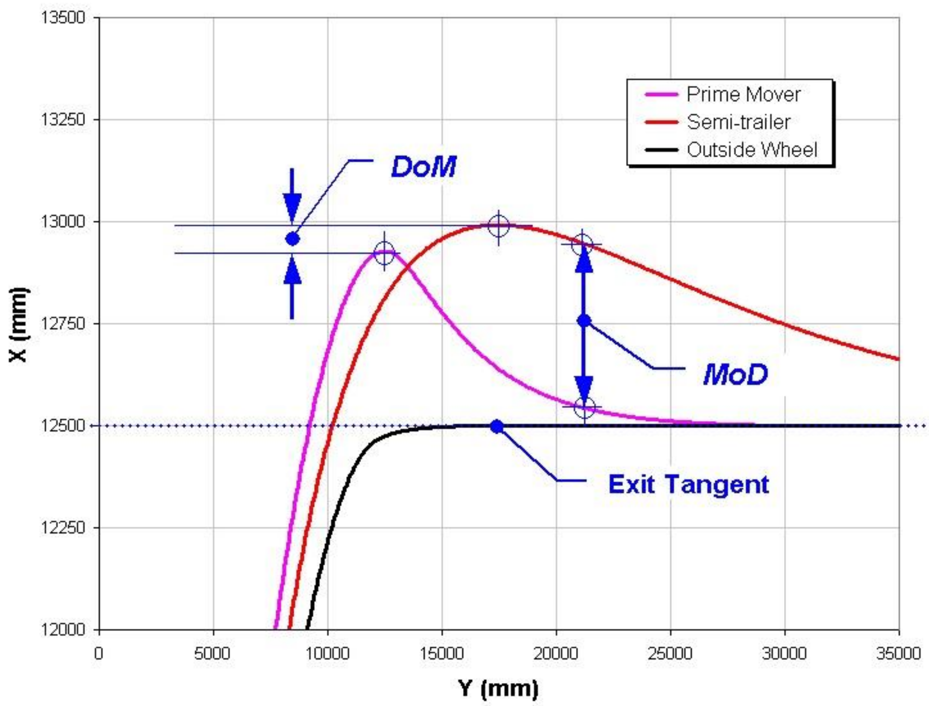

Figure 12. A contrasting example to the one shown in Figure 11 of the Parts B and C frontal swing DoM and MoD performance measures. Note that the vertical (X) axis scale is exaggerated.

(b) Performance levels

Table 12. Maximum difference of frontal swing path performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	
Level 2	
Level 3	No greater than 0.40 metre
Level 4	

C8.7 Test specification

(a) Test load

Same as for low-speed swept path.

(b) Test conditions

Same as for low-speed swept path.

(c) Test procedure

Same as for low-speed swept path.

(d) Test method

Same as for low-speed swept path.

PART C: SEMI-TRAILERS, DIFFERENCE OF MAXIMA (*DoM*)

C8.8 Definition

(a) Summary statement

The difference between the maximum frontal swing-out distances between adjacent vehicle units in a prescribed 90º low-speed turn.

(b) Detailed statement

When operating at the maximum laden mass and unladen, the difference between the maximum frontal swing-out distances of adjacent vehicle units of a vehicle participating in the Scheme, when measured relative to the exit tangent of the prescribed 90º low-speed turn performed at the specified speed, must be no greater than the specified value.

C8.9 Measure

(a) Performance value

The difference between the maximum frontal swing-out distances of adjacent vehicle units, referred to as frontal swing DoM, must be measured and reported as the achieved performance value, in units of metres rounded up to the nearest 0.01 metre The difference between the maximum values of frontal swing-out distances must be determined from the path trajectories of the outermost paths scribed in the ground plane by the vertical projection of the furthest forward or outside point, or points, on each of two adjacent vehicle units, one of which is a semi-trailer. Frontal swing DoM is the length difference between the two longest line segments perpendicular to the low-speed turn exit tangent intersecting it and one of the path trajectories, as shown in Figures 9 to 12. A negative value of DoM must be reported when the frontal swing-out of the second vehicle unit is less than the frontal swing-out of the first unit, examples are shown in Figures 10 and 11. If MoD is recorded as “not applicable”, *DoM* must also be recorded as “not applicable”.

(b) Performance levels

Table 13. Difference of maximum frontal swing out for performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	No greater than 0.20 metre
Level 2	
Level 3	
Level 4	

C8.10 Test specifications

(a) Test load

Same as for low-speed swept path.

(b) Test conditions

Same as for low-speed swept path.

(c) Test procedure

Same as for low-speed swept path.

(d) Test method

Same as for low-speed swept path.

C9: TAIL SWING

C9.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting the road space requirement of a vehicle participating in the Scheme when making a tight turn at low speed.

(b) Intent

Tail swing is important in situations where vehicle units with a large amount of rear overhang operate in an environment where tight turns are frequently required. Where tail swing is large, the rear outside corner of a rigid truck, bus or coach, prime mover or semi-trailer may swing-out a significant distance at the commencement of a turn. For conventional vehicles tail swing is only significant during commencement of a turn, but it must be tested on the entry approach and exit to the turn when a vehicle is towing trailers with steerable axles.

In urban operations, vehicles with significant rear overhang (such as route buses or semi-trailers), and/or coupling rear overhangs (such as car carriers with the turntable located behind the drive axle) will exhibit significant amounts of tail swing when negotiating tight manoeuvres (such as buses and coaches exiting kerbside pickup areas). Collisions with vehicles in adjacent lanes (including cyclists) and roadside objects may result.

C9.2 Definition

(a) Summary statement

The maximum outward lateral displacement of the outer rearmost point on a vehicle unit during the initial and final stages of a prescribed 90º low speed turn.

(b) Detailed statement

When operating at the maximum laden mass and unladen, the maximum outward lateral displacement of the outer rearmost point on a vehicle unit of a vehicle participating in the Scheme during the initial and final stages of a prescribed 90º low-speed turn performed at the specified speed must be no greater than the specified value.

C9.3 Measure

(a) Performance value

The maximum tail swing during the initial and final stages of the prescribed turn, referred to as TS_{entry} and TS_{exit}, respectively, must be measured and reported as the achieved performance value, in units of metres rounded up to the nearest 0.01 metre. Tail swing must be determined from the path trajectory of the outermost path scribed in the ground plane by the vertical projection of the furthest rearward or outside point, or points, on the vehicle unit having the greatest tail swing.

On the entry side of the turn, tail swing is the length of the longest line segment perpendicular to the low-speed turn entry tangent intersecting it and the path trajectory, similar to that shown in Figure 13.

On the exit side of the turn, tail swing is the length of the longest line segment perpendicular to the low-speed turn exit tangent intersecting it and the path trajectory, the same as that shown in Figure C9 referred to above. If there is no tail swing-out on the exit side of the turn "no swing-out" should be recorded.

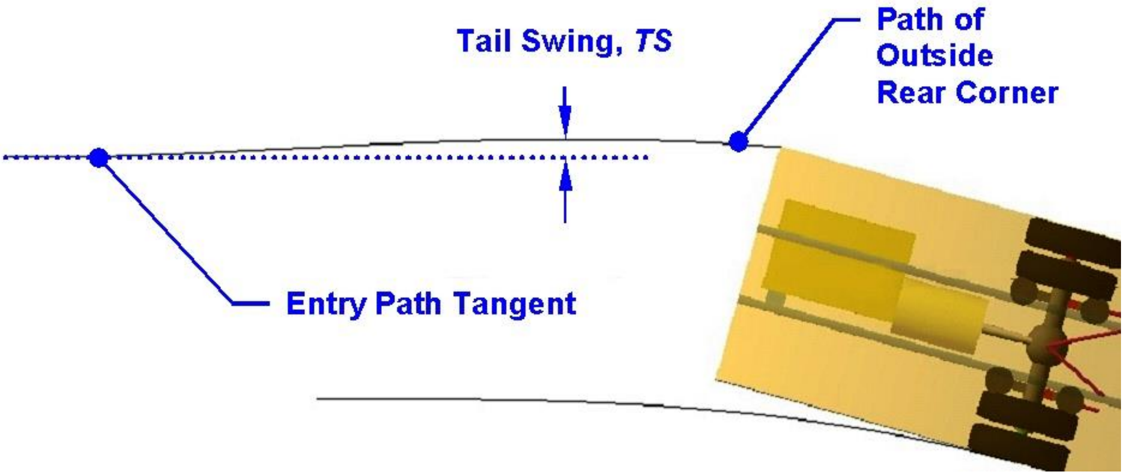

Figure 13. Illustration of tail swing performance measure at commencement of the Performance Based Standards low-speed turn.

(b) Performance levels

Table 14. Tail swing performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	No greater than 0.30 m
Level 2	No greater than 0.35 m
Level 3	No greater than 0.35 m
Level 4	No greater than 0.50 m

C9.4 Test specification

(a) Test load

Same as for low-speed swept path.

(b) Test conditions

Same as for low-speed swept path.

(c) Test procedure

Same as for low-speed swept path.

(d) Test method

Same as for low-speed swept path.

C10: STEER-TYRE FRICTION DEMAND

C10.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting the likelihood of a vehicle participating in the Scheme losing steering control when making a tight turn at low speed.

(b) Intent

During a small-radius turn at low-speed, loss of steering will occur when the available tyre/road friction limit at the steer-tyres is exceeded. In this situation the vehicle will tend to "plough straight ahead" exhibiting significant heavy understeer risking low-speed collisions with other vehicles or roadside objects. This phenomenon has been observed to occur on the hauling units of multi-combination vehicles (road trains) featuring tri-axle drive systems that have a widely spread axle layout. This is generally not an issue for prime movers with single-axle (or tandem-axle) drive systems, and less of an issue for prime movers equipped with twin-steer axles.

The problem of friction demand and "steerability" in a low-speed turn is greatest when the axle spread on the drive group is large and the prime mover wheelbase is small. Fore-aft and lateral forces from the towed trailers that are imposed on the prime mover kingpin, and kingpin lead will also influence friction demand on the steer tyres. Increasing the vertical load on the steer tyres, or decreasing the drive group load also serves to decrease the friction demand on the steer tyres.

C10.2 Definition

(a) Summary statement

The maximum friction level demanded of the steer tyres of the hauling unit in a prescribed 90º low speed turn.

(b) Detailed statement

When operating at the maximum allowed gross mass and unladen, the maximum friction level demanded of the steer tyres of the hauling in a prescribed 90º low-speed turn performed at the specified speed must be no greater than the specified value.

C10.3 Measure

(a) Performance value

The maximum value of steer tyre friction demand must be measured and reported as the achieved performance value, in percentage units, rounded up to the nearest 1%. The friction demand of an axle or axle group is given by the following expression:

$$\text{friction demand}\,(\%) = 100\left(\frac{\text{friction required}}{\text{friction available}}\right)$$

$$= 100\frac{\left|\dfrac{\sum_{n=1}^{N}\sqrt{F_{xn}^{2}+F_{yn}^{2}}}{\sum_{n=1}^{N}F_{zn}}\right|}{\mu_{peak}} \qquad \text{(C10)}$$

where:

F_{xn} = longitudinal tyre force at *n*th tyre (N)
F_{yn} = lateral tyre force at *n*th tyre (N)
F_{zn} = vertical tyre force at *n*th tyre (N)
N = number of tyres on the steer axle or axle group (-)
μ_{peak} = peak value of prevailing tyre/road friction (-)

Lateral, longitudinal and vertical tyres forces must be consistent with Society of Automotive Engineers (1976) as shown in Figure 14.

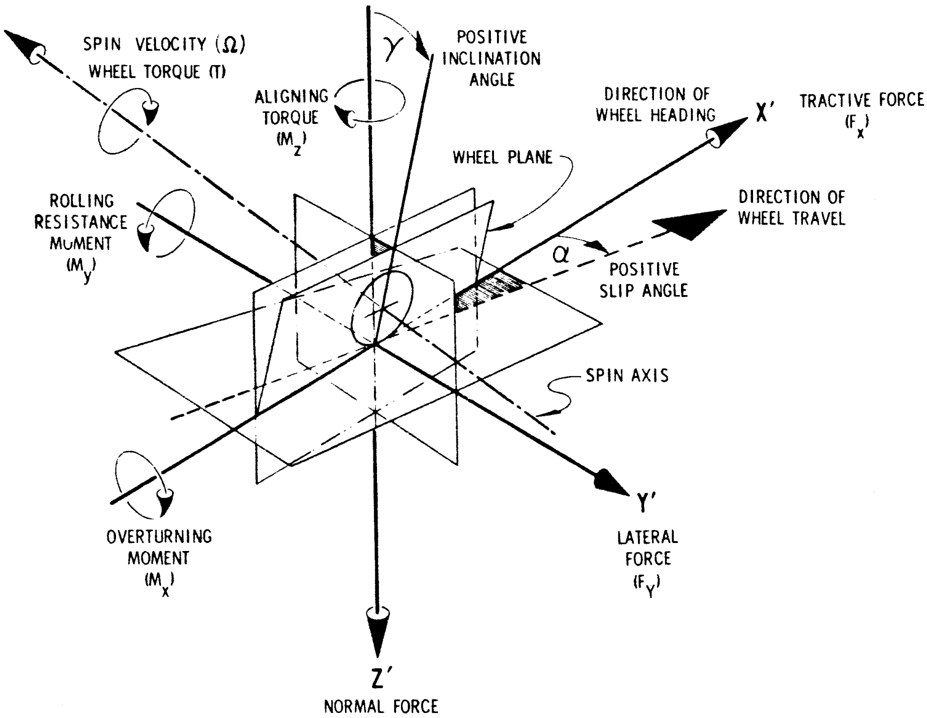

Figure 14. SAE Tyre Axis System (Society of Automotive Engineers, 1976)

The numerator in equation (C10) represents the absolute value of the ratio of the sum of horizontal tyre forces (all tyres on the axle, or axle group) to the vertical load supported by the axle, or axle group. Equation (C10) must be used to calculate steer tyre friction demand and its maximum value in the prescribed low-speed turn.

(b) Performance levels

Table 15. Steer tyre friction demand performance levels

Performance Based Standards Road Class	Performance Level Required
All levels	Not greater than 80% of the maximum available tyre/road friction limit.

C10.4 Test specification

(a) Test load

Same as for low-speed swept path.

(b) Test conditions

Same as for low-speed swept path.

(c) Test procedure

Same as for low-speed swept path.

(d) Test method

Same as for low-speed swept path.

C11: STATIC ROLLOVER THRESHOLD

C11.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting the rollover tendency of a vehicle participating in the Scheme during steady turns.

(b) Intent

A vehicle travelling along a curved path is subjected to an outward force and an overturning moment that is proportional to the lateral (or sideways) acceleration. Rollover occurs when the lateral acceleration that causes the overturning moment is sufficient to exceed the vehicle's rollover stability threshold.

Rollover stability is the most significant safety issue and arguably the most important performance measure for heavy vehicles because it has been strongly linked to rollover crashes. Crashes that involve heavy vehicle rollover are strongly associated with severe injury and fatalities (Winkler et al, 2000).

The basic measure of rollover stability is static rollover threshold, usually expressed as a fraction of the acceleration due to gravity in units of 'g', where 1g is an acceleration of $9.807 m/s^2$ corresponding to the force exerted by the earth's gravitational field. High values of static rollover threshold imply better resistance to rollover.

Rollover stability is very sensitive to the ratio of the overall track width to the height above ground of the centre of gravity of the vehicle. Rollover stability increases either by increasing this width or by decreasing centre of gravity height. Suspension properties influence static rollover stability but they are generally of lesser importance when compared with the ratio of track width to centre of gravity height.

Rollover stability for multiple trailer combinations is much more complex than for single, rigid units and depends on the type of coupling between trailers. Trailers that are connected through a turntable are said to be "roll-coupled" and will rollover together as connected units, whereas full trailers (comprising a dolly and semi-trailer) connected by a pin coupling, can both roll and rollover independently of the other units in the combination. This means that any full trailer in a combination reaching its own stability limit first would rollover before other trailers in the combination. This also applies to entire roll-coupled units within combinations, such as B-double trailer combinations in triple- or quad-trailer configurations (AB-triple, AAB-quad, or BAB-quad).

C11.2 Definition

(a) Summary statement

The steady state level of lateral acceleration that a vehicle can sustain without rolling over during turning.

(b) Detailed statement

When operating up to the maximum laden mass and least favourable load conditions, the highest steady state level of lateral acceleration that a vehicle participating in the Scheme can sustain without rolling over must be no less than the specified value.

C11.3 Measure

(a) Performance value

The rollover threshold of the vehicle, or vehicle unit with the lowest rollover stability, must be measured and reported as the achieved performance value, expressed as a fraction of the acceleration due to gravity in units of 'g', rounded down to the nearest 0.01g. For single unit vehicles, such as rigid trucks, buses and coaches, the rollover threshold is the lateral acceleration[13] of the sprung mass centre of gravity measured at the point of rollover instability. For combination and multi-combination vehicles, the rollover threshold is the resultant lateral acceleration of any unit or roll-coupled set of units, AY_{rcu}, as defined by equation C11.2a of this report, measured at the point of rollover instability.

Rollover instability is achieved when the lateral acceleration, or resultant lateral acceleration, starts to decrease with increasing roll angle, as illustrated in Figure 15 for a prime mover and semi-trailer vehicle or roll-coupled set. In general for heavy vehicles, the point of roll instability is also achieved when, or immediately after, the vertical load on all tyres along one side of the vehicle, excluding the tyres on the lightly loaded side of a steer axle(s) with soft springs, have reduced to zero.

Further, for combination and multi-combination vehicles, if the roll coupling between units in any set of units is either weak or is not continuous (such as found in double oscillating turntables or similar), and the roll angle[14] of any unit within the set is greater than 30º, rollover instability must be assumed to have been achieved.

Vehicles that reach or exceed the tyre/road friction limits before rollover occurs, and achieve a steady state lateral acceleration that is not less than the required performance level are deemed to have acceptable rollover stability.

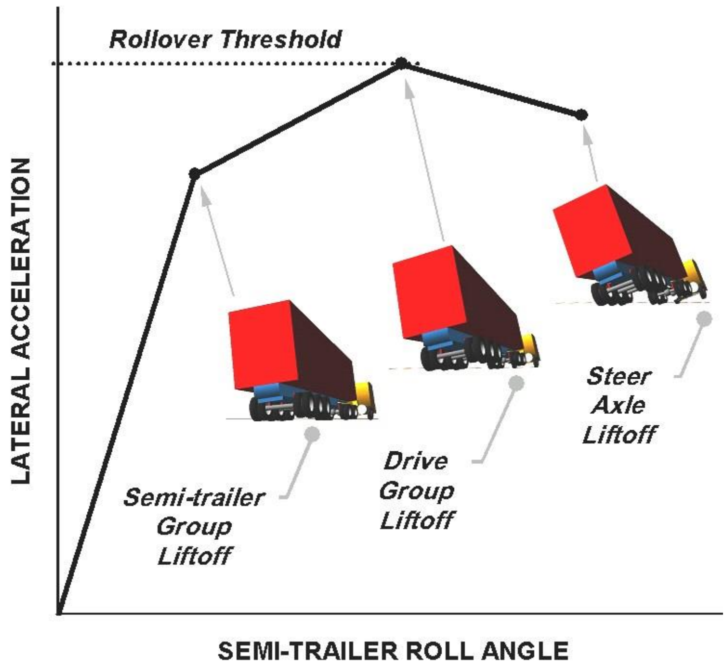

Figure 15. Typical axle lift-off sequence and rollover threshold for a prime mover and semi-trailer combination.

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13 As defined in Society of Automotive Engineers (1976).

14 As defined in Society of Automotive Engineers (1976).

Vehicles that reach or exceed the tyre/road friction limits before rollover occurs, and achieve a steady state lateral acceleration that is not less than the required performance level are deemed to have acceptable rollover stability.

(b) Performance levels

Table 16. Static rollover threshold performance levels

Performance Based Standards Road Class	Performance Level Required
All levels	Road tankers hauling dangerous goods in bulk and buses and coaches not less than 0.40g. All other vehicles not less than 0.35g

(c) Calculation of resultant lateral acceleration of roll-coupled units

This sub-section specifies the method that must be used to calculate the resultant lateral acceleration of a roll-coupled set of vehicle units in a multi-combination vehicle.

The parameter of prime interest is the resultant overturning moment and the key consideration being whether or not this moment is sufficient to cause the roll-coupled units to rollover. When the proximity of the roll-coupled units to rollover is expressed in terms of the resultant lateral acceleration, the static rollover threshold performance measure can be applied directly.

For the example of the 2 trailer roll-coupled rear units illustrated in Figure 16, the resultant lateral acceleration (ignoring the contribution from the dolly) when expressed in terms of roll moments is given by the following:

$$AY_{rcu} = \frac{m_1 h_1 AY_1 + m_2 h_2 AY_2}{m_1 h_1 + m_2 h_2} \quad \text{(C11.1)}$$

where:

AY_{rcu} = resultant lateral acceleration of the roll-coupled units (m/s^2)
$m_{1,2}$ = semi-trailer sprung mass (kg)
$h_{1,2}$ = height of sprung mass centre of gravity (m)
$AY_{1,2}$ = lateral acceleration[15] of sprung mass centre of gravity (m/s^2)

[15] As defined in Society of Automotive Engineers (1976)

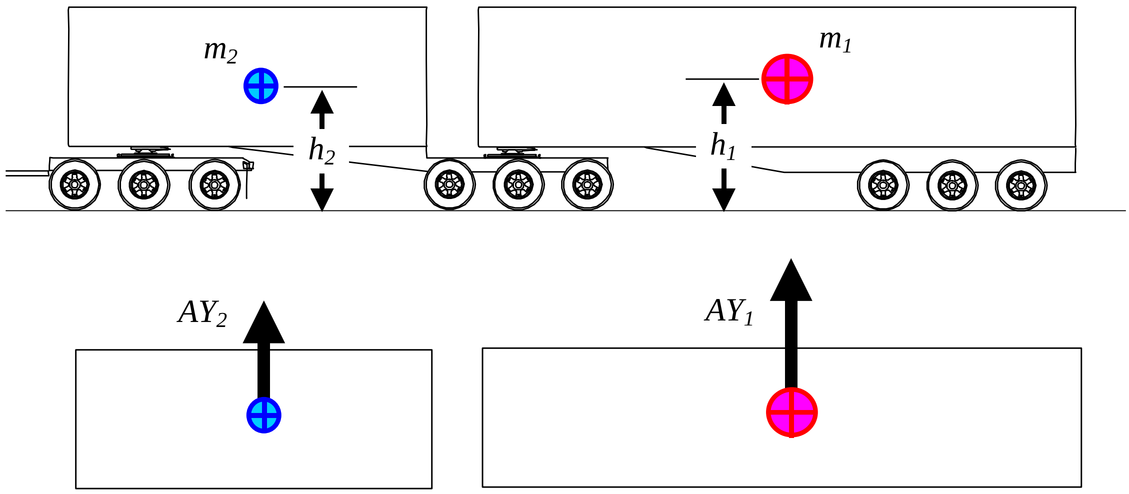

Figure 16. Side and plan view illustration of 2 roll-coupled trailers showing sprung masses, sprung mass centre of gravity heights, and lateral accelerations, *AY*.

Equation (C11.2a) shown below is the generalised form of equation (C11.1), which can be used to determine the resultant lateral acceleration for vehicles having any number (N) of roll-coupled units.

$$AY_{rcu} = \frac{\sum_{n=1}^{N} m_n h_n AY_n}{\sum_{n=1}^{N} m_n h_n} \qquad \text{(C11.2a)}$$

As the last trailer of a roll-coupled trailer set will generally have both a greater mass and slightly higher centre of gravity than the trailers ahead of it, as illustrated above in Figure 16, the average lateral acceleration will be weighted more heavily to the larger value of the rear trailer. However, it is useful to note that when the masses and centre of gravity heights of all the roll-coupled units are identical, equation (C11.2a) reduces to equation (C11.2b), which is simply the average value of lateral accelerations at any instant during the manoeuvre.

$$AY_{rcu} = \frac{\sum_{n=1}^{N} AY_n}{N} \qquad \text{(C11.2b)}$$

C11.4 Test specification

(a) Test load

The vehicle being assessed must be tested at the *maximum laden mass* and in both turn directions at the least favourable load conditions. Each tyre on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyre. Each tyre must be inflated to the pressure as specified by the vehicle and/or tyre manufacturer.

The tread depth of each tyre must not decrease by more than 2 mm during field testing.

(b) Test conditions

The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

One of the following two test procedures must be used to measure static rollover threshold:

(i) Constant radius quasi-steady turn – The vehicle being assessed must be driven along the specified path at an initial speed that is at least 10 km/h slower than the speed at which the rollover instability will occur. The path of the specified turn that the driver will use to guide the vehicle must be circular and of radius not less than 100 metres. In the turn the driver must steer the vehicle along the specified path. The vehicle must be steered such that the vertical projection in the ground plane of a point at the centre of the forward-most steer axle follows the specified path. Using the above point as a reference, the driver must steer the vehicle along the specified path and maintain a lateral distance error between the reference point and the specified path not greater than 1.5 metres. From the initial speed, which must be maintained for at least 15 seconds on the specified path, the driver must increase the speed of the vehicle to the point of rollover instability at:

(a) an average rate, measured over any 5-second period, not greater than 0.5 km/h per second; or

(b) in increments of 2 km/h per lap.

This procedure is particularly relevant to long multi-combination vehicles that take much longer to reach steady turn conditions than short vehicles.

(ii) Tilt table – In accordance with recommended practice SAE J2180 (Society of Automotive Engineers, 1998).

(d) Test method

Numerical modelling (computer-based simulation) or field-testing.

C12: REARWARD AMPLIFICATION

C12.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting the lateral-directional response of multi-articulated vehicles participating in the Scheme in avoidance manoeuvres performed at highway speeds without braking.

(b) Intent

Rearward amplification generally pertains to heavy vehicles with more than one articulation point, such as truck-trailers and road train combinations. It shows as a tendency for the following or trailing unit(s) to experience higher levels of lateral acceleration than the towing unit. It is a serious safety issue in rapid path-change manoeuvres as it can lead to rear-trailer rollover.

As the name rearward amplification suggests, each unit in the combination experiences lateral acceleration that is an amplification of that experienced by the unit immediately ahead of it, and thus amplification of lateral acceleration increases toward the rear of the vehicle. Lower values of rearward amplification indicate better performance. High values of rearward amplification imply high probabilities of rear-trailer rollover. In some cases rearward amplification is less than unity (i.e. lateral acceleration is attenuated).

Rearward amplification improves with fewer articulation points, a shorter distance from the centre of gravity of the hauling unit to the hitch point, roll-coupling through turntables at articulation points, shorter coupling rear overhang, longer drawbar lengths on dollies, longer trailer wheelbase, and tyres with higher cornering-stiffness.

C12.2 Definition

(a) Summary statement

The degree to which the trailing unit(s) amplify the lateral acceleration of the hauling unit.

(b) Detailed statement

When operating up to the maximum allowed gross mass and least favourable load conditions, the ratio of the maximum value of the specified lateral acceleration response of the rearmost unit, or rearmost roll-coupled units, to the lateral acceleration input measured at the steer axle of the vehicle being assessed in the specified test must be no greater than the specified value.

C12.3 Measure

(a) Performance value

The maximum value of the ratio of the specified lateral acceleration[16] response of the rearmost unit or roll-coupled set of units (referred to as the lateral acceleration output) to the specified lateral acceleration input, measured at the steer axle of the vehicle being assessed (referred to as the lateral acceleration input), must be measured and reported as the achieved performance value, expressed as a non-dimensional quantity, rounded up to

[16] As defined in Society of Automotive Engineers (1976).

the nearest 0.01. The specified lateral acceleration input must be measured at the centre of the forward-most steer axle of the vehicle in the specified single lane-change manoeuvre defined in Section C12.4(c). The specified lateral acceleration output must be measured, and rearward amplification calculated, in accordance with Section C12.3 (c).

(b) Performance levels

Table 17. Rearward amplification performance levels

Performance Based Standards Road Class	Performance Level Required
All levels	Not greater than 5.7 times the static rollover threshold of the rearmost unit or roll-coupled set of units taking account of the stabilising influence of the roll coupling.

(c) Measurement of rearward amplification

The general definition of rearward amplification presented in terms of lateral acceleration that must be used is given by the following:

$$RA = \frac{|AY|_{\max}\ of\ following\ vehicle\ unit}{|AY|_{\max}\ of\ first\ vehicle\ unit} \qquad \text{(C12.1)}$$

The following is ascribed to the numerator and the denominator terms, respectively:

$|AY|_{\max}$ *of following vehicle unit* = maximum absolute value of the lateral acceleration of the centre of mass of the sprung mass of the last vehicle unit (m/s^2)

$|AY|_{\max}$ *of first vehicle unit* = maximum absolute value of the lateral acceleration of the centre of the front axle (m/s^2)

(i) Rigid vehicles and combination vehicles with a single rear unit

For rigid vehicles the lateral acceleration of the "following vehicle unit" described above in equation (12.1) is simply that of the centre of gravity of the sprung mass. That is, for rigid vehicles the "following vehicle unit" and "first vehicle unit" is the same unit.

Where the last unit comprises a single full trailer, namely, a dolly and a single semi-trailer, the lateral acceleration of the "following vehicle unit" described above is simply that of the centre of gravity of the sprung mass of the last semi-trailer.

(ii) Combination Vehicles with Roll-Coupled Rear Units

All units in a vehicle combination that are connected to each other either by turntables or other means of transmitting overturning-moments are said to be roll-coupled. The <u>r</u>earmost <u>r</u>oll-<u>c</u>oupled <u>u</u>nits (rrcu) in a vehicle combination are all the rear units that are connected by mechanical components or devices able to transmit overturning moments. The rrcu in 3 example vehicles is illustrated below in Figure 17.

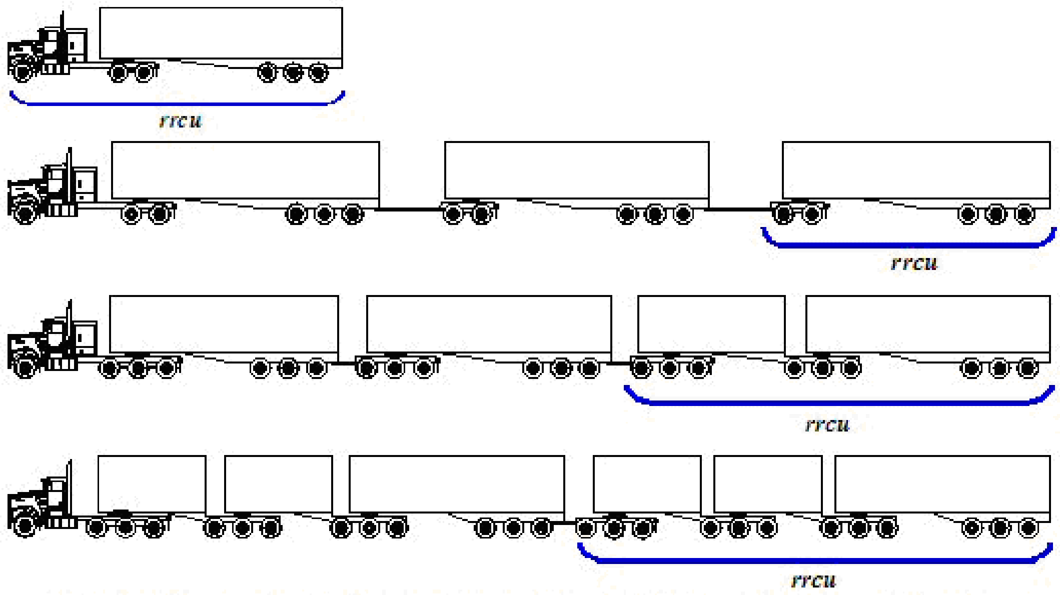

Figure 17. Illustration of rearmost roll-coupled units (rrcu) in 3 example vehicles; a prime mover and semi-trailer combination, an A-triple, an AAB-quad and a Double B-Triple.

Combination vehicles having rear units that are roll-coupled are generally able to perform better in a lane change manoeuvre than a vehicle having the same number of units but where roll coupling is not present. This is because where roll-coupling is present, overturning moments acting on one semi-trailer are transmitted through the points of connection, such as turntables, to the adjacent units thereby providing some additional roll support. Adjacent units connected by a turntable will only overturn when both units rollover.

The following method must be used to calculate rearward amplification for vehicles with rear units that are roll-coupled. The method is better able to quantify the proximity of the rearmost trailer set to rollover in the lane change manoeuvre, and, therefore, is consistent with setting a performance level linking rearward amplification to the static rollover threshold of the rearmost roll-coupled units.

(iii) Lateral acceleration of roll-coupled rear units

Where the rearmost vehicle units comprise, say, two or more semi-trailers that are roll-coupled, the lateral acceleration of the "following vehicle unit" described above in equation (12.1) must be calculated using the following scheme.

The parameter of prime interest is the resultant overturning moment and the key consideration being whether or not this moment is sufficient to cause the rear roll-coupled units to rollover. When the proximity of the rear roll-coupled units to rollover is expressed in terms of the lateral acceleration it can be compared directly to the static rollover threshold.

For the example 2 trailer roll-coupled rear units illustrated in Figure 17 the resultant lateral acceleration when expressed in terms of roll moments at each instant in the lane change is given by following (which is the same as equation C11.1):

$$AY_{rcu} = \frac{m_1 h_1 AY_1 + m_2 h_2 AY_2}{m_1 h_1 + m_2 h_2} \qquad \text{(C12.2)}$$

where:

AY_{rcu} = resultant lateral acceleration of the roll-coupled units (m/s^2)
$m_{1,2}$ = semi-trailer sprung mass (kg)
$h_{1,2}$ = height of sprung mass centre of gravity (m)
$AY_{1,2}$ = lateral acceleration of sprung mass centre of gravity (m/s^2)

Equation (C12.3a) shown below is the generalised form of equation (C12.2), which can be used to determine the resultant lateral acceleration for vehicles having any number (*N*) of roll-coupled rear units.

$$AY_{rcu} = \frac{\sum_{n=1}^{N} m_n h_n AY_n}{\sum_{n=1}^{N} m_n h_n} \qquad \text{(C12.3a)}$$

As the last trailer of a roll-coupled trailer set will generally have both a greater mass and slightly higher centre of gravity than the trailers ahead of it, as illustrated in Figure 16, the average lateral acceleration will be weighted more heavily to the larger value of the rear trailer. However, it is useful to note that when the masses and centre of gravity heights of all the roll-coupled rear units are identical, equation (C12.3a) reduces to equation (C12.3b), which is the mean of the lateral accelerations at any instant during the manoeuvre.

$$AY_{rcu} = \frac{\sum_{n=1}^{N} AY_n}{N} \qquad \text{(C12.3b)}$$

For a two-unit roll-coupled rear trailer set, with each unit having identical masses and centre of gravity heights, equation (C12.3b) shows that if the lateral accelerations are equal in magnitude and opposite in sign (making the average of AY_{rcu} equal to zero), the motion of the roll-coupled rear trailers are exactly out of phase and the roll moments exactly balance each other, one trailer trying to roll to the left while the other is trying to roll to the right. While this is unlikely to occur in practice, it is a simple illustration of the positive influence of roll coupling.

The generalised version of equation (C12.1), which must be applied as part of this specification to vehicles with rear units that are roll-coupled is given below in equation (C12.4).

$$RA_{rcu} = \frac{\left|AY_{rcu}\right|_{\max} \ of\ last\ vehicle\ unit}{\left|AY\right|_{\max} \ of\ steer\ axle} \qquad \text{(C12.4)}$$

where:

$|AY_{rcu}|_{max}$ of last vehicle unit = maximum absolute value of the resultant lateral acceleration of the roll-coupled rear units determined from equation (C12.3a) (m/s^2)

(iv) When all units are roll-coupled

As the input to the manoeuvre and excitation to the vehicle occurs at the hauling unit, the output/input relationship must clearly distinguish between the hauling unit (the steer input, or the source of the excitation) and the roll-coupled trailer set (the location where the response occurs). Therefore, when all units in a vehicle combination are roll-coupled, examples being a prime-mover and semi-trailer combination, B-doubles, B-triples and B-quad combinations, equation (C12.3a) should be applied to the semi-trailers. That is, the numerator of equation (C12.4) must include only a single semi-trailer for a prime mover and semi-trailer combination, and double, triple and quad semi-trailer sets for B-double, B-triple and B-quad combinations, respectively.

C12.4 Test specification

The vehicle must execute a single lane change manoeuvre in accordance with the "Single Lane-Change", "Single Sine-Wave Lateral Acceleration Input", specified in ISO 14791:2000(E) (International Standards Organisation, 2000)[17]. The basic course layout must be used. The manoeuvre must have a maximum lateral acceleration of not less than 0.15g and a steer frequency equal to 0.40 Hz. The test must be conducted at 88 km/h.

The driver must steer the vehicle along the specified path and maintain a lateral distance error between the reference point – taken to be the vertical projection in the ground plane of the centre of the forward most steer axle – and the specified path that is either:

- not greater than 30 mm; or,
- as specified in ISO 14791 such that the lateral acceleration and frequency of the input is not less than the value for the manoeuvre specified in the paragraph above.

If the specifications given in ISO 14791 differ to those described here, this specification takes precedence.

(a) Test load

In accordance with the "Single Lane-Change", "Single Sine-Wave Lateral Acceleration Input", specified in ISO 14791:2000(E) (International Standards Organisation, 2000).

Additionally, the vehicle being assessed must be tested laden at the least favourable load condition. If load asymmetries constitute the least favourable load condition then the vehicle must also be tested in both turn directions.

(b) Test conditions

In accord with the "Single Lane-Change", "Single Sine-Wave Lateral Acceleration Input", specified in ISO 14791:2000(E) (International Standards Organisation, 2000).

(c) Test procedure

In accord with the "Single Lane-Change", "Single Sine-Wave Lateral Acceleration Input", specified in ISO 14791:2000(E) (International Standards Organisation, 2000).

(d) Test method

Numerical modelling or field-testing.

17 SAE J2179 has been superseded by ISO 14791. The test specified above is equivalent to the SAE J2179 single lane change.

C13: HIGH-SPEED TRANSIENT OFFTRACKING

C13.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by limiting the sway of the rearmost trailers of multi-articulated vehicles participating in the Scheme in avoidance manoeuvres performed without braking, at highway speeds.

(b) Intent

In an abrupt evasive manoeuvre, the lateral displacement of the rear end of the last trailer of an articulated vehicle may "overshoot" the final path of the front axle of the hauling unit; the path achieved after the hauling unit has completed the manoeuvre and stabilised in its new straight ahead path parallel to its original path. The amount of overshoot, referred to as high-speed transient offtracking (and sometimes also referred to as trailer overshoot), can be viewed as an indication of the severity of intrusion into an adjacent or opposing lane, striking a kerb or dropping off the road seal (thus precipitating rollover) or collision with a roadside objects.

Crash studies suggest there is a trend of crash rate increasing with increased high-speed transient off tracking. The crash consequences of heavy vehicles performing avoidance manoeuvres will depend on the road environment and factors such as lane width and traffic volume. Where lane widths are narrow and traffic volumes are high, it is desirable for heavy vehicles to have lower levels of high-speed transient offtracking.

The parameters that influence rearward amplification have similar strong influences on High-Speed Transient Offtracking.

C13.2 Definition

(a) Summary statement

The lateral distance that the last-axle on the rearmost trailer tracks outside the path of the steer axle in a sudden evasive manoeuvre.

(b) Detailed statement

When operating up to the maximum laden mass and least favourable load conditions, the maximum lateral displacement between the specified point on the rearmost axle of the rearmost vehicle unit of a vehicle participating in the Scheme and the exit tangent in the specified test must be no greater than the specified value.

C13.3 Measure

(a) Performance value

The maximum lateral distance between the path trajectory of the specified point on the vehicle being assessed, measured in the ground plane and perpendicular to the exit tangent of the single lane change, single sine-wave lateral acceleration input, test course must be measured and reported as the achieved performance value, expressed in units of metres and rounded up to the nearest 0.1 metre. The specified point on the vehicle is the vertical projection in the ground plane of a point at the centre of the rearmost axle of the rearmost vehicle unit, as illustrated in Figure 18. When the maximum distance corresponds to an overshoot situation, as shown in Figure 18 and defined in Figure 19, the performance value must be recorded as a positive distance. When the maximum distance corresponds to an undershoot situation, as illustrated in Fig, C13.2, the performance value must be recorded as a negative distance.

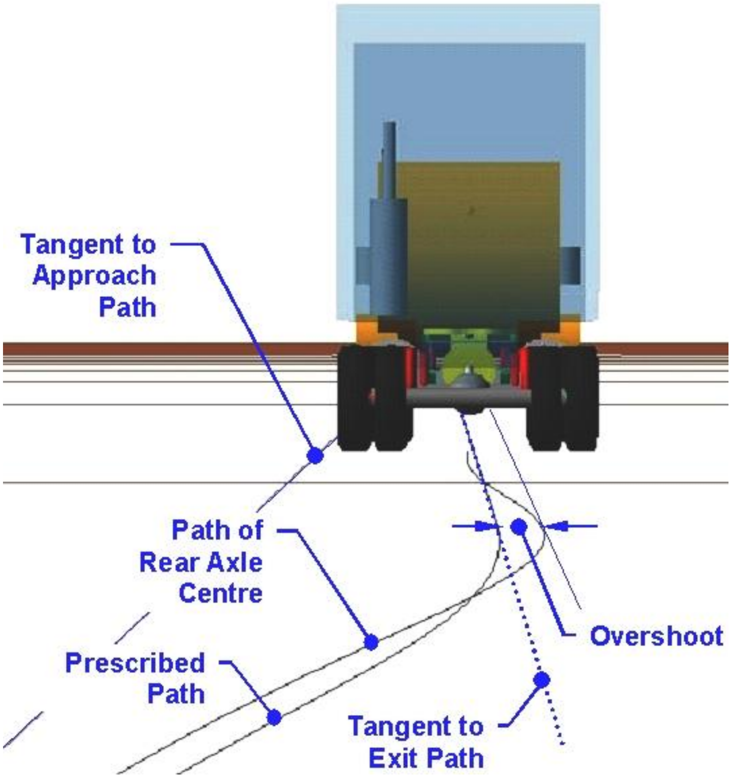

Figure 18. Perspective view illustration of final stages of the single lane change manoeuvre showing overshoot dimension in the ground plane of the rear axle centre for high-speed transient offtracking.

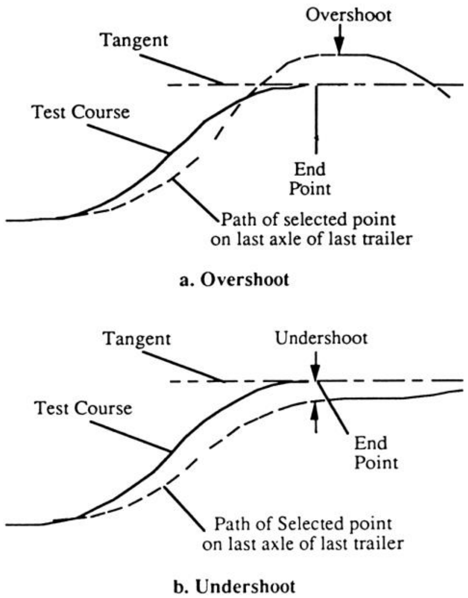

Figure 19. Illustration of high-speed transient offtracking overshoot and undershoot scenarios from Society of Automotive Engineers (1993a).

(b) Performance levels

Table 18. High speed transient offtracking performance levels

Performance Based Standards Road Class	Performance Level Required
Level 1	No greater than 0.6 m
Level 2	No greater than 0.8 m
Level 3	No greater than 1.0 m
Level 4	No greater than 1.2 m

C13.4 Test specification

(a) Test load

Same as for rearward amplification.

(b) Test conditions

Same as for rearward amplification.

(c) Test procedure

Same as for rearward amplification.

(d) Test method

Same as for rearward amplification.

(e) Further Notes

If the specification in ISO 14791:200(E) differs to those described here, this specification takes precedence.

C14: YAW DAMPING COEFFICIENT

C14.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by requiring acceptable attenuation of any sway oscillations of rigid vehicles participating in the Scheme or between the trailers of multi-articulated vehicles participating in the Scheme.

(b) Intent

An important consideration in the stability and handling of heavy vehicles is how quickly swing or sway oscillations take to "settle down" or decay after a severe manoeuvre has been performed. Vehicles that take a long time to settle increase the driver's workload[18] and represent a higher safety risk to other road users and to the driver. The yaw damping coefficient performance measure quantifies how quickly "sway", or yaw oscillations take to settle after application of a short duration steer input at the hauling unit.

Yaw damping decreases with speed, and at higher speeds the oscillations may take longer to decay or they may become divergent (increase in amplitude) and lead to rollover.

The parameters that influence rearward amplification have similar strong influences on yaw damping coefficient.

C14.2 Definition

(a) Summary statement

The rate at which "sway" or yaw oscillations decay after a short duration steer input at the hauling unit.

(b) Detailed statement

When operating up to the maximum allowed gross mass and least favourable load conditions, the maximum rate at which yaw oscillations decay in the specified test must be no less than the specified value.

C14.3 Measure

(a) Performance value

The damping ratio calculated from the specified motion variable in the specified test must be measured and reported as the achieved performance value, expressed as a dimensionless quantity and rounded down to the nearest 0.01. The specified motion variable is the articulation angle, or articulation angular velocity, between adjacent units, or the yaw rate of a unit, which gives the lowest damping of the vehicle combination. From the time history of the motion variable, all amplitudes starting with the first largest amplitude, A_1, after application of the specified steer input must be determined, as illustrated in Figure 20. The mean value of the amplitude ratios, $\bar{A}$, must be calculated separately for each articulation joint, or unit, using the following equation:

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[18] Driver workload, as reflected in the frequency of steering control movements, tends to increase with increasing speed and decreasing lane width, that is, as the driving task becomes 'tighter' (McLean and Hoffman, 1971; McLean and Hoffman, 1973). Adequate levels of yaw damping ensure lightly damped yaw oscillations, which typically fall in drivers' steer control bandwidth (up to 0.6 Hz), will help mitigate driver fatigue and vehicle controllability issues.

$$\bar{A} = \frac{1}{n-2}\left(\frac{A_1}{A_3} + \frac{A_2}{A_4} + \frac{A_3}{A_5} + \ldots + \frac{A_{n-2}}{A_n}\right) \qquad \text{(C14a)}$$

Amplitude A_n must be at least 5% of A_1 and the calculation of $\bar{A}$ must be based upon at least 6 amplitudes. The damping ratio, D, is calculated according to the following formula:

$$\mathrm{D} = \frac{\ln(\bar{A})}{\sqrt{(2\pi)^2 + [\ln(\bar{A})]^2}}, \qquad \text{(C14b)}$$

If the 5% limit referred to above is reached before the 6th amplitude, then the following formulae may be used in place of equations (C14a) and (C14b), respectively:

$$\bar{A} = \frac{1}{n-1}\left(\frac{A_1}{A_2} + \frac{A_2}{A_3} + \frac{A_3}{A_4} + \ldots + \frac{A_{n-1}}{A_n}\right) \qquad \text{(C15a)}$$

$$\mathrm{D} = \frac{\ln(\bar{A})}{\sqrt{(\pi)^2 + [\ln(\bar{A})]^2}}, \qquad \text{(C15b)}$$

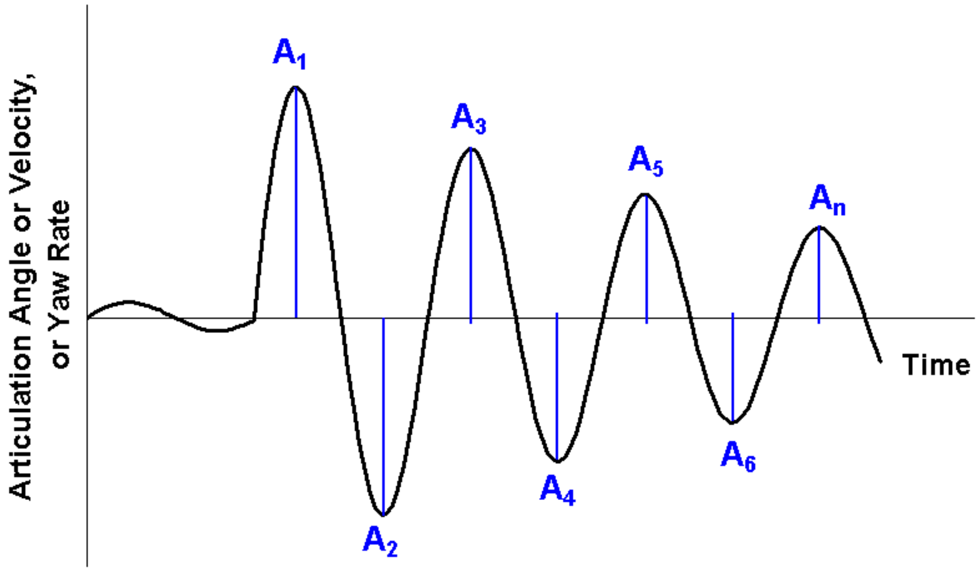

Figure 20. Determination of amplitudes for damping ratio calculation.

(b) Performance levels

Table 19. Yaw damping performance levels

Performance Based Standards Road Class	Performance Level Required
All levels	Not less than 0.15 at the certified vehicle speed.

C14.4 Test specifications

(a) Test load

In accordance with the "Pulse Input", "Steer Impulse", method specified in ISO 14791:2000(E) (International Standards Organisation, 2000).

Additionally, the vehicle being assessed must be tested laden at the least favourable load conditions and include load asymmetries. If load asymmetries constitute the least favourable load condition then the vehicle must also be tested in the left and right steer directions.

(b) Test conditions

In accord with the "*Pulse Input*", "*Steer Impulse*", method specified in ISO 14791:2000(E) (International Standards Organisation, 2000).

(c) Test procedure

In accord with the "*Pulse Input*", "*Steer Impulse*", method specified in ISO 14791:2000(E) (International Standards Organisation, 2000).

(d) Test method

Numerical modelling or field-testing.

(e) Further notes

If the specification in ISO 14791:2000(E) differs to those described here, this specification takes precedence.

C15: HANDLING QUALITY (UNDERSTEER/OVERSTEER)

C15.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk by ensuring adequate steering control over a wide range of turn conditions.

(b) Intent

For reasons of practicality and safety, a heavy vehicle should be controllable and stable enough to follow a desired path in response to steering. Handling quality, expressed in terms of the “understeer/oversteer” coefficient, in simple terms refers to the responsiveness and “feel” of the vehicle to driver steering control. The understeer/oversteer behaviour of heavy vehicles has been found to vary significantly with lateral acceleration, and in some situations this marked change in steering response may make the vehicle difficult to control or unstable.

Handling quality will be primarily influenced by the mechanical properties of the prime mover, including hauling unit wheelbase, king-pin lead, tyre cornering stiffness, steer-axle roll centre height, roll steer coefficient and total roll stiffness.

C15.2 Definition, measure and test specification

This standard has yet to be defined. Its three main components (a performance measure, a test procedure from which to obtain the performance measure and a performance level, or levels, to be satisfied) are not able to be defined to an acceptable level of robustness at this time based on current research.

There is one recognised method[19] for assessing heavy vehicle handling quality. The method was developed as a research tool and is presently not considered to be sufficiently robust to be incorporated as a performance standard. One known deficiency with the method is that its results are very sensitive to minor changes in vehicle design parameters. Further research is required in order to determine exactly what constitutes satisfactory (or unsatisfactory) heavy vehicle handling. This will enable the setting of a performance level, or levels, for this standard to be completed in a robust manner. Setting the performance level(s) such that they are too easy to satisfy will potentially allow all vehicles to pass the standard, regardless of their performance. Conversely, setting the performance level(s) such that they are too difficult to satisfy may potentially disallow all vehicles.

The NTC has initiated a project to finalise this standard in its 2007/2008 work programme. A proposal will be submitted to the Australian Transport Council for approval in 2008 following consultation with industry and Transport Agency Chief Executives.

[19] The ‘three-point’ handling measure, developed by El-Gindy and Woodrooffe in 1990.

C16: DIRECTIONAL STABILITY UNDER BRAKING

C16.1 Purpose and intent

(a) Purpose

The primary purpose of this standard is to manage safety risk of vehicle instability when braking in a turn or on pavement cross slopes.

(b) Intent

The ability of a vehicle to remain stable, controllable and kept within its lane during heavy braking is a key safety consideration in all road transport tasks and in all areas of heavy vehicle operation – urban, regional and remote. Rollover or loss of control (such as if a jack-knife occurs), present high safety risks to the driver and to other road users, which can lead to injury and fatalities.

Heavy braking in a turn is a challenging manoeuvre that subjects the vehicle to a complex combination of longitudinal and lateral acceleration placing severe demands on both driver skill and vehicle performance. A high level of stability reduces the likelihood of a crash and is therefore desirable, particularly in environments where traffic volumes and/or travel speeds are high, and the probability of a crash having a severe outcome is great.

C16.2 Definition

(a) Summary statement

The ability to maintain directional stability under braking.

C16.3 Measure

A vehicle must meet the performance level specified in paragraph (a) below, or one of the arrangements specified in paragraph (b) below must exist.

(a) Performance Level

- A vehicle must not exhibit gross wheel lock-up behaviour in any loading condition and must remain in a straight lane of width equal to that specified in the standard ‘Tracking ability on a straight path’ for the corresponding level of operation when it is braked from 60 km/h to achieve the assessment deceleration level on a high-friction surface roadway. The proposed assessment deceleration levels are shown in Table 20.

Table 20. Deceleration levels for vehicles participating in the Scheme

Performance Based Standards Network Access Level	Typical vehicle configuration	Average Deceleration from 60 km/h
Single motor vehicles (All access levels)	Rigid trucks and buses	0.40 g
1	Semi-trailers	0.35 g
2	B-double combinations	0.30 g
3	Road-train A-doubles and B-triples	0.25 g
4	Road-Train A-triples	0.20 g

- A vehicle (part) that relies upon an antilock brake system to comply with the standard must have automatic brake adjusters on each axle that are controlled by the anti-lock brake system.
- A (motor) vehicle that has an auxiliary brake system fitted that could produce an average deceleration of 0.1g or higher on the unladen (motor) vehicle must not be capable of applying automatically. This requirement is deemed to be met if the (motor) vehicle has an antilock brake system that both controls all the drive axle group wheels and has veto control over the auxiliary brakes.
- All parts of the (combination) vehicle must comply with the applicable Australian Design Rule for braking at the time of manufacture. If a load-proportion brake system is fitted it must comply with the unladen compatibility requirements in Australian Design Rule 35/02 (motor vehicles) or Australian Design Rule 38/03 (trailers). Concessions against the Australian Design Rule requirements in individual cases that have been agreed to by the Administrator of Motor Vehicle Standards are to be recognised when assessing compliance with this item.

Definitions:

The absence of gross wheel lock-up is defined as follows:

- Single and tandem axle groups do not exhibit sustained wheel lock-up on any axles at the assessment deceleration levels.
- Tri-axle and quad axle groups can exhibit sustained wheel lock-up on one axle only in the group at the assessment deceleration level.
- An axle group with more than four axles can exhibit wheel lock-up on any two axles in the group at the assessment deceleration level.
- Wheel lock-up that occurs on any wheel at speeds below 10 km/h can be ignored because the potential for a vehicle to deviate seriously from the preferred path is minor.

Axle groups are defined as follows:

- The axle-group definitions applicable to Australian Design Rules 35 and 38 are pertinent.
- The axles on a dolly trailer should be considered as forming one axle group.

(b) Deemed-to-comply provisions

Three deemed-to-comply arrangements are available as alternatives to independently finding means of meeting the proposed standard:

- a vehicle that has a functioning anti-lock brake system that effectively prevents gross wheel lock-up on each axle group (as defined in the definitions) is deemed to comply with the standard; or
- a motor vehicle in a combination vehicle that has a functioning anti-lock brake system that effectively prevents gross wheel lock-up behaviour on the motor vehicle, can be ignored when the test or simulation assessment is made. That is, the motor vehicle is deemed-to-comply and only the performance of the trailer(s) against the performance standard needs be addressed; or

- a combination vehicle that has a load proportioning brake system on each part that has been set to meet the lightly laden compatibility limits in the pending revisions to Australian Design Rules 35 and 38 (Australian Design Rule 35/02 and 38/03) is deemed to comply with this standard. Note that a motor vehicle that has an antilock brake system as described in the preceding paragraph and trailer(s) that meet the lightly laden compatibility limits are deemed to comply with this standard.

C16.4 Test specifications

(a) Test load

The vehicle being assessed should be tested in the unladen condition. If the vehicle complies in the unladen condition, it is deemed to comply in the laden condition.

Each tyre on the vehicle must have a tread depth of at least 90% of the original value over the whole tread width and circumference of the tyre. Each tyre must be inflated to the pressure as specified by the vehicle and/or tyre manufacturer. The tread depth of each tyre must not decrease by more than 2 mm during field testing.

(b) Test conditions

The test site must have uniform, smooth, dry, hard pavement, which is free from contaminants. The surface must have a coefficient of friction value, μ_{peak}, at the tyre/road contact surface of not more than 0.80.

(c) Test procedure

The test (initial) speed should be in the range 59 – 65 km/h.

The point where deceleration starts and the point where the vehicle stops should be marked on the test roadway. The computed average deceleration is then:

$$\text{Average deceleration} = \tfrac{1}{2}\,(\text{initial speed in m/s})^2 \,/\, (g \times \text{stopping distance in m})$$

$$\text{where } g = 9.81 \text{ m/s}^2$$

The wheel lock-up behaviour can be assessed by video recording the wheels on each side of the vehicle. Temporary marking of the exposed tyre walls will assist in assessing whether the wheels are locked or not.

Acceptable test conditions exists when the average deceleration is at least equal to the applicable assessment deceleration level in Table 20.

(d) Test method

Numerical modelling or field-testing.

(e) Further notes

All parts of the (combination) vehicle must comply with the applicable Australian Design Rule for braking at the time of manufacture.

If a load-proportion brake system is fitted it must comply with the unladen compatibility requirements in Australian Design Rule 35/02 (motor vehicles) or Australian Design Rule 38/03 (trailers).

APPENDIX D: [RESERVED]

APPENDIX E: ASSESSING SAFETY STANDARDS BY NUMERICAL MODELLING

This appendix specifies the methods by which the safety standards must be assessed when numerical modelling is selected as the method of assessment.

This appendix is supplementary to, and must be used in conjunction with, Appendix C.

Table 21. Numerical Modelling - Safety standards references

Standard	**Relevant Section in this appendix**
C1: Startability	E1
C2: Gradeability	E1
C3: Acceleration Capability	E1
C4: Overtaking Provision	Transferred to Network Classification Guidelines
C5: Tracking Ability on a Straight Path	E2
C6: Ride Quality (Driver Comfort)	not addressed in this appendix
C7: Low-Speed Swept Path	E3
C8: Frontal Swing	E3
C9: Tail Swing	E3
C10: Steer-Tyre Friction Demand	E3
C11: Static Rollover Threshold	E4
C12: Rearward Amplification	E4
C13: High-Speed Transient Offtracking	E4
C14: Yaw Damping Coefficient	E4
C15: Handling Quality (Understeer/Oversteer)	not addressed in this appendix
C16: Directional Stability Under Braking	E5

The **vehicle conditions** and **test conditions** must comply with the requirements of Appendix C and this appendix. If a conflict occurs between the requirements of Appendix C and this appendix, the requirements of Appendix C must be followed unless this appendix expressly recognises the conflict.

E1: STARTABILITY, GRADEABILITY AND ACCELERATION CAPABILITY

E1.1 General

The three standards in this group, startability, gradeability and acceleration capacity, assess the ability of heavy vehicles to start on grade, climb on grade, and accelerate from rest and increase speed on level ground, respectively. These standards are inter-related because each primarily depends on engine and driveline characteristics. They can all be evaluated using the same data set for a specific vehicle or combination.

Each of the three standards addresses a different aspect of performance that is influenced by different areas of engine and driveline characteristics. Startability, for example, is influenced by clutch engagement torque and low gear operation, while gradeability, in addressing both low and high-gear (speed) operations, is not influenced by clutch engagement torque at low speeds. Acceleration capability, on the other hand, depends on engine characteristics and gearing across the entire speed range as well as other factors such as the timing, duration and strategy of gear changes. In addition to the above listed factors, rolling losses, aerodynamic drag, gross mass and the prevailing tyre/road friction limits will also influence performance.

E1.2. Model construction

(a) Principles

Numerical models must account for:

- gross combination mass;
- engine power/torque-speed characteristics and any de-rating associated with ancillary equipment (if applicable);
- clutch engagement (manual transmission) or torque converter (automatic transmission) considerations;
- transmission and final drive reduction ratios and the influence of tyre size (rolling radius) on net tractive effort;
- the influence of inertia of rotating components;
- losses due to grade resistance (if applicable);
- losses due to rolling resistance;
- losses due to aerodynamic drag;
- time delays associated with gear shifting (manual or automatic transmissions); and
- limitations in performance due to tyre/road friction considerations, that is, if the tractive effort exceeds the available tyre/road friction limits then performance will be friction limited.

(b) Explanation

(i) Grade

Grade changes a vehicle's orientation with respect to gravity so that:

- The normal force exerted by the tyres on the road surface is reduced in comparison with the zero-grade condition, in turn reducing the available friction at the driven axles and the tyre rolling resistance at all axles.

- A down-the-grade component acts to resist forward motion on an upgrade and to aid forward motion on a downgrade.
- The vector sum of the normal and down-the-grade forces is equal to the total weight of the vehicle or combination when the vehicle is in equilibrium.

(ii) Drive axle traction

Drive axle traction must be considered as a function of:

- Normal force exerted by each driven axle on the pavement at the specified grade.
- Distribution of engine torque to the driven axles.
- Rolling radius of the tyre and any changes that occur with changes in tyre normal load.
- Prevailing tyre/road friction coefficient.

(iii) Mass moments of inertia

- The mass moment of inertia of the rotating components in the driveline induces a resisting inertia force in response to angular acceleration.
- The mass moment of inertia of the road wheels induces a resisting inertia force in response to the angular acceleration of the road wheels.

(iv) Tyre rolling resistance

Tyre rolling resistance induce a resisting force on the system, which is a function of tyre normal force, speed and road surface unevenness.

(v) Aerodynamic drag

Aerodynamic drag can be calculated according to the equation:

$$D = C_D \frac{1}{2} \rho V^2 S$$

where	D	=	Aerodynamic drag (N)
	C_D	=	Aerodynamic drag coefficient (-)
	ρ	=	Air density at sea level or a specified altitude (kg/m^3)
	V	=	Forward velocity (m/s)
	S	=	Frontal area (m^2)

(vi) Engine torque-speed curve

The engine torque should be considered as a function of engine speed.

(vii) Engine speed range

The engine should operate within a speed range specified by the manufacturer.

(viii) Clutch engagement torque

At forward speeds less than that at which minimum engine speed is achieved in the starting gear ratio, a manufacturer-specified clutch engagement torque must be applied.

(ix) Gear ratios

The ratios incorporated in the transmission and in the driven axles must be considered.

(x) Driveline mechanical efficiency

Mechanical losses must be incorporated into the driveline, such that the torque delivered to the driven axles is less than that calculated from the engine torque and transmission gear ratios.

(xi) Gear changes

When the engine reaches the upper or lower limit of its speed range, an algorithm for selecting a more suitable gear must be applied. This algorithm must consider the time required to change gears (the gear change time must be no less than 1.5 sec).

E1.3 Input data sets

Gross mass:	Maximum gross mass of vehicle.
Engine:	Engine power/torque versus engine speed curves and de-rating associated with ancillary equipment, i.e. net engine torque.
Clutch/converter:	Clutch engagement torque or torque converter multiplier factors (stall torque ratio and stall speed).
Transmission:	Gear reduction ratios (and rotational inertias).
Final drive:	Reduction ratio (and rotational inertias).
Wheels:	Rolling radius at specified wheel load (and rotational inertia).
Losses:	Rolling resistance and aerodynamic drag.
Gear shift:	Time delays associated with gear shift, and gear shift sequencing if other than sequential.
Road Surface:	Friction coefficient as specified in the test procedure (Appendix C).

E1.4 Model verification

In accordance with the requirements of Attachment A to Appendix E.

E1.5 Simulation model application

The following is one method of performing startability and gradeability simulations.

For startability and gradeability*:* The simulation should first be attempted on an upgrade appropriate to the road classification level, having a whole-number value when expressed in percent. If the first simulation is successful, it should be repeated on an upgrade which is 1% greater than the previously tested upgrade. This process should be repeated until the first failure is encountered. If the first simulation is unsuccessful, it should be repeated on an upgrade which is 1% less than the previously tested upgrade. This process should be repeated until the first success is encountered. The greatest upgrade on which a successful test is simulated must be reported as the performance of the vehicle.

For acceleration capacity: In accordance with Appendix C.

E1.6 Simulation model output

According to the requirements of Appendix C.

E1.7 Sensitivity testing

In accordance with the requirements of Division 4 of Part 2.

E1.8 Reporting

In accordance with the requirements of Attachment B to Appendix E and with Appendix G.

E2 TRACKING ABILITY ON A STRAIGHT PATH

E2.1 General

The “tracking ability on a straight path” standard measures the ability of the trailing units in the combination vehicle, or rear of a single-unit vehicle, to faithfully track along the same path as the front of the vehicle. The standard effectively establishes the vehicle’s lane width requirement when travelling along a straight path in the presence of roadway disturbances (unevenness and cross slope) and driver steer activity. To evaluate performance the vehicle must traverse a road segment of the specified length, unevenness and cross slope at the specified travel speed.

E2.2 Model construction

(a) Principles

The ability of the trailing units in a combination vehicle, or rear of a single-unit vehicle, to faithfully track along the same path as the front of the vehicle depends on a range of vehicle-related factors, including:

- number of trailers and the location and type of coupling between them (turntable or pintle hitch);
- wheelbase dimensions;
- mass properties;
- alignment of axles;
- suspension geometry (roll and bump steer effects);
- tyre cornering stiffness;
- vehicle length; and
- speed.

Tracking ability performance will also depend on vehicle width, front and rear overhang dimensions, and plan view details of the outside corners of the front and rearmost vehicle units. External disturbances imposed on the system by road surface unevenness, cross slope, and driver steer activity, are the main sources of excitation causing the rearmost part of the vehicle to deviate from the path of the front of the vehicle when travelling along a straight path.

(b) Explanation

i) Topology

There are various ways of constructing models. One method is to separately represent the motions of each rigid body of the vehicle or combination. In this context, a rigid body is any part that is either defined as a rigid part, or alternatively, one that is subject to significant motion (in translation and/or rotation) in relation to the other parts in the system. The precise method of defining parts, either rigid or flexible, will depend on the specific modelling techniques employed. Where structural deflections may have a significant effect on the behaviour of the vehicle, flexibility should be considered in the construction of the model.

Examples of more common rigid bodies are:

- the combination of a trailer chassis and everything rigidly attached to it, including the body and the restrained payload, but not the axles, hubs, wheels and tyres; and
- the combination of an axle and the parts that are rigidly attached to it. This may include the hubs, wheels and tyres, but the hubs, wheels and tyres could be treated as separate rigid parts that rotate in relation to the axle.

Examples of less common rigid bodies are:

- a link in a specialised trailer steering or coupling system; and
- a translating or rotating sub-frame in a specialised trailer steering system.

A rigid body may be classified as either sprung, unsprung or auxiliary, dependent upon its location in the system.

ii) Mass properties

Mass properties may or may not be assigned to each part of the simulation model, and will depend on how the model has been constructed. Parts which have been assigned a mass will generally have the following properties:

- Mass;
- moments of inertia;
- centre-of-gravity location; and

iii) Coupling properties

Vehicle couplings, such as fifth-wheels, pin-couplings and ball-couplings, typically inter-connect the sprung parts of a vehicle. They are generally represented with the appropriate articulation degrees of freedom. Any resistance offered by the couplings, such as fifth-wheel overturning resistance, should be represented with an appropriate level of compliance.

iv) Suspension properties

Suspensions typically connect the unsprung parts of a vehicle (axles) to the sprung parts of a vehicle (chassis). Suspension properties maybe represented as defined below:

- Bounce degree of freedom – if appropriate, relative vertical movement must be possible between the axle and the chassis, such as that which occurs when the vehicle travels over a bump.
- Roll degree of freedom – if appropriate, relative roll movement must be possible between the axle and chassis, such as that which occurs when the vehicle travels around a bend at speed. The roll degree of freedom must be configured such that the axis of roll motion passes through the suspension roll centre and is inclined to induce suspension roll-steer. Suspension roll properties can differ considerably within an axle group, so the model needs to be capable of representing different roll properties within an axle group.
- Vertical stiffness and damping–if bounce and roll degrees of freedom exist, vertical force elements must be applied between the axle and chassis to control the bounce and roll degrees of freedom by way of stiffness and damping in a manner that is representative of the vehicle design.

- Auxiliary roll stiffness - If a roll degree of freedom exists, a moment may need to be applied in addition to that provided by vertical stiffness, because the roll stiffness generated by vertical stiffness may not represent the total roll stiffness of the suspension. Total roll stiffness includes such effects as torsion in suspension components.

v) Tyre properties

Tyre properties must include at least the following (with reference to Society of Automotive Engineers[20]):

- Vertical stiffness – the stiffness that causes normal force to vary with tyre compression.
- Lateral force characteristics in the free-rolling condition – the characteristics that define lateral force as a function of normal force and lateral slip angle.
- Aligning torque characteristics – the characteristics that define aligning torque as a function of normal force and lateral slip angle.

Forces and moments must be applied to the tyre such that their line of action is normal to the road surface at the point of contact. The orientation of the road surface must vary as a function of the road crossfall and the longitudinal road profile.

<u>Values for vertical stiffness, lateral force and aligning moment are provided for by the generic tyre datasets within Appendix N.</u>

vi) Driver properties

The simulation model must be steered by the steering tyres of the vehicle via a control system with parameters that can be modified to achieve the desired steering performance.

E2.3 Input data sets

(a) Geometric properties

The following parameters define the minimum set of dimensions that must be represented in the model:

- Major units – detailed geometric descriptions of each of the major units, particularly features that influence the specified path trajectories.
- Wheelbases – the overall distance between centrelines of the steer axle or axle group, and the drive axle or axle group, on a rigid truck, bus/coach or prime mover. The overall distance between the forward coupling point and the centreline of the axle or axle group on a semi-trailer, converter dolly or pig/tag trailer. In all cases, wheelbase dimensions must be measured either to single axles, or to the centreline of the axle group, located midway between the centrelines of the outermost axles of the group. If the group consists of two axles, one of which is fitted with twice the number of tyres as the other axle, the centre of the axle group is the line located one-third of the way from the centreline of the axle with more tyres towards the centreline of the axle with fewer

[20] Society of Automotive Engineers (1976). *Vehicle Dynamics Terminology*. SAE Recommended Practice J670e, Society of Automotive Engineers: Warrendale, PA, United States of America.

tyres. If the group contains self-steer axles, the centreline of the axle group is taken to be the centreline of the non-steered axles in the group. Force or command-steer axles are treated the same as non-steered axles.

- Axle group spread – distances between the centrelines of axles within a group.
- Track width – width related dimensions are measured from the centre of an axle to the wheel centreline or suspension element centreline. For tyres, these dimensions locate either the centrelines of single tyres, such as on steering axles, or the centre of the dual tyre pair with an accompanying dual spacing dimension.
- Longitudinal location of couplings – the longitudinal location of each coupling element, typically either turntables (fifth wheel couplings) or pin-type couplings is specified in terms of distances from the centreline of either a single axle or axle group.
- Height of couplings – the vertical location of couplings is specified in terms of the height above the ground. For turntables the vertical location of the coupling is the height of the coupler face and skid plate above the ground. For pin couplings the vertical location of the coupling is the height of the centre of the drawbar eye, or equivalent joint centre, above the ground.

(b) Mass properties

The following parameters define the minimum set of mass properties that must be used in the model:

- Sprung and unsprung masses – sprung and unsprung masses[21] of each major vehicle unit for the laden state.
- Centre of gravity locations – longitudinal locations of sprung and unsprung mass centre of gravities of each major vehicle unit for the laden state. If the vehicle or its load is not symmetric then lateral locations of centre of gravities must be specified.
- Mass moments of inertia – these must be defined about a set of orthogonal axles, consistent with the Society of Automotive Engineers co-ordinate system (Society of Automotive Engineers , 1976), whose origin is located at the component centre of gravity.

(c) Couplings

The following parameters define the minimum set of characteristics of couplings that must be represented in the model:

- Turntable couplings – vehicle units connected through turntable couplings must be constrained in such a way that they cannot translate relative to each other but can rotate relative to each other in roll, pitch and yaw[22]. Further, the constraints imposed on the joint must provide little or no resistance to rotations in pitch and yaw. Rotation about the roll axis must be resisted by either a linear or non-linear rotational spring element whose mechanical properties (roll moment versus angular deflection) are largely consistent with the roll characteristics of a turntable coupling.

[21] As defined in Society of Automotive Engineers (1976)

[22] Rotation angles are defined in Society of Automotive Engineers (1976)

- Pin couplings – vehicle units connected through a pin coupling must be constrained in such a way that there is no translation of one unit with respect to the other unit at the point of connection. The coupling constraint must provide little or no resistance to rotational motion with the units free to rotate relative to each other about all three axes (roll, pitch and yaw).
- Other – couplings that are not turntable or pin couplings must be modelled in a way that largely reproduces the main mechanical properties of the physical component.

(d) Suspensions

The minimum requirement for suspension components that must be defined in the model are the following mechanical properties measured at each axle:

- Composite vertical stiffness – The most fundamental property of all suspensions is vertical stiffness provided by the spring elements. When the entire suspension deflects in the vertical direction from its nominal static position, all the spring elements deflect in unison and their individual stiffness's sum to the determine the composite vertical stiffness, K_v, of the suspension as follows:

$$K_v = \frac{F_z}{Z} = \sum K_s \qquad (1)$$

  This equation shows that composite vertical stiffness (K_v) is defined as the vertical force (K_s) required per unit of vertical deflection (Z) and is composed of the sum of the stiffness's of all the springs of the suspensions (ΣK_s).

  Most heavy commercial vehicles use either multi-leaf steel springs or air springs (airbag). Steel torsion bars or rubber elements may also be used to provide the spring action. Multi-leaf steel springs display a complex force/displacement relationship which includes friction as well as stiffness qualities. The stiffness of air springs is generally strongly dependent on vertical load.

  Other suspension springs must be modelled in a way that largely reproduces the main mechanical properties of the physical component.

- Composite roll stiffness – When the sprung mass rolls relative to the unsprung mass (referred to as suspension roll), the suspension springs on each side of the vehicle deflect in opposite directions to produce a restoring overturning moment. The relationship between suspension roll angle and restoring moment is known as the composite roll stiffness of the suspension. Composite roll stiffness depends on individual spring rates and the lateral spring spacing, plus any auxiliary roll stiffness, as follows:

$$K_r = \frac{M_x}{\phi_s} = 2K_s\left(\frac{T_s}{2}\right)^2 + K_{aux} \qquad (2)$$

  This equation shows that composite roll stiffness (K_r) is the roll moment (M_x) per degree of suspension roll angle (Φ_s) and derives from the spring stiffness (K_s) times the square of one half of the lateral spring spacing (T_s) plus any auxiliary roll stiffness (K_{aux}).

  Multi-leaf steel spring suspensions usually have a small amount of auxiliary roll stiffness, produced as the springs are twisted along their length in order for the axle to roll. By contrast, air suspensions, which generally have low vertical stiffness, usually require an auxiliary roll stiffness device, either in the form of an anti-sway bar, or the trailing arm is rigidly clamped to the axle so that the whole assembly acts as an anti-sway bar.

- Damping – suspension damping in heavy vehicle suspensions derives from two major sources, viscous friction from the shock absorbers and coulomb friction from springs, linkages and bushings. Coulomb friction in multi-leaf steel spring suspensions is typically so large that the additional damping from shock absorbers is usually not required. Coulomb (or "dry") friction can be represented as a force, F_c, for steel spring suspensions. Viscous friction can be represented as a simple linear viscous damping element having a damping coefficient, F_d.

  Other damping devices must be modelled in a way that largely reproduces the main mechanical properties of the physical component.

- Roll centre height – Suspension roll is assumed to take place about a specific point referred to as the suspension roll centre. The location of the suspension roll centre for each axle depends on the details of the suspension parts that locate the axle laterally. The roll centre height is assumed to remain at a fixed height beneath the sprung mass. Formally, the roll centre is the point in the transverse-vertical plane through any pair of wheel centres at which lateral forces may be applied to the sprung mass without producing suspension roll (Society of Automotive Engineers, 1976).

- Roll steer coefficient – When a tyre travels over a bump or through a depression along the road and the axle rolls relative to the sprung mass, the wheels of the non-steered axle may steer slightly. This effect is also present when the vehicle rolls on its suspension during a turning manoeuvre. This steer behaviour is commonly referred to as roll steer[23] and results from the fact that when a spring deflects and the axle moves up and down relative to the sprung mass, the axle motion is not purely vertical. The layout of suspension links or other parts that locate the axle in the fore/aft direction may cause one end of the axle to move slightly forward and the other end to either move forward slightly less or slightly rearward. The roll steer effect is illustrated in Figure 21. Formally, the roll steer coefficient is the rate of change in roll steer with respect to change in suspension roll angle at a given trim (Society of Automotive Engineers, 1976).

[23] Formally, roll steer is the change in steer angle of front or rear wheels due to suspension roll.

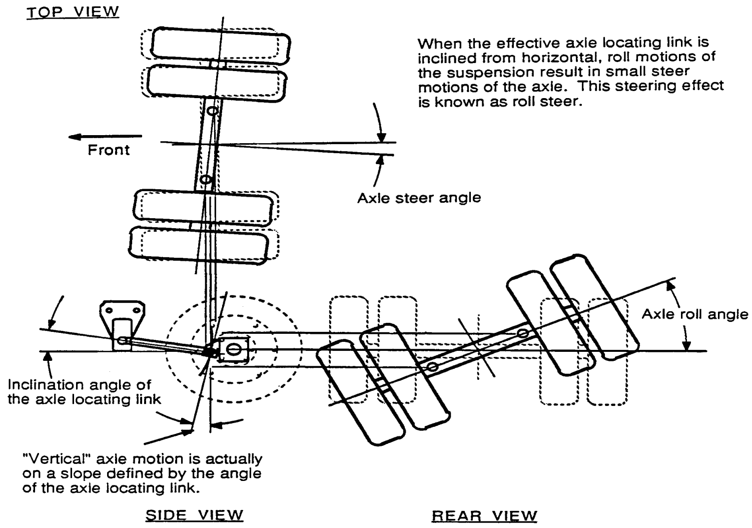

Figure 21. Illustration of roll steer effect on a beam axle (from Fancher et al, 1986).

(e) Tyres

All the forces needed to both support and guide a vehicle ultimately arise in the area of contact between the tyre and the roadway. These forces are generated at the road surface in response to deformation of the tyre structure. Vertical forces arise in response to vertical deflection of the tyre structure, cornering forces that are developed to control the vehicle, change direction, and resist sideways disturbances are produced in response to lateral slip (slip angle) and/or inclination of the tyre to the road surface (camber angle), and forces in the longitudinal direction for acceleration or braking are generated by longitudinal slip.

The tyre model must feature, or be capable of producing, the following external forces on the tyre by the road:

- Normal Force: A vertical force normal to the road surface. The relationship between vertical force exerted by the road on the tyre and tyre deflection. In its basic form the tyre vertical load-deflection relationship is expressed conveniently by tyre vertical stiffness:

$$k_t = \frac{F_z}{Z} \quad (3)$$

  This equation shows that the tyre vertical stiffness (k_t) is defined as the vertical force (K_z) required per unit of vertical deflection (Z).

- Lateral Force: The relationship between lateral or side force (F_y) exerted by the road on the tyre and sideslip or slip angle (α), and the influence of vertical load (F_z) on the relationship. For a typical truck tyre the relationship is illustrated in Figure 22.

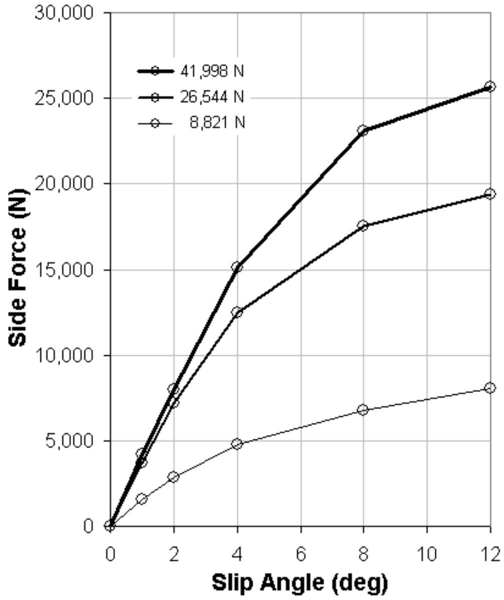

Figure 22. Side force characteristics of an 11R22.5 size truck tyre showing the influence of tyre vertical load.

- Aligning Moment: A moment in the road plane exerted on the tyre by the road that aligns the wheel plane with the direction of travel. The relationship between aligning moment (M_z) exerted by the road on the tyre and sideslip or slip angle (α) and the influence of vertical load (F_z) on the relationship. For a typical truck tyre the relationship is illustrated in Figure 23.

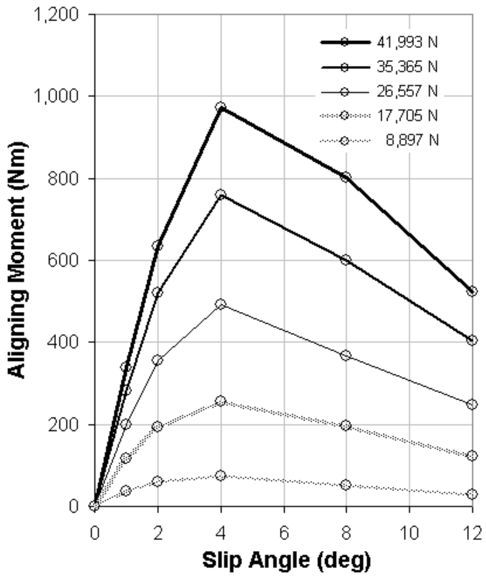

Figure 23. Aligning moment characteristics of an 11R22.5 size truck tyre showing the influence of tyre vertical load.

<u>Values for vertical stiffness, lateral force and aligning moment are provided for by the generic tyre datasets within Appendix N.</u>

(f) Propulsion

Forward speed is one of the greatest influences on the majority of the standards. The model must feature a means of maintaining a constant forward speed. There are several methods of propelling the vehicle model to maintain forward velocity that can be used. The model can either be propelled by:

- the application of tractive effort to the tyres;
- the longitudinal degree-of-freedom can be removed from the model and the forward velocity of the lead or towing unit constrained mathematically such that its speed is constant during the manoeuvre; or
- the application of an external force to the chassis.

(g) Steer control

Directional control of the model is achieved through the steer controller. Depending on the manoeuvre, steer control is intended to accomplish either a specific, precisely defined sequence of steer angle input, or it will guide the vehicle along a prescribed path approximating the same way that a real driver would steer the vehicle along a path. These activities are conveniently separated into the following two distinct forms of control, namely, open-loop control and closed-loop control.

- Open-loop control: This form of control is used for the purposes of characterising only vehicle response. In an open-loop control sequence the input steer is defined precisely and must be applied exactly as specified.
- Closed-loop control: In this form of control a desired vehicle motion or trajectory is achieved, such as following a precisely prescribed path – either a straight path or one that is complex such as a lane change – by continuously monitoring vehicle response (longitudinal and lateral position in the lane change example cited) and adjusting steering actions accordingly. In closed-loop control the driver is actively involved in the control process throughout the manoeuvre. In a closed-loop system the driver is considered an integral part of the system to the extent that in the numerical model the equations of motion for the entire system are actually modified.

The steering controller must produce representative steering activity largely consistent with the performance of actual drivers in a demanding straight-path tracking task in the presence of external disturbances (road surface unevenness). This means steer frequencies in the range 0.1 to 0.9 Hz must be present, and the lateral displacement of a point at the centre of the forward-most steer-axle must have a root-mean-square (r.m.s) value of not less than 25 millimetres. The steer frequency requirement referred to above is achieved when the contribution to the total mean square value of steer angle (measured at the road wheels) from steer activity in the frequency range 0.1 to 0.9 Hz is not less than 60% (Prem, Mai and McLean, 2005).

(h) Road profiles and surface friction

For standards such as "Tracking ability on a straight path" the wheel path road profiles provide part of the external disturbances to the numerical model through the tyre contact areas. However, most simulated manoeuvres in Performance Based Standards are performed on perfectly smooth surfaces and do not require a specific set of road profiles.

Surface friction values are specified in Appendix C.

E2.4 Model verification

In accordance with the requirements of Attachment A to Appendix E.

E2.5 Simulation model application

In accordance with Appendix C and this section.

The simulation model must be initialised to reach steady-state before entering the 1,000 m test section as an unsettled manner will result in erroneous results.

E2.6 Simulation model output

According to the requirements of Appendix C.

E2.7 Sensitivity testing

In accordance with the requirements of Division 4 of Part 2.

E2.8 Reporting

In accordance with the requirements of Attachment B to Appendix E and with Appendix G.

E3 LOW SPEED SWEPT PATH, FRONTAL SWING, TAIL SWING AND STEER TYRE FRICTION DEMAND

E3.1 General

The performance levels for the standards of low-speed swept path, frontal swing and tail swing are determined from the path trajectories of specified points on the vehicle. The performance level in the fourth standard (steer tyre friction demand) is determined from the horizontal and vertical tyre forces at the steer tyres under the specified tyre/road friction conditions.

E3.2 Model construction

(a) Principles

Heavy vehicle offtracking in a low-speed small-radius turn primarily depends upon:

- lead unit wheelbase;
- coupling locations; and
- the lengths between articulation points and axle locations.

This dependence varies in accordance with the squares of the (trailer/semi-trailer) lengths for a particular vehicle, and the longest trailer wheelbase is a critical parameter in determining the level of offtracking. Axle group loads and tyre properties have an important influence; maximum offtracking occurs when a vehicle operates at low axle loads on tyres that have high cornering stiffness. A number of software packages are commonly used to estimate low speed swept width. However, most ignore tyre mechanics and not all of these packages could satisfy all of the requirements of Appendix C.

Additionally, low-speed swept path, frontal swing and tail swing performance will depend on vehicle width, front and rear overhang dimensions, and plan view details of the outside corners of vehicle major units (truck, bus/coach or prime mover, in particular).

Steer tyre friction demand is largely a function of hauling unit wheelbase and drive axle-group spread. For steer tyre friction demand, steering must be effected by the steer tyres (should be applied to all measures except low-speed longitudinal and low-speed directional).

(b) Explanation

As specified in Section E2.2.

E3.3 Input data sets

As specified in Section E2.3.

E3.4 Model verification

In accordance with the requirements of Attachment A to Appendix E.

E3.5 Simulation model application

According to the requirements of Appendix C.

Care must be taken to ensure that the trajectory of the point of maximum offtracking on the inside of the turn is computed. This point will be in a different position on every vehicle. Further, it moves with the vehicle and during the turn it may move on the vehicle relative to its initial location. Particular care must be taken with vehicles that have command-steer systems on trailing units to ensure the point of maximum offtracking is correctly located throughout the turn.

E3.6 Simulation model output

According to the requirements of Appendix C.

E3.7 Sensitivity testing

In accordance with the requirements of Division 4 of Part 2. However, the value of sensitivity testing will depend on the features contained in the numerical model. For example, models based purely on geometry will not be responsive to changes in tyre loads and must only be used as preliminary indicators of performance level.

E3.8 Reporting

In accordance with the requirements of Attachment B to Appendix E and with Appendix G.

E4 STATIC ROLLOVER THRESHOLD, REARWARD AMPLIFICATION, HIGH SPEED TRANSIENT OFFTRACKING AND YAW DAMPING COEFFICIENT

E4.1 General

The four standards in this group, these being static rollover threshold, rearward amplification, high speed transient offtracking and yaw damping coefficient, are based on three different high-speed turn manoeuvres in which the vehicle is required to follow specified paths or respond to a specified open-loop steer input. The vehicle is required to cover a range of constant and quasi-steady speeds on a flat and level high-friction surface.

E4.2 Model construction

(a) Principles

Heavy vehicle rollover stability and dynamics in lane change and pulse steer manoeuvres address, respectively, performance under static or quasi-static steady turn conditions and transient conditions due to moderate and high frequency steer inputs producing abrupt large and small motion lateral-direction changes. Rollover under steady or quasi-steady turn conditions can be addressed using models whose components have been “lumped” into the roll plane(s). Rollover is very sensitive to the ratio of the overall track width to the height above ground of the centre of gravity of the vehicle. Suspension properties influence static rollover stability but they are generally of lesser importance when compared with the ratio of width to centre of gravity height. Rollover stability for multiple trailer combinations is much more complex than for rigid single-unit vehicles and depends on the type of coupling between trailers. All these features must be included in the model.

(b) Explanation

As outlined in Section E2.2.

E4.3 Input data sets

As specified in Section E2.3.

E4.4 Model verification

In accordance with the requirements of Attachment A to Appendix E.

E4.5 Simulation model application

In accordance with the requirements of Appendix C.

For calculation of static roll threshold and rearward amplification, care must be taken to ensure that lateral acceleration is computed in the horizontal direction, so that the effect of body roll on lateral acceleration is excluded.

For calculation of yaw damping coefficient, the exact form of the steering impulse that may be used is given by equation E4a below, which is illustrated in Figure 24.

$$\delta(t) = \begin{cases} 0 & t \le t_0 \\ \dfrac{\delta_m}{2} + \dfrac{\delta_m}{2}\sin\left[2\pi\left(\dfrac{t-t_0}{t_1-t_0}\right) - \dfrac{\pi}{2}\right] & t_0 < t < t_1 \\ 0 & t \ge t_1 \end{cases} \qquad \text{(E4a)}$$

where:

t = time (s)
t_0 = commencement of pulse steer application (s)
t_1 = termination of pulse steer application (s)
δ = steer angle (deg)
δ_m = amplitude of steer angle pulse (peak value)(deg)

The following alternative equation, which is equivalent to equation E4a, may also be used:

$$\delta(t) = \begin{cases} 0 & t \le t_0 \\ \dfrac{\delta_m}{2} - \dfrac{\delta_m}{2}\cos\left[2\pi\left(\dfrac{t-t_0}{t_1-t_0}\right)\right] & t_0 < t < t_1 \\ 0 & t \ge t_1 \end{cases} \qquad \text{(E4b)}$$

Either equation E4a or equation E4b must be used.

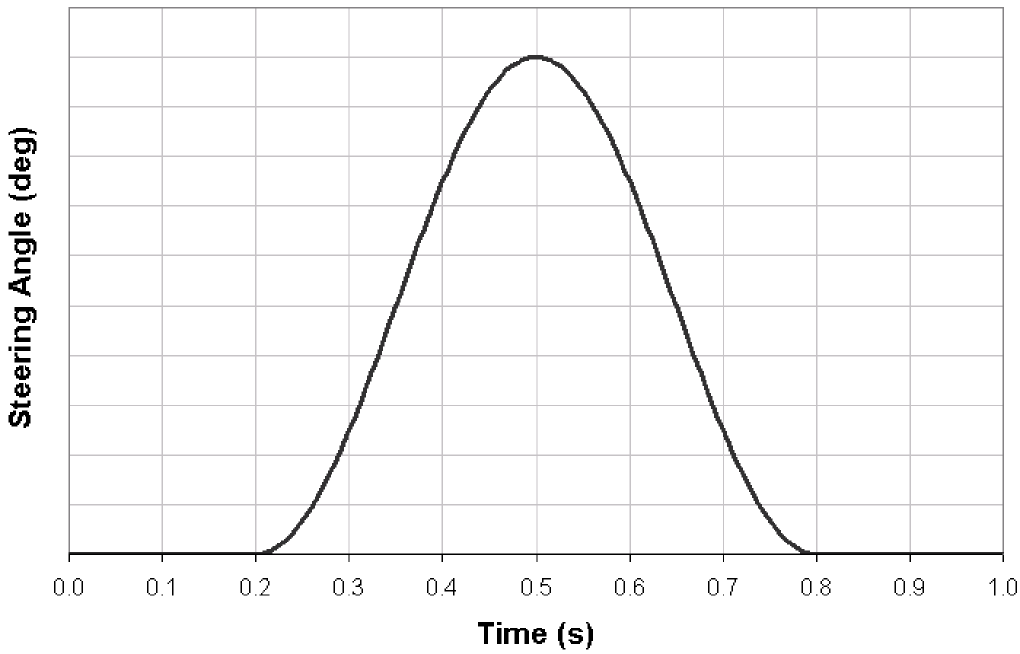

Figure 24. Exact form of the pulse steer input given by equation E4a.

E4.6 Simulation model output

In accordance with the requirements of Appendix C.

E4.7 Sensitivity testing

In accordance with the requirements of Division 4 of Part 2.

E4.8 Reporting

In accordance with the requirements of Attachment B to Appendix E and with Appendix G.

E5 DIRECTIONAL STABILITY UNDER BRAKING

E5.1 General

When demonstrated by simulation, a compliant vehicle must not have an instantaneous Friction Utilisation value on any axle group that exceeds 0.7 for any instantaneous vehicle deceleration up to and including the assessment deceleration levels given in Table 20.

(a) Principles

The Friction Utilisation of an axle group is defined as:

Utilisation = total axle group retardation forces at the pavement / total axle group weight

where the summations are over all the axles in the group. (E5a)

The definition of an axle group is as given in C16(d).

The simulation algorithm should use foundation brake models that are based upon the certification status or other justifiable test performance of the actual vehicle brake types. For example, the brake torque model can be based upon the average torque data for trailer axles that have Subassembly Reference Numbers (SARNs) which are available on the Department of Transport and Regional Service's web site.

The road surface can be assumed to have a high friction coefficient exceeding 0.7 and hence wheel lock-up behaviour need not be simulated.

The simulation should account for load transfers between axle groups however, dynamic load distribution changes between axles in each group need not be simulated.

The axle group weight to be used in equation (E5a) is the dynamic level that is affected by weight transfer at the simulation deceleration level.

An approach to computation of the friction utilisation is illustrated in Figure 25. The purpose of the computation is to compute the friction utilisation ratios for the axle groups U1, U2, U3 at the assessment deceleration levels specified in the standard.

(b) Explanation

An acceptable computation approach involves the following aspects:

- The brake application pressure at each axle is computed using the known air control valve static characteristics and the selected brake control level.
- At the selected brake control level, the brake torque at each axle is computed.
- The axle retardation forces are computed using the known tyre radius and the axle torques (T1-T6 in Figure 25).
- An average tyre radius for each group can be used. The tyre radius should be varied depending upon the dynamic load carried by the axle group.
- An allowance should be made for engine drag, aerodynamic drag and tyre loss force. This adds to vehicle retardation force. The engine drag force for example adds the drive axle group force F2 in Figure 25. There is also a tyre loss force that contributes to F1-F6 (Figure 25) and should be modelled.

- The instantaneous deceleration is calculated using the known vehicle weight and the total computed retardation forces.
- The weight carried by each axle is calculated using the known static weights and the deceleration level. Load transfers between axle groups are computed using basic physics.
- The friction utilisation on each axle group is calculated using the known weight force ΣW_{axle} and the computed retardation force ΣF_{axle}.
- The simulation should be started at low brake levels and stepped up until the instantaneous deceleration level of the vehicle equals or exceeds the assessment deceleration level stated in Table 20.
- At each instantaneous deceleration level the friction utilisation of each axle group must be less than 0.7.

(c) Acceptable simplifying assumptions

This simulation procedure can apply the following simplifying assumptions:

- Instantaneous axle torque values can be based on average torque levels established from stopping tests or dynamometer tests.
- It is impractical to compute the friction utilisation of individual axles within an axle group because the load proportioning behaviour of the axle group suspension is generally unknown. Hence only the axle group friction utilisation should be considered.
- The rolling resistance retardation force of the tyres can be assumed to be 0.0015 x weight carried for a driven axle and 0.0010 x weight carried for a non-driven axle (see ECE R13V9, Annex 13, Appendix 2 Cl. 1.1.4.)

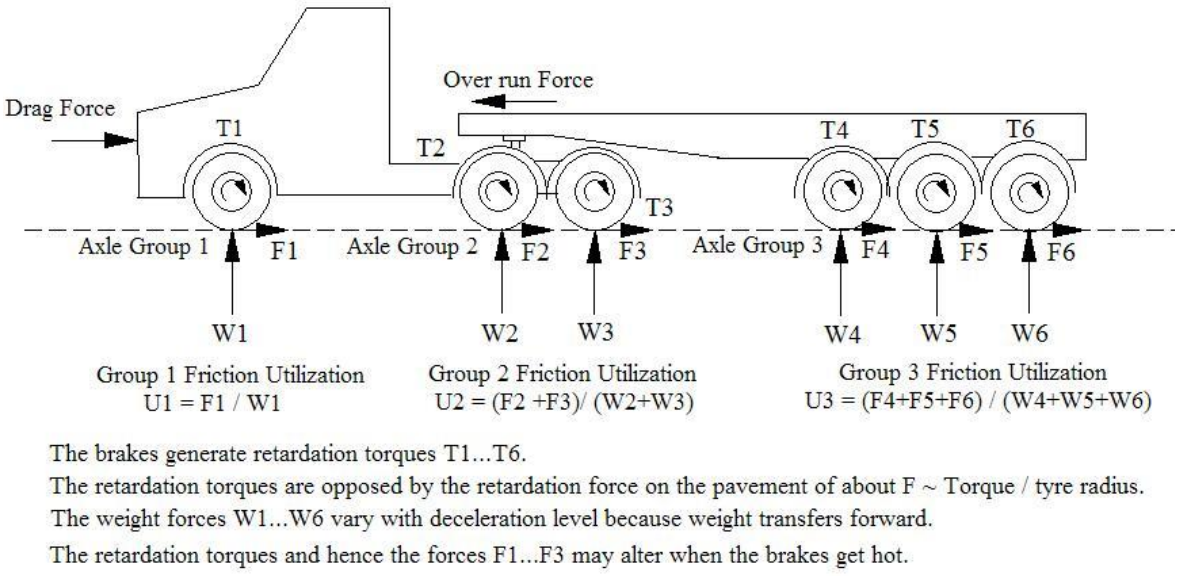

Figure 25. Idealised brake forces acting on a semi-trailer.

E5.2 Model verification

In accordance with the requirements of Attachment A to Appendix E.

E5.3 Simulation model output

In accordance with the requirements of Appendix C.

E5.4 Sensitivity testing

In accordance with the requirements of Division 4 of Part 2.

E5.5 Reporting

In accordance with the requirements of Attachment B to Appendix E and with Appendix G.

ATTACHMENT A TO APPENDIX E

Model validation and verification

If component level performance data or mechanical properties are obtained, either from component suppliers/manufacturers or by direct measurement, it is essential that the performance of the modelled component be specified over the entire operating range that will be used in the model of the vehicle being assessed in the prescribed manoeuvres. This check is necessary to ensure the performance boundaries of the component model are not exceeded in the simulation. If component level performance data or mechanical properties are estimated by calculation, these must be able to be verified.

The extent of physical testing should reflect the degree of risk associated with the proposal. Where the design being assessed is very similar to an existing prescriptive vehicle or vehicle participating in the Scheme, physical testing may only need to be conducted through on-road performance monitoring. This approach can be used to provide validation of numerical models.

Definitions

- Validate: To compare measurements from a test of a physical system with outputs from a numerical simulation of the test, showing that the numerical model adequately represents the physical system under those conditions.
- Verify: To warrant that the modelling principles of a validated numerical model are suitable for the construction of numerical models applied to similar systems under similar conditions.

ATTACHMENT B TO APPENDIX E

(a) The assessor must ensure that the relevant details in Tables 22 to 36 are recorded for each series of numerical modelling.

Note: On completion, these tables must be retained by the assessor for at least 5 years (see rule 20(1)(a)). Copies of completed tables should not accompany any certificate the assessor prepares, nor should they be sent to the Secretariat (unless they are specifically requested).

(b) Results of the assessment must be reported in Table 55.

(c) All sheets containing tables must be sequentially numbered.

Table 22. General application information

Assessor:		Approval No.	
Client:		Reference No.	
Standard/s tested:	Note: more than one standard may be listed		
Date:			
Operator:			
General Description of Vehicle (including commodity(s) to be transported):			
Drawings:	Drawings of the vehicle used in the assessment must be attached		

SOURCE DATA FOR MECHANICAL PROPERTIES

Table 23. Vehicle dimensions

Obtained from outline drawings:	
Obtained from detailed CAD drawings (electronic):	
Supplied by manufacturer:	
Determined by measurement:	
Other, please specify:	

Table 24. Mass properties

Estimated from first principles:	
Calculated by a CAD package (electronic):	
Determined by physical measurement:	
Supplied by applicant:	
Supplied by manufacturer:	
Other, please specify:	

Table 25. Suspensions

Estimated from first principles:	
Determined by physical measurement:	
Supplied by applicant:	
Supplied by manufacturer:	
Other, please specify:	

Table 26. Tyres

This table is not to be used after the date specified in Rule 8A(1).

Determined by calculation:	
Determined by physical measurement:	
Supplied by applicant:	
Supplied by manufacturer:	
Other, please specify:	

Table 26A Tyres

This table may be used from the date specified in Rule 8A(3) and must be used on or after the date specified in Rule 8A(1).

<table>
<tr><td rowspan="5">Generic Tyre Dataset/s used in assessment (Appendix N)</td><td>Steer:</td><td></td></tr>
<tr><td>Drive:</td><td></td></tr>
<tr><td>Dolly:</td><td></td></tr>
<tr><td>Trailer:</td><td></td></tr>
<tr><td>Other*:</td><td></td></tr>
<tr><td rowspan="5">Tyre Size/s and minimum load index nominated</td><td>Steer:</td><td></td></tr>
<tr><td>Drive:</td><td></td></tr>
<tr><td>Dolly:</td><td></td></tr>
<tr><td>Trailer:</td><td></td></tr>
<tr><td>Other*:</td><td></td></tr>
<tr><td rowspan="5">Axle configuration</td><td>Steer:</td><td></td></tr>
<tr><td>Drive:</td><td></td></tr>
<tr><td>Dolly:</td><td></td></tr>
<tr><td>Trailer:</td><td></td></tr>
<tr><td>Other*:</td><td></td></tr>
</table>

*A specific axle group/axle where it differs from the general case (for example a split or mixed axle group).

Table 27. Chassis properties (flexible)

Determined by calculation:	
Determined by physical measurement:	
Supplied by applicant:	
Supplied by manufacturer:	
Other, please specify:	

Table 28. Powertrain

Supplied by manufacturer:	
Determined by measurement:	
Other, please specify:	

NUMERICAL MODELS – Tables 29 to 34 must be completed for each separate model that is used in the assessment.

Table 29. Standards assessed with models described in Tables 30 to 34

Simulation software

Formulae:	
Custom code (2-dimensional model):	
Custom code (3-dimensional model):	
Commercial package, please specify:	
Other, please specify:	

Suspensions

Table 30. Suspension vertical spring element

Linear:	
Non-linear (no hysteresis):	
Non-linear (with hysteresis):	
Other, please specify:	

Table 31. Suspension spring elements (roll)

Linear:	
Non-linear:	
Other, please specify:	

Table 32. Suspension damping elements (roll)

Linear:	
Non-linear:	
Other, please specify:	

Table 33. Suspension other features

Please describe and specify:	

Table 34. Tyres

Identify the tyre forces and moments (with a tick in the appropriate box) used in the model described in accordance with Society of Automotive Engineers (1976).

Simulation Model	**Slip Conditions**	**Force and Moment Components**	**Tick**
spring		0, 0, F_z, 0, 0, 0	
steady state	pure longitudinal	F_x, 0, F_z, 0, M_y, 0	
steady state	pure lateral	0, F_y, F_z, 0, 0, M_z	
steady state	Longitudinal and lateral (not combined)	F_x, F_y, F_z, 0, M_y, M_z	
steady state	Combined slip forces	F_x, F_y, F_z, 0, M_y, M_z	
transient	pure longitudinal	F_x, 0, F_z, 0, M_y, 0	
transient	pure lateral	0, F_y, F_z, 0, 0, M_z	
transient	Longitudinal and lateral (not combined)	F_x, F_y, F_z, 0, M_y, M_z	
transient	Combined slip forces	F_x, F_y, F_z, 0, M_y, M_z	

Other, please specify______________________________________

Output

Table 35. Numerical modelling results

Standard	**Performance achieved**	**Performance Level achieved**
C1: Startability		
C2: Gradeability		
a) Maintain forward motion on grade (%)		
b) Minimum speed on 1% grade (km/h)		
C3: Acceleration capability		
C4: Overtaking Provision	*Moved to Network Classification Guidelines*	
C5: Tracking ability on a straight path		
C6: Ride Quality (Driver Comfort)	*No assessment required*	
C7: Low speed swept path		
C8: Frontal swing		
a) Prime mover (m)		
b) Prime mover and semi-trailer		
i) maximum of difference (*MoD*) (m)		
ii) difference of maxima (*DoM*) (m)		
C9: Tail swing		
C10: Steer tyre friction demand		
C11: Static rollover threshold		
C12: Rearward amplification		
C13: Yaw damping coefficient		
C14: High speed transient offtracking		
C15: Handling Quality (Understeer/Oversteer)	*No assessment required*	
C16: Directional stability under braking		
Overall Result		
Lowest road class for which all standards are achieved		

APPENDIX F: ASSESSING SAFETY STANDARDS BY PRACTICAL TESTING

This Appendix specifies the methods by which the safety standards must be assessed when testing is selected as the method of assessment.

This Appendix is supplementary to, and must be used in conjunction with, Appendix C, the standards, together with the applicable section in this Appendix.

Table 36. Practical testing - Safety standards references

Standard	Relevant Section in this appendix
C1: Startability	F1
C2: Gradeability	F2
C3: Acceleration Capability	F3
C4: Overtaking Provision	Transferred to Network Classification Guidelines
C5: Tracking Ability on a Straight Path	F5
C6: Ride Quality (Driver Comfort)	not addressed in this appendix
C7: Low-Speed Swept Path	F7
C8: Frontal Swing	F8
C9: Tail Swing	F9
C10: Steer-Tyre Friction Demand	F10
C11: Static Rollover Threshold	F11
C12: Rearward Amplification	F12
C13: High-Speed Transient Offtracking	F13
C14: Yaw Damping Coefficient	F14
C15: Handling Quality (Understeer/Oversteer)	not addressed in this appendix
C16: Directional Stability Under Braking	F16

The **vehicle conditions** and **test conditions** must comply with the requirements of Appendix C and this Appendix. If a conflict occurs between the requirements of Appendix C and this Appendix, the requirements in Appendix C must be followed unless this Appendix expressly recognises this conflict.

F1. STARTABILITY

F1.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F1.2 Test conditions

Test conditions must comply with the requirements of Section C1.4 (b) of Appendix C, and with Attachment B.

F1.3 Data acquisition

None.

F1.4 Data processing

None.

F1.5 Test procedure

Vehicle position markings

The following three positions must be marked on the test site prior to execution of the test. These are listed in order of increasing elevation on the grade:

- Initial position of the rear most axle (rear mark)
- Initial position of the front axle (start mark)
- Target position of the front axle (finish mark)

The rear mark and the start mark must be spaced according to the dimensions of the extreme axles. The start mark and the finish mark must be spaced 5 metres apart longitudinally.

The vehicle must be placed with its front axle at the start mark and its rear axle at the rear mark. The service brakes must be engaged and a suitable gear ratio selected.

The driver must release the service brakes and drive the vehicle forward at constant or increasing speed until the front axle passes the finish mark.

The test may be performed at one or more test sites and may be attempted one or more times at each test site.

F1.6 Reporting

The following items must be reported:

i) all test, vehicle and site details in Attachment E.

ii) the road profile (plot of elevation versus distance) for the driver and passenger wheel paths.

iii) the grade profile (percentage grade versus distance) for the driver and passenger wheel paths, and the grade profile of the point-by-point average of the driver and passenger wheel path profiles.

iv) maximum and minimum grade values (driver and passenger wheel paths, and average) in accordance with the grade specification defined in Section C1.4 (b) of Appendix C.

F1.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F2. GRADEABILITY

F2.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F2.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

F2.3 Data acquisition

Data acquisition requirements, including anti-aliasing filtering and bandwidth requirements, are specified in Section 3.1 of SAE J2181.

Instrumentation to acquire vehicle performance data must meet the requirements detailed in Table 1 of SAE J2181.

F2.4 Data processing

None.

F2.5 Test procedure

As defined in Appendix C.

F2.6 Reporting

All test, vehicle and site details in Attachment E must be reported.

For the standard “maintain motion”, the grade of the test length must be reported.

For the standard “maintain speed”, the following items must be reported:

i) the maximum speed at which the vehicle satisfied the requirements of Appendix C;

ii) the road profile (plot of elevation versus distance) for the driver and passenger wheel paths.

iii) the grade profile (percentage grade versus distance) for the driver and passenger wheel paths, and the grade profile of the point-by-point average of the driver and passenger wheel paths profiles.

iv) Maximum and minimum grade values (driver and passenger wheel paths, and average) in accordance with the grade specification defined in Section C2.7 (b) of Appendix C.

F2.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F3. ACCELERATION CAPABILITY

F3.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F3.2 Test conditions

Test conditions must comply with the requirements of Section 3.4(b) of Appendix C (except for grade) and with Attachment B. Appendix C states:

> The full length of the vehicle must be on a site with zero grade throughout the test.

With field testing, if a zero grade site is not available, it is acceptable to average the results of two runs in opposite directions over a test length that does not have a zero grade, even if the grade varies.

F3.3 Data acquisition

Data acquisition requirements including anti-aliasing filtering and bandwidth requirements are specified in Section 3.1 of SAE J2181.

Instrumentation to acquire vehicle performance data must meet the requirements detailed in the Table 1 of SAE J2181.

F3.4 Data processing

Assessors must prepare the distance versus time data to be presented as defined in Appendix C3.3.

F3.5 Test procedure

As defined in Appendix C. In order to minimise the influence of grade on the performance results during a field test, at least two valid test runs must be conducted on the same section of pavement, one run in each travel direction. The results from an equal number of runs in each direction must be averaged and reported as the achieved performance.

F3.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) the time taken to travel 100 metres;

iii) the road profile (plot of elevation versus distance) for the driver and passenger wheel paths;

iv) the grade profile (percentage grade versus distance) for the driver and passenger wheel paths, and the grade profile of the point-by-point average of the driver and passenger wheel path profiles;

v) maximum and minimum grade values (driver and passenger wheel paths, and average) in accordance with the grade specification defined in Section C3.4 (b) of Appendix C;

F3.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F4. [RESERVED]

F5. TRACKING ABILITY ON A STRAIGHT PATH

F5.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F5.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

F5.3 Data acquisition

Data acquisition and processing must be conducted as outlined in ISO 14791:2000(E) Sections 5.1, 5.2 and 5.3. Instrumentation to acquire vehicle performance data must meet these requirements.

Table 37. Tracking ability instrumentation requirements

Variable	Typical operating range	Combined system error
Swept width (m)	0 to 3.5 *	0.05
Longitudinal distance (m)	0 to 2,000	0.1

*** this is the overall swept width and assessors may use different techniques which many not include the vehicle width in the measurement**

F5.4 Data processing

Data processing must be undertaken as outlined in ISO 14791:2000(E) section 5.3.

Compute the vehicle swept width for each valid run. Completion of a test in accordance with the test procedure and method of Appendix C constitutes a valid run.

F5.5 Test procedure

As defined in Appendix C.

Three valid runs must be completed.

F5.6 Reporting

The following must be reported for each of three valid runs:

i) all test, vehicle and site details in Attachment E;

ii) swept width value expressed as a 99th percentile value;

iii) vehicle swept width time (or distance) history over the test length;

iv) road-wheel steer angle time (or distance) history over the test length;

v) maximum, minimum and average vehicle speeds over the test length;

vi) road-wheel steer angle expressed as the root-mean-square (RMS) over the test length;

vii) steer angle expressed as an autospectral density function (temporal);

viii) the road profile (plot of elevation versus distance) for the driver and passenger wheel paths;

ix) the IRI values reported every 100 metres the percentage grade profiles (percentage grade versus distance) for the driver and passenger wheel paths, and the grade profile of the point-by-point average of the driver and passenger wheel path profiles;

x) maximum and minimum grade values (driver and passenger wheel paths, and average) in accordance with the grade specification defined in Section C5.4 (b) of Appendix C; and

xi) the percentage crossfall profiles (percentage crossfall versus distance), average and standard deviation of the crossfall.

F5.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F6. RIDE QUALITY (DRIVER COMFORT)

This standard is not covered in this Appendix at this time. See section C6.2.

F7. LOW-SPEED SWEPT PATH

F7.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F7.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

F7.3 Data acquisition

Data acquisition requirements including anti-aliasing filtering and bandwidth requirements are specified in Section 3.1 of SAE J2181. Instrumentation requirements are specified in Table 1 of SAE J2181 and instruments to acquire vehicle performance data must meet the following requirements.

Table 38. Low speed swept path instrumentation requirements

Variable	Typical operating range	Combined system error
Swept path (m)	0 to 15	0.05
Path following error of the steer tyre (m)	0 to 0.1	0.02

* this is the overall swept path and assessors may use different techniques which may not included the vehicle width in the measurement.

(a) Swept path

Measurement of the swept path must use either road-based or vehicle-based methods or a combination of both.

(b) Tyre path

Measurement of the tyre path must be referenced against a marked path on the road surface which the driver must follow as specified in Appendix C.

The test is validated by the measurement of the tyre path reference as defined in Appendix C. The tyre path reference point must be located on the vehicle as defined in Appendix C.

F7.4 Data processing

Data processing must be undertaken as defined in Appendix C figure 6.

F7.5 Test procedure

As defined in Appendix C.

F7.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) inner and outer path trajectories of the swept path envelope as defined in Appendix C;

iii) maximum width of the swept path as defined in Appendix C; and

iv) maximum deviation from the prescribed path.

F7.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F8. FRONTAL SWING

F8.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F8.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

F8.3 Data acquisition

Data acquisition requirements including anti-aliasing filtering and bandwidth requirements are specified in Section 3.1 of SAE J2181.

If transducers are used to measure frontal swing requirements as defined in Part A, Part B and Part C in Appendix C they must be located within 150 mm of the extremity of the vehicle being assessed and appropriate corrections must be made for the location of these transducers during data processing. Instrumentation to acquire vehicle performance data must meet the following requirements.

Table 39. Frontal swing instrumentation requirements

Variable	Typical operating range	Combined system error
Frontal swing (m)	0 to 1	0.05
Path following error of the steer tyre (m)	0 to 0.1	0.02

(a) Tyre path

Measurement of the tyre path must be referenced against a marked path on the road surface which the driver is to follow as defined in Appendix C.

The test must be validated by the measurement of the tyre path reference as defined in Appendix C. The tyre path reference point must be located on the vehicle as defined in Appendix C.

F8.4 Data processing

Data processing must be undertaken as defined in Appendix C8.6, Figures 9, 10, 11 and 12.

F8.5 Test procedure

As defined in Appendix C.

F8.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) maximum frontal swing A;

iii) maximum frontal swing B;

iv) maximum frontal swing C; and

v) maximum deviation from the prescribed path.

F8.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F9. TAIL SWING

F9.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F9.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

F9.3 Data acquisition

Data acquisition requirements including anti-aliasing filtering and bandwidth requirements are specified in Section 3.1 of SAE J2181.

If transducers are used to measure frontal swing requirements as defined in Part A, Part B and Part C in Appendix C they must be located within 150 mm of the extremity of the vehicle being assessed and appropriate corrections must be made for the location of these transducers during data processing. Instrumentation to acquire vehicle performance data must meet the following requirements.

Table 40. Tail swing instrumentation requirements

Variable	Typical operating range	Combined system error
Tail swing (m)	0 to 0.5	0.02
Path following error of the steer tyre (m)	0 to 0.1	0.02

(a) Tyre path

Measurement of the tyre path must be referenced against a marked path on the road surface which the driver must follow as defined in Appendix C.

The test must be validated by the measurement of the tyre path reference as defined in Appendix C. The tyre path reference point must be located on the vehicle as defined in Appendix C.

F9.4 Data processing

Data processing must undertaken be as defined in Appendix C9 Figure 13.

F9.5 Test procedure

As defined in Appendix C.

F9.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) tail swing path trajectories as defined in Appendix C; and

iii) tail swing.

iv) maximum deviation from the prescribed path.

F9.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

F10. STEER-TYRE FRICTION DEMAND

F10.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F10.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

F10.3 Data acquisition

Data acquisition requirements including anti-aliasing filtering and bandwidth requirements are specified in Section 3.1 of SAE J2181. Instrumentation to acquire vehicle performance data must meet the following requirements.

Table 41. Steer tyre friction demand instrumentation requirements

Variable	Typical operating range	Combined system error
Lateral Tyre Force (N) (Lateral force)	60,000	600
Longitudinal Tyre Force (N) (Tractive force)	10,000	100
Vertical Tyre Force (N) (Normal force)	60,000	600
Path following error of the steer tyre (m)	0 to 0.1	0.02

(a) Tyre path

Measurement of the tyre path must be referenced against a marked path on the road surface which the driver is to follow as defined in Appendix C.

The test must be validated by the measurement of the tyre path reference as defined in Appendix C. The tyre path reference point must be located on the vehicle as defined in Appendix C.

F10.4 Data processing

As defined in Appendix C10, Figure 14.

F10.5 Test procedure

As defined in Appendix C.

F10.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) maximum deviation from the prescribed path;

iii) the measured tyre forces;

iv) the steer-tyre friction demand as a function of time; and

v) maximum steer tyre friction demand.

F10.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D of this appendix.

F11. STATIC ROLLOVER THRESHOLD

F11.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

The vehicle being assessed must be loaded as outlined in ISO 14791:2000(E) section 6.4 and the axle masses recorded in accordance with Attachment E.

F11.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

If the constant radius method is used, the test site must comply with the specifications in SAE J2181 section 4. The radius of the test must be not less than 100 metres.

If the tilt table method is used, the tilt table must comply with the specifications in SAE J2180 section 4, Table 1.

F11.3 Data acquisition

Data acquisition requirements including anti-aliasing filtering and bandwidth requirements are specified in Section 3.1 of SAE J2181.

Constant radius method: The data acquisition and processing must be conducted as outlined in Section 4, Table 1 of SAE J2181.

Tilt table method: The tilt angle of the table must be measured to an accuracy of ±0.1 deg as outlined in Section 4 of SAE J2180.

F11.4 Data processing

If the constant radius method, data processing must be conducted as outlined in Section 7 of SAE J2181 and as defined in Appendix C11.3.

If the tilt table method is used, data processing must be conducted as outlined in SAE J2180 section 5.

F11.5 Test procedure

If the constant radius method is used, as outlined in SAE J2181 section 6.2, the vehicle must be driven at a constant road speed and data recorded once the vehicle has achieved steady-state cornering. The test must be repeated, in both clockwise and counter clockwise directions at a higher speed up to the point of rollover instability (defined in Appendix C), increasing either:

- in equal to or less than 2 km/h increments up to the speed when wheel lift occurs; or
- at a rate measured over any 5 second period not greater than 0.5 km/h per second.

If the tilt table method is used, the test procedure as outlined in SAE J2180 section 4 must be used.

F11.6 Reporting

The following items must be reported:

i) all test, vehicle and site details in Attachment E; and

ii) Appendix C section 11.3 (c) for constant radius method or SAE J2180 section 5 for tilt table method.

F11.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

Since the objective of these tests is to determine the rollover threshold of a vehicle or vehicle combination, the risk of rollover during testing is high.

Engineering-based methods (such as computer simulation) should be used to estimate the stability limit of the vehicle and the maximum manoeuvre severity which may be safely applied. Tests should progressively increase in severity and test data should be compared with the initial estimate of stability limit. The maximum manoeuvre severity should be adjusted as required, and this should be a prime safety management parameter for the testing.

Rollover protection: For the constant radius testing an outrigger system should be designed and fitted to the vehicle at appropriate locations to prevent rollover. Any outrigger should not restrict vehicle performance until beyond the rollover threshold. The extent to which the outrigger(s) affects the centre of mass must also be considered, and a reduction or redistribution of the load may be required to achieve the desired overall vehicle mass and centre of mass.

Vehicle restraint: For tilt table tests a vehicle security system should be employed to restrain the vehicle when wheel lift-off has been reached. Any vehicle security system should not restrict vehicle performance until beyond the rollover threshold.

F12. REARWARD AMPLIFICATION

F12.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

The vehicle being assessed must be loaded as outlined in ISO 14791:2000(E) section 6.4 and the axle masses recorded in accordance with Attachment E.

Tyres fitted to the vehicle must be in accordance with ISO 14791:2000(E) section 6.2, with tread depth measurements as detailed in Attachment A.

F12.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

Despite the requirements of Appendix C, if a test track is selected that does not conform to the requirements of ISO 14791, the tests must be carried out in both directions if either the grade or crossfall of the test track is greater than 1%. If testing in both directions is not possible, testing should be carried out under the least favourable conditions (e.g. down grade and down crossfall for all manoeuvres if the grade is more than 1%).

The test site must comply with the specifications in ISO 14791:2000(E) section 6.1. The layout of the test course is shown in ISO 14791:2000(E) Figure 2.

The pavement surface characteristics of the test length must be measured and reported.

F12.3 Data acquisition

The data acquisition must be conducted as outlined in Sections 5.1, 5.2 and 5.3 of ISO 14791:2000(E) except that transducers for measuring lateral acceleration on the first unit must be installed on the axle (unsprung mass).

F12.4 Data processing

Data processing must be conducted as outlined in ISO 14791:2000(E) section 5.3, and as defined in Appendix C12.3.

F12.5 Test procedure

The test must be conducted as described in ISO 14791:2000(E) sections 7.1, 7.2, 7.3 and 7.5 (single lane-change). Section 7.5.3 provides an equation to compute the test course coordinates for a given maximum lateral acceleration, steer input frequency and test speed.

The manoeuvre as described in Appendix C must be planned to provide a peak lateral acceleration of 0.15 g and a steer frequency equal to 0.40 Hz at a vehicle speed of 88 km/h. When field testing, it is recommended to not perform the test if the response of the last unit is likely to exceed 75% of the estimated rollover limit or 75% of any tyre friction limit unless suitable safety mechanisms are in place. Trial runs at lower severity (e.g. lower speed) are encouraged to predict the ability of the vehicle to safely complete the manoeuvre.

F12.6 Reporting

i) all test, vehicle and site details in Attachment E must be reported;

ii) data analysis and reporting must be conducted as described in ISO 14791:2000(E) sections 8.1 and 8.2.3; and

iii) the rearward amplification must be computed as outlined in Appendix C.

F12.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

This test is designed to induce lateral dynamics in the vehicle, so there is a risk that this test will produce vehicle responses that approach the rollover threshold. Therefore, steps should be taken to mitigate the rollover risk.

Engineering-based methods (such as computer simulation) should be used to estimate the stability limit of the vehicle and the maximum manoeuvre severity which may be safely applied. Tests should progressively increase in severity and test data should be compared with the initial estimate of stability limit. The maximum manoeuvre severity should be adjusted as required, and this should be a prime safety management parameter for the testing.

Outriggers, which are lateral extensions added to both sides of a vehicle unit to prevent it from rolling over, should be designed and fitted. Any outriggers must be adjusted to allow the unit to roll beyond its rollover threshold before touching the road surface and supplying a righting moment to prevent rollover.

F13. HIGH-SPEED TRANSIENT OFFTRACKING

F13.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

The vehicle being assessed must be loaded as outlined in ISO 14791:2000(E) section 6.4 and the axle masses recorded in accordance with Attachment E.

Tyres fitted to the vehicle must be in accordance with ISO 14791:2000(E) section 6.2, with tread depth measurements as detailed in Attachment A.

F13.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

Despite the requirements of Appendix C, if a test track is selected that does not conform to the requirements of ISO 14791, the tests must be carried out in both directions if either the grade or crossfall of the test track is greater than 1%. If testing in both directions is not possible, testing should be carried out under the least favourable conditions (e.g. down grade and down crossfall for all manoeuvres if the grade is more than 1%).

The test site must comply with the specifications in ISO 14791:2000(E) section 6.1. The layout of the test course is shown in ISO 14791:2000(E) Figure 2.

The pavement surface characteristics of the test length must be measured and reported.

F13.3 Data acquisition

Data acquisition must be conducted as outlined in sections 5.1, 5.2 and 5.3 of ISO 14791:2000 except that transducers for measuring lateral acceleration on the first unit must be installed on the axle (unsprung mass).

F13.4 Data processing

Data processing must be conducted as outlined in ISO 14791:2000(E) section 5.3 and as defined in Appendix C13.3.

F13.5 Test procedure

The test must be conducted as outlined in ISO 14791:2000(E) sections 7.1, 7.2, 7.3 and 7.5 (single lane-change). Section 7.5.3 provides an equation to compute the test course coordinates for a given maximum lateral acceleration, steer input frequency and test speed.

F13.6 Reporting

The following must be reported:

i) All test, vehicle and site details in Attachment E; and

ii) reporting as described in ISO 14791:2000(E) sections 8.1 and 8.3.

F13.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

This test is designed to induce lateral dynamics in the vehicle, therefore there is a risk that this test will produce lateral activity near the rollover threshold and steps should be taken to mitigate the rollover risk.

Engineering-based methods (such as computer simulation) should be used to estimate the stability limit of the vehicle and the maximum manoeuvre severity which may be safely applied. Tests should progressively increase in severity and test data should be compared with the initial estimate of stability limit. The maximum manoeuvre severity should be adjusted as required, and this should be a prime safety management parameter for the testing.

Outriggers, which are lateral extensions added to both sides of a vehicle unit to prevent it from rolling over, should be designed and fitted. Any outriggers must be adjusted to allow the unit to roll beyond its rollover threshold before touching the road surface and supplying a righting moment to prevent rollover.

F14. YAW DAMPING COEFFICIENT

F14.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

The vehicle being assessed must be loaded as outlined in ISO 14791:2000(E) section 6.4 and the axle masses must be recorded in accordance with Attachment E.

Tyres fitted to the vehicle must be in accordance with ISO 14791:2000(E) section 6.2, with tread depth measurements as detailed in Attachment A.

F14.2 Test conditions

Test conditions must comply with the requirements of Appendix C and with Attachment B.

Despite the requirements of Appendix C, if a test track is selected that does not conform to the requirements of ISO 14791, the tests must be carried out in both directions if either the grade or crossfall of the test track is greater than 1%. If testing in both directions is not possible, testing should be carried out under the least favourable conditions (e.g. down grade and down crossfall for all manoeuvres if the grade is more than 1%).

The test site must be selected as outlined in ISO 14791:2000(E) section 6.1. The layout of the test course is shown in ISO 14791:2000(E) Figure 2.

The pavement surface characteristics of the test length must be measured and reported.

F14.3 Data acquisition

Data acquisition must be conducted as outlined in sections 5.1, 5.2 and 5.3 of ISO 14791:2000.

F14.4 Data processing

Data processing must be conducted as outlined in ISO 14791:2000(E) section 5.3 and as defined in Appendix C14.3.

F14.5 Test procedure

The test must be conducted as described in ISO 14791:2000(E) sections 7.6, 7.6.5.

F14.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) reporting as described in ISO 14791:2000(E) sections 8.1, 8.4 and 8.4.1.

F14.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D.

This test is designed to induce lateral dynamics in the vehicle, therefore there is a risk that this test will produce lateral activity near the rollover threshold and steps should be taken to mitigate the rollover risk.

Engineering-based methods (such as computer simulation) should be used to estimate the stability limit of the vehicle and the maximum manoeuvre severity which may be safely applied. Tests should progressively increase in severity and test data should be compared with the initial estimate of stability limit. The maximum manoeuvre severity should be adjusted as required, and this should be a prime safety management parameter for the testing.

Outriggers, which are lateral extensions added to both sides of a vehicle unit to prevent it from rolling over, should be designed and fitted. Any outriggers must be adjusted to allow the unit to roll beyond its rollover threshold before touching the road surface and supplying a righting moment to prevent rollover.

F15. HANDLING QUALITY (UNDERSTEER/OVERSTEER)

This standard is not covered in this appendix at this time. See section C15.2

F16. DIRECTIONAL STABILITY UNDER BRAKING

F16.1 Vehicle conditions

Vehicle conditions must comply with the requirements of Appendix C and Attachment A.

F16.2 Test conditions

Test conditions must comply with the requirements of Section C16.4 (b) of Appendix C, and with Attachment B.

F16.3 Data acquisition

None.

F16.4 Data processing

None.

F16.5 Test procedure

The test procedure must comply with the requirements of Section C16.5 (c) of Appendix C, and with Attachment B.

F16.6 Reporting

The following must be reported:

i) all test, vehicle and site details in Attachment E;

ii) average deceleration rate;

iii) identification and location of occurrence of any wheel lock up;

iv) stopping distance; and

v) vehicle position within lane during braking procedure.

F16.7 Safety

The test site must be safe for all personnel, including but not limited to those conducting and observing the test and the general public. The site manager must follow the safety requirements outlined in Attachment D of this appendix.

ATTACHMENT A TO APPENDIX F – VEHICLE CONDITIONS

All vehicles must be in a roadworthy condition for the testing process.

Tyres fitted to the vehicle being assessed must be of the size and have the same specifications as used on the vehicle in practice. Inflation pressures must be set as recommended by the tyre manufacturer.

New tyres must be run-in for at least 200 kilometres.

The tread depth at a single point on the tyre that is representative of the overall tyre tread depth must be measured before and at the conclusion of the testing along with a visual inspection of each tyre. Each tyre must be measured for vehicles with less than 27 tyres. For vehicles with more than 27 tyres, the tyres that must be measured are:

- all tyres on the steer and drive groups;
- at least four tyres, selected at random, on each of the remaining axle groups.

The tread depth of any tyre measured must be not less than 90% of the tread depth when new.

The tyres and engine must be at operating temperatures prior to commencing the test.

The mass of the vehicle must be within the allowable variations set out in Austroads (2004), Table 1, Category 2.

In the case of road tankers designed to haul dangerous goods in bulk, the load must be substituted with a non-flammable and/or safe product that best replicates the load conditions of the vehicle being assessed in-service. The fill levels of all tank compartments must be recorded.

For unrestrained loads, load restraint must be sufficient for the levels of acceleration expected during testing.

Testing of vehicles loaded with livestock must comply with animal welfare legislation.

In the case of loose cargo, the load should be monitored during the test and any shifting, movement or non-typical behaviour must be documented. If any non-typical load shifting behaviour is observed the assessor must determine if this contributed to the vehicle failing to meet any relevant requirement.

ATTACHMENT B TO APPENDIX F – AMBIENT AND PAVEMENT CONDITIONS

The ambient air temperature at the test site must be within the range of 0ºC to 40ºC.

Ambient wind speed during testing must not exceed 5 m/s except that for a tilt table static rollover threshold test, testing should not be conducted when the wind speed exceeds 1.7 m/s.

The road surface must be free of loose material and be free of contamination at the time of the vehicle testing, and the surface must be dry.

Road profile measurements must be conducted with a World Bank (Sayers et al 1986) Class 1 device.

The International Roughness Index (IRI) values must be computed as outlined in Sayers et al (1986) and be reported at 100 metre intervals.

Acceptable pavement surface types for vehicle testing are:

- concrete;
- dense graded asphalt;
- stone mastic asphalt; and
- chip seal.

If a chip seal or other surface is used it must be of adequate strength to not deteriorate during testing.

ATTACHMENT C TO APPENDIX F – DATA ACQUISITION

The vehicle performance data may be:

- vehicle-based; or
- road-based; or
- a combination of vehicle-based and road-based systems.

Data must be recorded against either a time-base or a distance-base.

If a combination of data recording techniques are used, there must be a common time-base or distance-base between the vehicle-based and road-based data acquisition systems.

Transducers, if used, must be firmly attached to the axles, the chassis or the vehicle body in a manner which avoids vibration transmitted from the vehicle.

ATTACHMENT D TO APPENDIX F – SAFETY

The test site manager is responsible for safety and must ensure that:

- a risk assessment is conducted of the field work as outlined in AS/NZS 4360:2004, and if the test is to be conducted on a public road then appropriate road closure and traffic control/management and a pilot vehicle are implemented in accordance with AS1742.3:2002.
- a “safe” and “keep clear” area(s) should be defined and clearly marked.
- no person must enter the “keep clear” area during execution of the test.
- no person must be in front of or behind the vehicle during the test manoeuvre and a safe distance between the vehicles must be maintained at all times as outlined in AS 1742.3:2002.
- audible warning or radio communication must be given to alert all personnel on site that the test has commenced.
- all personnel on site must be in contact with the site manager.
- all vehicle testing personnel must be trained in traffic management and fatigue management.
- a person trained with at least a certificate in Level II First Aid must be present at the site.
- all personnel present at the test site (including the driver) must sign a register requiring the information detailed in Table 53.
- all personnel must be briefed on the tasks, responsibilities and safety procedures.
- all personnel must wear suitable clothing and footwear as determined by the site manager.
- all high visibility safety garments must comply with AS/NZS 4602:1999.
- any driver of a vehicle under test must hold the licence appropriate to the vehicle being driven.
- the vehicle under test must not exceed the posted speed limit or any speed limits imposed on the vehicle type.

ATTACHMENT E TO APPENDIX F – REPORTING REQUIREMENTS

The assessor must ensure that the relevant details in Tables 43 and 53 are recorded for each test. If all details are not available, the assessor must ensure that the details marked with an asterisk (*) are recorded for each test and reasons for not reporting other details are given in Table 42. Results of the testing must be reported in Table 55.

Note: On completion, these tables must be retained by the assessor for five years (see rule 11(1)(b)). Copies of completed tables should not accompany any certificate the assessor prepares, nor should they be sent to the Secretariat (unless they are specifically requested).

All sheets containing tables must be sequentially numbered.

Table 42. General application information

*	Assessor:		Approval No.	
*	Client:		Reference No.	
*	Standard/s tested:			
*	Vehicle description:			
*	Operator:			
*	Date:			
*	Vehicle supplied by:			
*	Contact name:		* Contact number	
*	Combination type:			
*	Number of trailers:		* Number of dollies	
*	GCM (Rated):	(t)	* GCM (tested)	(t)
	OAL:	(m)		

Table 43. Driver details

	Driver supplied by:	
*	Driver's name:	
	Contact number:	
*	Driver licence type and driver experience:	
*	Licence number:	

Table 44. Prime mover specification

*	Body type:				
	Vehicle unit no.:				
*	VIN:				
*	Make, year, model:				
*	Registration or permit no.:				
	Odometer:				
	Tare weight:	Front		Rear	
*	GCM rating:				
*	Transmission type:				
*	Drive type (ratio):				
	Engine capacity (l):				
*	Engine power (kW):				
*	No of axles:			No of tyres	
*	Suspension type:	Front		Rear	
*	Suspension make:				
*	Tyre size:				
*	Tyre make (retread):				
	Tyre manufactured date:				
*	Description of load:				

Table 45. Transducer location

	Transducer	**X (mm)**	**Y (mm)**	**Z (mm)**
	Example: Lateral acceleration unit 1 body	2,500	0	-1,100

Note: all dimensions are referenced to first axle at ground level

Table 46. Vehicle unit details

	Unit number:			Body type:		
	Trailer manufacturer:					
	Date of manufacture:					
*	VIN:					
*	Registration no.:					
*	No. of axles:			* Tare mass		
*	Suspension type:					
*	Suspension make/model:					
*	Steerable axle make/model:					
*	Tyre size:					
*	Description of load:					
*	Load dimensions:	Height:			Length:	
*	Tanker compartments:	No. :			Capacity:	
*	Tanker compartments:	Fill level:				

Note: all units must be reported

Table 47. Vehicle unit dimension details

	Unit #	**Unit type**	**WB/S (mm)**	**FOH (mm)**	**FWL (mm)**	**ROH (mm)**	**AS (mm)**
*	1						
*	2						
*	3						
*	4						
*	5						
*	6						
*	7						
*	8						

Note: all vehicle units must be reported

Table 48. Axle group mass details

Axle group #	Mass (t)	
	Tare	**Laden***
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

Note: all axle groups must be reported

Table 49. Tyres

	Unit #	Make/model	Tyre size	Tyre pressure (psi) cold	Tread depth (mm) new	Tread depth (mm) prior to test	Tread depth (mm) after to test
*	1 Left						
*	1 Right						
*	2 Left						
*	2 Right						
*	3 Left						
*	3 Right						
*	4 Left						
*	4 Right						
*	5 Left						
*	5 Right						
*	6 Left						

Note: specified tyres must be reported

Table 50. Test conditions

*	Location:	
*	Surface description:	
*	Average Crossfall (%):	
*	Test pavement heading	
*	Average longitudinal gradient (%):	
*	Average crossfall (%):	
	Road profile data supplied (attached):	Yes □ No □
	Grades for wheel paths data supplied (attached):	Yes □ No □

Table 51. Weather conditions

*	Temperature (°C):	
*	Wind velocity (m/s):	
*	Wind direction:	

Table 52. Testing personnel

*	Site Manager:	
*	Company name:	
*	Contact details:	
	Other personnel:	
	UHF radio:	Yes □ No □
*	Traffic management:	Yes □ No □
*	Fatigue management:	Yes □ No □
*	First aid training:	Yes □ No □
	Other relevant training:	

Table 53. Vehicle safety check

		Signed (person checking)	**Name** (person checking)
*	Prime mover GCM rating:	□	
*	Brake connections:	□	
*	Tyres (condition and inflation):	□	
*	Axle weights:	□	
*	Driver licence:	□	
*	Vehicle registration:	□	
*	Oversize sign (if required):	□	
*	Load restraints:	□	
*	Outriggers (if required):	□	

Note: sign after completion of check

Table 54. Test results

Standard	**Results Reporting Requirement**	**Result or Reference**	**Lowest Performance Level met by the Vehicle**
C1: Startability	F1.6 ii: the incline of the test length F1.6 iii: the road profile measurements for the driver and passenger wheel paths F1.6 iv: the grades for the driver and passenger wheel paths, computed from the road profile measurements, along with their associated average values Startability result		
C2: Gradeability	F2.6 For the standard “maintain motion”, the value of the incline of the test length Gradeability result For the standard “maintain speed” F2.6 i**:** the maximum speed at which the vehicle satisfied the requirements of Appendix C F2.6 ii: the road profile measurements for the driver and passenger wheel paths F2.6 iii: the grades for the driver and passenger wheel paths, computed from the road profile measurements, along with their associated average values		
C3: Acceleration Capability	F3.6 i: a distance versus time plot F3.6 ii: a distance versus time table		

Standard	**Results Reporting Requirement**	**Result or Reference**	**Lowest Performance Level met by the Vehicle**
C5: Tracking Ability on a Straight Path	F5.6 ii: swept width expressed as a 99th percentile value		
	F5.6 iii: vehicle swept width time (or distance) history over the test length F5.6 iv: maximum, minimum and average vehicle speeds over the test length F5.6 v: steer angle expressed as the root-mean-squares (RMS) over the test length F5.6 vi: steer angle expressed as a power spectral density function		
C7: Low-Speed Swept Path	F7.6 ii: maximum swept path width		
	F7.6 iii: steer wheel reference point path		
C8: Frontal Swing	F8.6 ii: maximum frontal swing A F8.6 iii: maximum frontal swing B F8.6 iv: maximum frontal swing C		
	F8.6 v: steer wheel reference point path		
C9: Tail Swing	F9.6 ii: tail swing		
	F9.6 iii: steer wheel reference point path.		
C10: Steer-Tyre Friction Demand	F10.6 ii: maximum steer tyre friction demand		
	F10.6 iii: steer wheel reference point path		
C11: Static Rollover Threshold	F11.6 ii: Appendix C section 11.3 (c) for constant radius method or SAE J2180 section 5 for tilt table method		
C12: Rearward Amplification	F12.6 ii: Data analysis and reporting must be conducted as described in ISO 14791:2000(E) sections 8.1 and 8.2.3		
C13: High-Speed Transient Offtracking	F13.6 ii: Reporting as described in ISO 14791:2000(E) sections 8.1 and 8.3		
C14: Yaw Damping Coefficient	F14.6 ii: Reporting as described in ISO 14791:2000(E) sections 8.1, 8.4 and 8.4.1		
C16: Directional Stability Under Braking	F16.6 ii Average deceleration rate F16.6 iii Identification of any wheel lock up and location of axle group F16.6 iv Stopping distance F16.6 v Vehicle position within lane during braking procedure		

Table 55. Comments

Reasons why some details are not supplied:
Other comments:

Assessor signature

________________________________Date:___________________

APPENDIX G – VEHICLE CERTIFICATION INFORMATION

Instructions for the assessor

1. The assessor must complete Column 3 in accordance with the requirements of rules 9 and 10 of *The Standards and Vehicle Assessment Rules* for each vehicle design being assessed. If the proposed vehicle is a combination, Part A2 and Part A3 must be completed for each trailer/semi trailer and dolly in the combination.

2. Some rows of column 3 may be left blank provided the category or component is adequately described elsewhere in the Schedule.

3. When the vehicle design is completely described, the assessor must sign the certificate below.

Assessor name and approval number		Date:	
Description of vehicle design being assessed			
I certify that Column 3 provides a complete specification of the potential vehicle described above in accordance with *The Standards and Vehicle Assessment Rules*		Signed:	

Office use only:

Date received:		Draft Approval No:	

Date dispatched to Certifier 1		Name of Certifier 1		Approved (yes/no)	
Date dispatched to Certifier 2		Name of Certifier 2		Approved (yes/no)	
Date dispatched to Certifier 3		Name of Certifier 3		Approved (yes/no)	

Instructions for the certifier

4. The certifier must complete Columns 4 and 5 after having inspected the vehicle in accordance with the requirements of the *Vehicle Certification Rules*.

5. If the physical requirement in Column 3 (Specification) is present on the vehicle, the certifier must complete Column 4 with a **yes** and provide a justification for the yes. For example, it may be simply that the dimensions are correct and the justification is “measured”, it may be that the specified engine is present and the engine manufacturer has provided a documentation as to torque speed characteristics. Column 5 would be completed by indicating that inspection showed that the specified engine was present and the documentation from the engine manufacturer was satisfactory and is attached to this form (in accordance with the *Vehicle Certification Rules*).

6. If the physical requirement in Column 3 (Specification) is **not** present on the vehicle, the Inspector must complete Column 4 with a **no** and provide any justification for the no.

7. If a **yes** answer is present in Column 4 for each specification in Column 3, the certifier must complete the certifier’s certificate required by the Vehicle Certification Rules and must fulfil the other requirements of those Rules.

8. If a **no** answer is present in Column 4 for any specification in Column 3, the certifier must not complete the certificate.

Part A1: Motor Vehicle

Column 1	Column 2	Column 3 (to be completed by Assessor)	Column 4 (to be completed by Certifier)	Column 5 (to be completed by Certifier)
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present** **(yes/no)**	**Justification**
Vehicle	Make Model			
Engine	Make Model			
Gearbox	Make Model			
Differential	Make Model			
Mass	Gross Vehicle Mass or Gross Combination Mass			
Engine and driveline	Engine torque-speed characteristics (if make/model details do not provide this information)			
	Clutch engagement torque (manual transmission) (if make/model details do not provide this information)			
	Torque converter characteristics (automatic transmission) (if make/model details do not provide this information)			

Column 1	Column 2	Column 3 (to be completed by Assessor)	Column 4 (to be completed by Certifier)	Column 5 (to be completed by Certifier)
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present** **(yes/no)**	**Justification**
	Gearbox and final drive ratios (if make/model details do not provide this information)			
	Automatic transmission shift time delays (if make/model details do not provide this information)			
Tyres (specify for each axle group)* *For prescriptive nomination of tyre brand and model considering Rule 8A.	Tyre size, make and model <u>OR</u>			
	Tyre rolling radius, cornering characteristics and vertical stiffness			
Tyres (specify for each axle group)* *For nomination of tyres in accordance with Appendix N.	Tyre size, load index and configuration			
Body/ construction	Body type			
	Wheelbase			
	King pin lead or coupling rear overhang			

Column 1	Column 2	Column 3 (to be completed by Assessor)	Column 4 (to be completed by Certifier)	Column 5 (to be completed by Certifier)
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present (yes/no)**	**Justification**
	Front overhang, width plan-profile and plan-profile of front outside corners and protuberances			
	Rear overhang			
	Plan-profile of rear outside corners and protuberances			
Suspension (specify for each axle group)	Suspension make and model <u>OR</u> suspension characteristics			
Wheels and axles (specify for each axle group)	Drive group axle spread (if applicable)			
	Track width, and dual tyre spacing (if applicable)			
	Axle spacing and axle steering			
	Drive axle group tractive effort distribution			
Couplings	Couplings (conventional, double oscillating turntables, ball, other)			
Other	Any additional or special requirements			

<u>Part A2: Trailer/Semi-trailer</u>

Column 1	Column 2	Column 3 (to be completed by Assessor)	Column 4 (to be completed by Certifier)	Column 5 (to be completed by Certifier)

Category or component	**Parameter**	**Specification**	**Physical parameter requirement present (yes/no)**	**Justification**
Trailer	Make Model			
Mass	Aggregate Trailer Mass			
Tyres (specify for each axle group)* *For prescriptive nomination of tyre brand and model considering Rule 8A.	Tyre size, make and model <u>OR</u>			
	Tyre rolling radius, cornering characteristics and vertical stiffness			
Tyres (specify for each axle group)* *For nomination of tyres in accordance with Appendix N.	Tyre size, load index and configuration			
Body/ construction	Body type			
	Wheelbase			
	King pin/pivot pin lead or coupling rear overhang			
	Drawbar length			
	Width plan-profile			

Column 1	**Column 2**	**Column 3** **(to be completed by Assessor)**	**Column 4** **(to be completed by Certifier)**	**Column 5** **(to be completed by Certifier)**
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present** **(yes/no)**	**Justification**
	Forward projection and plan-profile of front outside corners and protuberances			
	Rear overhang			
	Plan-profile of rear outside corners and protuberances			
Suspension	Suspension make and model <u>OR</u> suspension characteristics			
Wheels and axles	Track width, and dual tyre spacing (if applicable)			
	Axle spacing & axle steering			
Couplings	Couplings (conventional, double oscillating turntables, ball, other)			
Other	Any additional or special requirements			

<u>Part A3: Dolly</u>

Column 1	**Column 2**	**Column 3** **(to be completed by Assessor)**	**Column 4** **(to be completed by Certifier)**	**Column 5** **(to be completed by Certifier)**
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present** **(yes/no)**	**Justification**
Dolly	Make Model			
Mass	Aggregate Trailer Mass			

Column 1	**Column 2**	**Column 3** (to be completed by Assessor)	**Column 4** (to be completed by Certifier)	**Column 5** (to be completed by Certifier)
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present** (yes/no)	**Justification**
Tyres (specify for each axle group)* *For prescriptive nomination of tyre brand and model considering Rule 8A.	Tyre size, make and model <u>OR</u>			
	Tyre rolling radius, cornering characteristics and vertical stiffness			
Tyres (specify for each axle group)* *For nomination of tyres in accordance with Appendix N.	Tyre size, load index and configuration			
Body/ construction	Rolling losses			
	King pin/pivot pin lead			
	Wheelbase			
	Drawbar length			
	Width plan-profile			
Suspension	Suspension make and model <u>OR</u> suspension characteristics			

Column 1	**Column 2**	**Column 3** **(to be completed by Assessor)**	**Column 4** **(to be completed by Certifier)**	**Column 5** **(to be completed by Certifier)**
Category or component	**Parameter**	**Specification**	**Physical parameter requirement present** **(yes/no)**	**Justification**
Wheels and axles	Track width, and dual tyre spacing (if applicable)			
	Axle spacing and axle steering			
Couplings	Couplings (conventional, double oscillating turntables, ball, other)			
Other	Any additional or special requirements			

APPENDIX H – RISK SENSITIVE PARAMETERS RELATED TO VEHICLE DESIGN FEATURES

Table H1(a) Longitudinal Performance (Low Speed) – Startability

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Startability	Gross Vehicle Mass or Gross Combination Mass	Drive axle group load should be not less than assumed in the assessment.	1		
	Engine torque-speed characteristics	If vehicle is to operate at altitude de-rating of engine with altitude could be an issue and needs to be checked.	1		
	Clutch engagement torque (manual transmission) or torque converter characteristics (automatic transmission)	Not readily available, in which case a conservative value should be used in the analysis.	1		
	Gearbox and final drive ratios		1		
	Tyre rolling radius (drive axle group)	Radius should be for new tyre at the recommended inflation pressure, which has the largest loaded radius.	1		
	Drive train mechanical losses of the hauling unit (rigid truck, bus, prime mover)	Values supplied may be approximate, in which case a conservative value should be used in the analysis.	2		
	Rolling losses (semi-trailer, dolly, trailers)	Values supplied may be approximate, in which case a conservative value should be used in the analysis.	2		

Table H1 (b) Longitudinal Performance (Low Speed) – Gradeability

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Gradeability	Gross Vehicle Mass or Gross Combination Mass	To prevent loss of traction drive axle group load should be not less than assumed in the assessment.	1		

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Gradeability (cont)	Engine torque-speed characteristics	If vehicle operating at altitude de-rating of engine with altitude could be an issue and needs to be checked.	1		
	Gearbox and final drive ratios		1		
	Tyre rolling radius (drive axle group)	Radius should be for new tyre at the recommended inflation pressure, which has the largest loaded radius and greatest influence on low-speed gradeability. Further, normal decreases in rolling radius with wear can influence maximum speed on grade. Performances of vehicle that are marginal need to be checked with largest/smallest radius tyre, as appropriate.	1		
	Aerodynamic drag	Values for the entire vehicle may not be available, in which case a conservative value should be used in the analysis.	2		
	Drive train mechanical losses of the hauling unit (rigid truck, bus, prime mover)	Values supplied may be approximate, in which case a conservative value should be used in the analysis.	2		
	Rolling losses (semi-trailer, trailers)	Values supplied may be approximate, in which case a conservative value should be used in the analysis.	2		

Table H1(c) Longitudinal Performance (Low Speed) – Acceleration Capability

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Acceleration Capability	Gross Vehicle Mass or Gross Combination Mass	To prevent loss of traction drive axle group load should be not less than assumed in the assessment.	1		

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Acceleration Capability (cont)	Engine torque-speed characteristics	If vehicle operating at altitude de-rating of engine with altitude could be an issue and needs to be checked.	1		
	Gearbox and final drive ratios		1		
	Tyre rolling radius (drive axle group)	Radius should be for new tyre at the recommended inflation pressure, which has the largest loaded radius.	1		
	Time delays associated with gear shifting (automatic transmissions only). For manual transmissions this parameter is driver dependent.	Gearshift times for manual transmissions used in the analysis must not be too short and must reflect real world situation.	1		
	Drive train mechanical losses of the hauling unit (rigid truck, bus, prime mover)	Values supplied may be approximate, in which case a conservative value should be used in the analysis.	2		
	Rolling losses (semi-trailer, trailers)	Values supplied may be approximate, in which case a conservative value should be used in the analysis.	2		

Table H2 (a) Longitudinal Performance (High Speed) – Tracking Ability on a Straight Path

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Tracking Ability on a Straight Path	Tyre cornering characteristics	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	May not be possible or convenient to conduct tilt test. For some loads payload centre-of-gravity heights may be difficult to estimate.	1		
	Gross Vehicle Mass or Gross Combination Mass		1		

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Tracking Ability on a Straight Path (cont)	Wheelbase (each unit)		1		
	Coupling lead or coupling rear overhang (each applicable unit)		2		
	Width plan-profile (each unit, but rearmost unit in particular)	Critical points may be difficult to identify from plan view drawings (if available) and visual inspection of vehicle.	3		
	Suspension characteristics (spring deflection-load characteristics, damper force-velocity characteristics, auxiliary roll stiffness, roll-steer characteristics)	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	3		

Table H3 (a) Directional Performance (Low Speed) – Low Speed Swept Path

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Low Speed Swept Path	Wheelbase dimensions (all units)		1		
	Front overhang and plan-profile of front outside corners and protuberances (hauling unit)	Critical points may be difficult to identify from plan view drawings (if available) and visual inspection of vehicle.	2		
	Coupling rear overhang		2		

Note: (This note applies in particular to performances of Tables H3 (a) to H3 (d), and similarly to those of Tables H2 (a) and H4 (a) to H4 (d))

Vehicle units with forced-steer axles or axle groups will have variable offtracking point(s) belonging to different vehicle units depending on the position of the vehicle along the travel path. Low speed swept path performance will have to be assessed and checked for all intended steering arrangements and combinations of vehicle units.

Critical parameters that require checking include all geometries and mechanical properties relating to the steering system and all assumed functional relationships (for forced-steer system).

Table H3 (b) Directional Performance (Low Speed) – Frontal Swing

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Frontal Swing	Front overhang (hauling unit) and forward projection (lead semi-trailer)		1		
	Plan-profile of front outside corners and protuberances (hauling unit and lead semi-trailer)	Critical points may be difficult to identify from plan view drawings (if available) and visual inspection of vehicle.	1		
	Rigid truck/bus, prime mover wheelbase		1		
	Wheelbase of first semi-trailer		2		

Table H3(c) Directional Performance (Low Speed) – Tail Swing

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Tail Swing	Rear overhang of rigid truck/bus, or rear overhang of first semi-trailer if articulated vehicle		1		
	Plan-profile of rear outside corners and protuberances (vehicle unit that has the critical overhang dimension)	Critical points may be difficult to identify from plan view drawings (if available) and visual inspection of vehicle.	1		
	Wheelbase of vehicle unit that has the critical overhang dimension		2		

Table H3 (d) Directional Performance (Low Speed) – Steer Tyre Friction Demand

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Steer Tyre Friction Demand	Wheelbase of rigid truck/bus or prime mover		1		

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
	Drive group axle spread		1		
	Steer axle load	Should be not less than assumed in the assessment.	1		
Steer Tyre Friction Demand (cont)	King-pin lead or coupling rear overhang (first vehicle unit)		2		

Table H4 (a) Directional Performance (High Speed) – Static Rollover Threshold

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Static Rollover Threshold	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	May not be possible or convenient to conduct tilt test. For some loads payload centre-of-gravity heights may be difficult to estimate. Measurement tolerances.	1		
	Tyre track width, and dual tyre spacing (if applicable)	Tyre track width may be less than was assumed in the assessment.	1		
	Chassis torsional flexibility	May be difficult to estimate for loaded vehicle.	1		
	Suspension total roll stiffness (spring deflection-load characteristics, auxiliary roll stiffness, and freeplay)	If generic, non-descript suspensions are used in the analysis these should have characteristics that are consistent with worst-case performing suspensions of the same type. This ensures that any suspensions of the same type can be used.	2		
	Tyre vertical stiffness	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	2		
	Couplings (conventional, double oscillating turntables, ball, other)	If generic, non-descript couplings were used in the analysis these should be consistent with worst-case performers.	2		

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
	Tyre cornering characteristics	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	3		

Table H4 (b) Directional Performance (High Speed) – Rearward Amplification

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Rearward Amplification	Tyre cornering characteristics	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	1		
	Wheelbase (trailer and semi-trailer)		1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	May not be possible or convenient to conduct tilt test. For some loads payload centre-of-gravity heights may be difficult to estimate. Measurement tolerances.	1		
	Chassis torsional flexibility	May be difficult to estimate for loaded vehicle.	1		
	Coupling lead or coupling rear overhang (each applicable unit)		2		
	Wheelbase (dolly)		3		
	Wheelbase (prime mover)		3		

Table H4(c) Directional Performance (High Speed) – Yaw Damping Coefficient

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Yaw Damping Coefficient	Wheelbase (trailer and semi-trailer)		1		
	Tyre cornering characteristics	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	1		
Yaw Damping Coefficient (cont)	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	May not be possible or convenient to conduct tilt test. For some loads payload centre-of-gravity heights may be difficult to estimate. Measurement tolerances.	2		

Table H4 (d) Directional Performance (High Speed) – High Speed Transient Offtracking

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
High Speed Transient Offtracking	Tyre cornering characteristics	If generic, non-descript tyres were used in the analysis these should have cornering characteristics that are consistent with worst-case performing tyres of the same size to ensure that any tyre of the same size can be used.	1		
	Wheelbase (trailer and semi-trailer)		1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	May not be possible or convenient to conduct tilt test. For some loads payload centre-of-gravity heights may be difficult to estimate. Measurement tolerances.	1		
	Coupling lead or coupling rear overhang (each applicable unit)		2		
	Wheelbase (dolly)		3		

APPENDIX I – RISK SENSITIVE PARAMETERS RELATED TO VEHICLE OPERATING FACTORS

Table I1(a): Longitudinal Performance (Low Speed) – Startability

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Startability, Gradeability and Acceleration Capability	Gross Vehicle Mass or Gross Combination Mass	To prevent loss of traction, drive axle group load should be not less than critical value assumed in the assessment.	1		
	Tyre rolling radius (drive axle group)		2		

Table I1 (b) Longitudinal Performance (Low Speed) – Gradeability

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Gradeability	Gross Vehicle Mass or Gross Combination Mass		1		
	Tyre rolling radius (drive axle group)		2		

Table I1(c) Longitudinal Performance (Low Speed) – Acceleration Capability

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Acceleration Capability	Gross Vehicle Mass or Gross Combination Mass	To prevent loss of traction, drive axle group load should be not less than critical value assumed in the assessment.	1		
	Tyre rolling radius (drive axle group)		2		

Table I2 (a) Longitudinal Performance (High Speed) – Tracking Ability on a Straight Path

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Tracking Ability on a Straight Path	Tyre cornering characteristics	Tyre cornering characteristics are sensitive to inflation pressure, tread pattern and wear.	1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	For some loads payload centre-of-gravity heights may be difficult to estimate. Slosh effects of liquid loads.	1		
	Gross Vehicle Mass or Gross Combination Mass		1		
	Suspensions	Characteristics sensitive to airbag pressure (potential issue only applicable to airbag suspensions).	3		

Table I3 (a) Directional Performance (Low Speed) – Low Speed Swept Path

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Low Speed Swept Path					

Note: Vehicle units with forced-steer axles or axle groups will require special consideration and treatment to be defined by the Assessor and/or manufacturer. This note applies in particular to performances of Tables B3(a) to B3(d), and similarly to those of Tables B2(a) and B4(a) to B4(d).

Table I3(b) Directional Performance (Low Speed) – Frontal Swing

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Frontal Swing					

Table I3(c) Directional Performance (Low Speed) – Tail Swing

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Tail Swing					

Table I3 (d) Directional Performance (Low Speed) – Steer Tyre Friction Demand

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Steer Tyre Friction Demand	Steer axle load	In practice can be easily changed with incorrect loading of vehicle.	1		

Table I4 (a) Directional Performance (High Speed) – Static Rollover Threshold

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Static Rollover Threshold	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	For some loads payload centre-of-gravity heights may be difficult to estimate.	1		
	Suspensions	Characteristics sensitive to airbag pressure (issue only applicable to airbag suspensions).	2		
	Tyre vertical stiffness	Influenced by inflation pressure.	2		

Table I4 (b) Directional Performance (High Speed) – Rearward Amplification

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Rearward Amplification	Tyre cornering characteristics	Tyre cornering characteristics are sensitive to inflation pressure, tread pattern and wear.	1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	For some loads payload centre-of-gravity heights may be difficult to estimate.	2		

Table I4(c) Directional Performance (High Speed) – Yaw Damping Coefficient

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
Yaw Damping Coefficient	Tyre cornering characteristics	Tyre cornering characteristics are sensitive to inflation pressure, tread pattern and wear.	1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	For some loads payload centre-of-gravity heights may be difficult to estimate.	1		

Table I4 (d) Directional Performance (High Speed) – High Speed Transient Offtracking

Standard	Critical Parameter	Potential Issues	Initial Rank	Assessors Rank	Off-baseline variation used (%)
High Speed Transient Offtracking	Tyre cornering characteristics	Tyre cornering characteristics are sensitive to inflation pressure, tread pattern and wear.	1		
	Centre-of-gravity height of each vehicle unit, and load offset (if applicable)	For some loads payload centre-of-gravity heights may be difficult to estimate.	2		

APPENDIX J – INFORMATION AND RECOMMENDATIONS CONCERNING VEHICLE OPERATING CONDITIONS

1. Acceptable Load Types

Describe completely each of the load types that were assessed. The description of a liquid load must be accompanied by a specific gravity, the description of a solid load by its assumed density and any loading patterns.

2. Mass Management

(a) If relevant, specify the centre-of-gravity height of each load type on each motor vehicle and trailer or semi-trailer (as appropriate) that was assumed in the assessment.

	Motor vehicle	Semi-trailer(s)	Trailer(s)
Centre-of-gravity height and load offset (if applicable)			

(b) Specify any part loading conditions to be avoided that are derived from the 'least favourable loading condition' in *The Standards and Rules for Assessment for Vehicles*.

Specification	

3. Tyres

(a) Specify maximum and minimum tyre pressures for each axle group (or each axle if different within a group)

<table>
<tr><td rowspan="2"></td><td colspan="2">Motor vehicle</td><td rowspan="2">Semi-trailer(s)</td><td rowspan="2">Trailer(s)</td></tr>
<tr><td>Steer axle(s)</td><td>Drive axle(s)</td></tr>
</table>

Maximum tyre pressure (kPa)				
Minimum tyre pressure (kPa)				

(b) (i) Is compliance with safety standards very sensitive to tyre pressures? Yes/no

(ii) Do some or all of the tyres fitted to the vehicle have particularly different characteristics to those usually fitted to heavy vehicles? Yes/no

(iii) If the answer was yes to either (i) or (ii), provide details and recommendations as to how to ensure that assumed conditions will be met.

4. Other

Specify any special operating conditions assumed in the assessment.

5. Recommended operating conditions

List any recommended operating conditions.

APPENDIX K - CERTIFICATE THAT A DESIGN/VEHICLE MEETS ALL THE PERFORMANCE BASED STANDARDS

Part A – Details of the primary assessor and of the person who commissioned the assessment

Date:				Approval No.	
Primary assessor:				Reference No.	
Person who commissioned the assessment	Name:				
	Address:				
Contact details (if different from the above)	Name:				
	Address:				
	Position:				
	Tel:		Fax:		
	Email:				
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Part B – Details of the design/vehicle that was assessed

Include a brief description of the design/vehicle that was assessed.

Include both side and plan view layout drawing(s) showing all relevant dimensions, axle group loads and gross combination mass.

A full description of any innovative or unique features of the design/vehicle must accompany the drawing(s).

Part C – Recommended overall performance level

After conducting a global assessment of the performance levels achieved by the design/vehicle with respect to each standard for which a performance level is relevant, I recommend that the *design/*vehicle be given an overall classification level of–

☐ Level 1
☐ Level 2
☐ Level 3
☐ Level 4.

Part D – Details of prescriptive requirements from which exemption needed

In my opinion, the vehicle, or a vehicle built to the design, will require exemption from the following prescriptive requirements –
[*tick one or more of the following*]

☐ clause 64 (Axle configuration)
☐ clause 65 (Relation between axles in a group)
☐ clause 66 (Width)
☐ clause 67 (Length of single motor vehicles)
☐ clause 68 (Length of single trailers)
☐ clause 69 (Length of combinations)
☐ clause 70 (Rear overhang)
☐ clause 71 (Trailer drawbar length)
☐ clause 72 (Height)
☐ clauses 169 (b) and (c) (Attachment of couplings and drawbar eyes on long road trains);
☐ clause 171 (Tow coupling overhang on long road trains)
☐ the following ADRs:

- ☐ Rule 43, clause 6.1 (Length)
- ☐ Rule 43, clause 6.2 (Rear overhang)(other than clause 6.2.1)
- ☐ Rule 43, clause 6.2.1 (Rear overhang)
- ☐ Rule 43, clause 6.3 (Height)
- ☐ Rule 43, clause 6.5 (Width)
- ☐ Rule 43, clause 9.4 (Retractable axles)
- ☐ Rule 43, clause 9.5 (Retractable axles)
- ☐ Rule 62, clause 5.3 (Tow coupling overhang)
- ☐ Rule 63, clause 63.5.1 (Tow coupling location)

Part E – Details of the results of the assessment against infrastructure standards

Attach results of the assessments conducted in accordance with Appendix A.

Part F – Details of the results of the assessment against safety standards

If any part of the assessment has been undertaken by numerical simulation, attach Table 36.

If any part of the assessment has been undertaken by testing, attach Table 55.

If any part of the assessment relies on an assessment made by one or more other assessors, attach copy of certificate relied on from those other assessments.

Part G – Details of vehicle physical characteristics

Attach the Vehicle Certification Information (Appendix G) for the vehicle.

Part H – Details of sensitivity testing

If any risk sensitivity testing was undertaken, attach copy of completed Appendix H or I or both, as the case may be.

Part I – Details of critical characteristics

Include a list of the vehicle physical characteristics that are most important to the capability of the vehicle, or a vehicle built to the design, to comply with, or to continue to comply with, the standards.

Part J – Details of vehicle operating conditions

Attach Appendix J (Information and recommendations concerning vehicle operating conditions).

If recommending that an operator, as a national operating condition, be required to have a quality system to control the performance of the vehicle, the recommendation must include the items that must be specified in the quality system.

Part K – Details of assumptions relied on

Include a list of assumptions on which reliance has been placed in conducting the assessment, or in forming an opinion in relation to the design or vehicle.

Part L – Certification

I certify:

(a) that in my opinion, based on the assessment I have undertaken:

*(i) a vehicle built to the design set out under Part B will meet all the infrastructure and safety standards set out in Appendices A and C of *The Standards and Vehicle Assessment Rules*;

*(ii) the vehicle described under Part B meets all the infrastructure and safety standards set out in Appendices A and C of *The Standards and Vehicle Assessment Rules*;

(* omit whichever paragraph does not apply)

(b) that all details given in Parts A to K are true and correct or, in the case of an opinion, accurately express my opinion.

Name:	
Signature:	
Date:	

APPENDIX L - CERTIFICATE THAT A DESIGN/VEHICLE MEETS ONE OR MORE SPECIFIC PERFORMANCE BASED STANDARDS

Part A – Details of the assessor and of the person who commissioned the assessment

Date:			Approval No.	
Assessor:			Reference No.	
Person who commissioned the assessment	Name:			
	Address:			
Contact details (if different from the above)	Name:			
	Address:			
	Position:			
	Tel:		Fax:	
	Email:			
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Part B – Details of the design/vehicle assessed

Include a description of the design/vehicle assessed and include both side and plan view layout drawing(s) showing all relevant dimensions, axle group loads and gross combination mass that relate to the standard/s assessed.

A full description of innovative or unique features (if any) relevant to the standard/s assessed must accompany the drawing(s).

Part C – Details of performance level

If different performance levels are specified in relation to the standard/s in relation to which this certificate is being provided, the assessor must state the performance level achieved by the design/vehicle in the assessment. For each relevant standard assessed specify –

☐ Level 1
☐ Level 2
☐ Level 3
☐ Level 4.

Part D – Details of prescriptive requirements from which exemption needed

In my opinion, the vehicle, or a vehicle built to the design, will require exemption from the following prescriptive requirements in relation to the standard/s assessed –
[*tick one or more of the following*]

☐ clause 64 (Axle configuration)
☐ clause 65 (Relation between axles in a group)
☐ clause 66 (Width)
☐ clause 67 (Length of single motor vehicles)
☐ clause 68 (Length of single trailers)
☐ clause 69 (Length of combinations)
☐ clause 70 (Rear overhang)
☐ clause 71 (Trailer drawbar length)
☐ clause 72 (Height)
☐ clauses 169 (b) and (c) (Attachment of couplings and drawbar eyes on long road trains);
☐ clause 171 (Tow coupling overhang on long road trains)
☐ the following ADRs:

- ☐ Rule 43, clause 6.1 (Length)
- ☐ Rule 43, clause 6.2 (Rear overhang)(other than clause 6.2.1)
- ☐ Rule 43, clause 6.2.1 (Rear overhang)
- ☐ Rule 43, clause 6.3 (Height)
- ☐ Rule 43, clause 6.5 (Width)
- ☐ Rule 43, clause 9.4 (Retractable axles)
- ☐ Rule 43, clause 9.5 (Retractable axles)
- ☐ Rule 62, clause 5.3 (Tow coupling overhang)
- ☐ Rule 63, clause 63.5.1 (Tow coupling location)

Part E – Details of the results of the assessment

Attach any relevant results as recorded in accordance with Appendix E (Tables 36) or Appendix F (Table 55).

Part F – Details of vehicle physical characteristics

Attach the Vehicle Certification Information (Appendix G) for the vehicle (but only in relation to vehicle physical characteristics that are relevant to the standard/s assessed).

Part G – Details of vehicle operating conditions

If any risk sensitivity testing was undertaken, attach copy of completed Appendix H or I or both, as the case may be (but only in relation to testing that is relevant to the standard/s assessed).

Part H – Details of critical characteristics

Include a list of the vehicle physical characteristics that are most important to the capability of the vehicle, or a vehicle built to the design, to comply with, or to continue to comply with, the standard/s assessed.

Part I – Details of vehicle operating conditions

Attach Appendix J (Information and recommendations concerning vehicle operating conditions)(but only in relation to conditions that are relevant to the standard/s assessed).

Part J – Details of assumptions relied on

Include a list of assumptions on which reliance has been placed in conducting the assessment, or in forming an opinion in relation to the design or vehicle.

Part K – Certification

I certify:

(a) that in my opinion, based on the assessment I have undertaken:

*(i) a vehicle built to the design set out under Part B will meet the following standard/s set out in Appendix A or C of *The Standards and Vehicle Assessment Rules*:

[*insert name of standard/s assessed and being certified*]

*(ii) the vehicle described under Part B meets the following standard/s set out in Appendix A or C of *The Standards and Vehicle Assessment Rules*:

[*insert name of standard/s assessed and being certified*]

(* omit whichever subparagraph does not apply)

(b) that all details given in Parts A to J are true and correct, or, in the case of an opinion, accurately express my opinion.

Name:	
Signature:	
Date:	

APPENDIX M - CERTIFICATE FOR A DESIGN/VEHICLE THAT DOES NOT MEET ALL THE PERFORMANCE BASED STANDARDS

Part A – Details of the primary assessor and of the person who commissioned the assessment

<table>
<tr><td>Date:</td><td></td><td>Approval No.</td><td></td></tr>
<tr><td>Primary assessor:</td><td></td><td>Reference No.</td><td></td></tr>
<tr><td>Person who commissioned the assessment</td><td colspan="3">Name:</td></tr>
<tr><td></td><td colspan="3">Address:</td></tr>
<tr><td>Contact details (if different from the above)</td><td colspan="3">Name:</td></tr>
<tr><td></td><td colspan="3">Address:</td></tr>
<tr><td></td><td colspan="3">Position:</td></tr>
<tr><td></td><td>Tel:</td><td></td><td>Fax:</td></tr>
<tr><td></td><td>Email:</td><td colspan="2"></td></tr>
<tr><td>Office use only</td><td colspan="3"></td></tr>
</table>

Part B – Details of the design/vehicle that was assessed

Include a brief description of the design/vehicle that was assessed.

Include both side and plan view layout drawing(s) showing all relevant dimensions, axle group loads and gross combination mass.

A full description of any innovative or unique features of the design/vehicle must accompany the drawing(s).

Part C – Details of non-compliance with standards and why design/vehicle may be eligible for approval under rule 33A or 33B

Set out which standards the design/vehicle does not comply with.

State under which rule (33A or 33B) of the Business Rules the design/vehicle may be eligible for approval.

Explain the basis on which the design/vehicle may be eligible for that approval.

Part D – Recommended overall performance level

After conducting a global assessment of the performance levels achieved by the design/vehicle with respect to each standard for which a performance level is relevant, and on the assumption that the design/vehicle is eligible for approval, I recommend that the *design/*vehicle be given an overall classification level of–

□ Level 1
□ Level 2
□ Level 3
□ Level 4.

Part E – Details of prescriptive requirements from which exemption needed

In my opinion, the vehicle, or a vehicle built to the design, will require exemption from the following prescriptive requirements –
[*tick one or more of the following*]

□ clause 64 (Axle configuration)
□ clause 65 (Relation between axles in a group)
□ clause 66 (Width)

□ clause 67 (Length of single motor vehicles)

□ clause 68 (Length of single trailers)

□ clause 69 (Length of combinations)

□ clause 70 (Rear overhang)

□ clause 71 (Trailer drawbar length)

□ clause 72 (Height)

□ clauses 169 (b) and (c) (Attachment of couplings and drawbar eyes on long road trains);

□ clause 171 (Tow coupling overhang on long road trains)

□ the following ADRs:

- □ Rule 43, clause 6.1 (Length)
- □ Rule 43, clause 6.2 (Rear overhang)(other than clause 6.2.1)
- □ Rule 43, clause 6.2.1 (Rear overhang)
- □ Rule 43, clause 6.3 (Height)
- □ Rule 43, clause 6.5 (Width)
- □ Rule 43, clause 9.4 (Retractable axles)
- □ Rule 43, clause 9.5 (Retractable axles)
- □ Rule 62, clause 5.3 (Tow coupling overhang)
- □ Rule 63, clause 63.5.1 (Tow coupling location)

Part F – Details of the results of the assessment against infrastructure standards

Attach results of the assessments conducted in accordance with Appendix A.

Part G – Details of the results of the assessment against safety standards

If any part of the assessment has been undertaken by numerical simulation, attach Table 36.

If any part of the assessment has been undertaken by testing, attach Table 55.

If any part of the assessment relies on an assessment made by one or more other assessors, attach copy of certificate relied on from those other assessments.

Part H – Details of vehicle physical characteristics

Attach the Vehicle Certification Information (Appendix G) for the vehicle.

Part I – Details of sensitivity testing

If any risk sensitivity testing was undertaken, attach copy of completed Appendix H or I or both, as the case may be.

Part J – Details of critical characteristics

Include a list of the vehicle physical characteristics that are most important to the capability of the vehicle, or a vehicle built to the design, to comply with, or to continue to comply with, the standards.

Part K – Details of vehicle operating conditions

Attach Appendix J (Information and recommendations concerning vehicle operating conditions).

If recommending that an operator, as a national operating condition, be required to have a quality system to control the performance of the vehicle, the recommendation must include the items that must be specified in the quality system.

Part L – Details of assumptions relied on

Include a list of assumptions on which reliance has been placed in conducting the assessment, or in forming an opinion in relation to the design or vehicle.

Part M – Certification

I certify:

(a) that in my opinion, based on the assessment I have undertaken:

*(i) although a vehicle built to the design set out under Part B will not meet all the infrastructure and safety standards set out in Appendices A and C of *The Standards and Vehicle Assessment Rules*, it may be eligible for approval under rule 33A or 33B of the *Review Panel Business Rules* for the reasons set out in Part C;

*(ii) the vehicle described under Part B does not meet all the infrastructure and safety standards set out in Appendices A and C of *The Standards and Vehicle Assessment Rules*, but it may be eligible for approval under rule 33A or 33B of the *Review Panel Business Rules* for the reasons set out in Part C;

(* omit whichever paragraph does not apply)

(b) that all details given in Parts A to L are true and correct or, in the case of an opinion, accurately express my opinion.

Name:	
Signature:	
Date:	

APPENDIX N: THE GENERIC TYRE DATA STANDARD

N1 GENERIC TYRE DATA

N1.1 Purpose and Intent

a) Purpose

The purpose of the generic tyre data standard is to provide assessors with standardised tyre properties for use when undertaking a PBS assessment.

b) Intent

The basis of the standard is to define the generic tyre data approach for use in PBS assessments, the methodology for calculation of assessment input values (where required) and provision of calculated values for required input parameters (the generic tyre datasets and other standardised input values).

Through the generic tyre data approach, the use of standardised inputs will provide greater certainty around PBS assessment outcomes and associated safety and performance of the PBS fleet.

N1.2 Definition

a) Summary statement

The selection of tyres with appropriate size and load rating for each axle position on a PBS vehicle.

b) Detailed statement

When operating at maximum laden mass, a vehicle participating in the Scheme must be fitted with tyres that support the load of the given axle group configuration.

N1.3 Requirements

In relation to the assessor:

- The assessor must use specified tyre properties found in the applicable sections of this Appendix.
- Where an assessor seeks to specify a range of tyre size and rated load options for particular axle positions, a separate assessment for each option must be undertaken.
- Assessors must only specify the tyre size, load rating requirements and tyre configuration (single/dual) for all axle positions on the vehicle.

In relation to operators:

- For each axle position, the operator must select tyres that:
    - meet the tyre size specified by the assessor; and
    - meet the minimum load index specified by the assessor.
- The operator must not select a retreaded tyre for the steer axle of the motor vehicle.

N1.4 Test Specifications

a) Test load

The vehicle being assessed must be loaded to its maximum laden mass.

b) Test procedure

The selection of generic tyre data by the assessor is to be undertaken in-line with the following steps:

STEP 1 – Determine generic tyre dataset to be used in assessment

Select appropriate generic tyre dataset for each axle group based on tyre load index and rated load from Table 56. For generic tyre datasets 1-9, rated load values have been determined based on a load index representing the middle of each range. For generic tyre data set 10, rated load values have been determined based on a load index range of 164-168.

Table 56. Rated loads for generic tyre datasets 1-10

Generic tyre dataset	Load Indices	Rated Load (kg)	Rated Load(N)	Vertical Stiffness (kN/m)
1	128-132	1900	18633	642
2	132-136	2120	20790	681
3	136-140	2360	23144	725
4	140-144	2650	25988	777
5	144-148	3000	29420	840
6	148-152	3350	32852	902
7	152-156	3750	36775	974
8	156-160	4250	41678	1064
9	160-164	4750	46582	1154
10	164 +	5300	51975	1253

Lateral force and aligning moment values for generic tyre datasets 1-10 are included in Attachment A to Appendix N. In accordance with Appendix E, an appropriate method of propulsion is to be used by the assessor. The assessor is to record the method of propulsion used and any data used by the assessor to propel the vehicle is to be retained for at least 5 years in accordance with Rule 20(1)(a).

Generic Tyre Datasets used in assessment are to be recorded in accordance with Table 26A.

STEP 2 – Select tyre size options

For each axle group select tyre size, or tyre size options, to be specified ensuring that available tyre options support the rated load/s selected from Table 56. For each tyre size selected determine the minimum load index to be specified in accordance with Table 57. The assessor must ensure that inflation pressure limits prescribed in ADR 95/00 (or later), or by a Gazetted Notice, are not exceeded for any tyre size option selected for the relevant axle position and configuration.

Table 57. Rated loads for generic tyre datasets 1-10

Load Index	Rated Load (kg)	Load Index	Rated Load (kg)	Load Index	Rated Load (kg)
129	1850	142	2650	155	3875
130	1900	143	2725	156	4000
131	1950	144	2800	157	4125
132	2000	145	2900	158	4250
133	2060	146	3000	159	4375
134	2120	147	3075	160	4500
135	2180	148	3150	161	4625
136	2240	149	3250	162	4750
137	2300	150	3350	163	4875
138	2360	151	3450	164	5000
139	2430	152	3550	165	5150
140	2500	153	3650	166	5300
141	2575	154	3750	167	5450

Tyre size and load rating options selected are to be recorded in accordance with Table 26A.

STEP 3 – Determine vertical stiffness

Select the vertical stiffness value associated with the selected generic tyre dataset in Table 56.

STEP 4 – Calculate rolling radius

Calculate the loaded rolling radius in millimetres (mm) using the following equation:

$Rr = 0.47D$

Where:
D is the ‘new tyre overall diameter’ as stated in *The Tyre and Rim Association of Australia - Standards Manual*. Tolerances allowed for tyre manufacture are not to be applied, ‘new tyre overall diameter’ as stated in the tables shall be used.

‘New tyre overall diameter’ for ‘highway tread’ shall be used for all tyre positions except for drive axle in which case the ‘New tyre overall diameter’ for ‘traction tread’ shall be used.

STEP 5 – Set tyre relaxation length

Set tyre relaxation length, in metres (m), to zero.

STEP 6 – Set vertical damping value

Set vertical damping, in newton second per metre (Ns/m), to zero.

STEP 7 - Set rolling resistance values

Set rolling resistance values, in newtons per kilonewton (N/kN), for axles positions as follows:

- Drive axles: 8 N/kN
- All other axle positions: 6 N/kN.

(c) Test method

Numerical modelling (computer-based simulation)

ATTACHMENT A TO APPENDIX N

Generic Tyre Datasets 1-10

Table 58. Lateral force (N) vs vertical load and slip angle for generic dataset 1.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
3727	665	1273	1788	2200	2518	2760	2942	3078	3181	3258	3316	3360
7453	1279	2442	3417	4190	4784	5232	5570	5824	6017	6164	6276	6363
11180	1806	3448	4828	5924	6767	7406	7888	8253	8531	8744	8908	9034
14906	2225	4262	5991	7381	8461	9287	9914	10391	10754	11032	11246	11410
18633	2534	4877	6900	8559	9871	10888	11666	12258	12709	13052	13313	13511
22360	2739	5305	7569	9469	11006	12215	13149	13861	14400	14805	15109	15334
26086	2857	5570	8020	10132	11880	13278	14367	15198	15821	16283	16620	16864
29813	2905	5701	8285	10573	12512	14089	15326	16267	16965	17472	17833	18083
33539	2899	5727	8400	10827	12930	14666	16034	17070	17828	18366	18735	18981
37266	2855	5675	8397	10928	13165	15033	16509	17616	18411	18959	19321	19549

Table 59. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 1.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
3727	20	32	35	34	32	29	26	24	21	19	17	15
7453	45	74	85	85	81	75	68	62	55	50	44	40
11180	73	124	147	152	147	137	126	114	103	92	83	73
14906	105	181	221	233	229	216	199	181	164	147	131	116
18633	139	245	306	329	327	311	289	263	238	213	190	168
22360	175	314	400	438	441	423	395	361	326	291	259	228
26086	214	389	504	560	571	552	517	473	427	381	338	297
29813	255	469	615	693	715	697	655	601	543	483	427	373
33539	298	552	734	838	873	858	811	745	672	598	526	458
37266	342	640	860	993	1046	1035	983	906	817	725	636	551

Table 60. Lateral force (N) vs vertical load and slip angle for generic dataset 2.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
4158	742	1420	1995	2454	2810	3079	3282	3435	3549	3635	3700	3749
8316	1427	2724	3813	4675	5338	5838	6215	6499	6714	6878	7003	7099
12474	2015	3848	5387	6610	7550	8263	8801	9208	9518	9756	9939	10080
16632	2483	4755	6684	8235	9441	10362	11062	11594	11999	12309	12548	12731
20790	2827	5441	7699	9550	11014	12148	13016	13677	14180	14563	14854	15075
24948	3057	5919	8445	10566	12280	13629	14671	15466	16067	16519	16858	17109
29106	3188	6215	8948	11304	13255	14815	16030	16957	17653	18168	18544	18816
33264	3241	6361	9244	11797	13960	15720	17100	18150	18929	19495	19897	20177
37422	3235	6390	9372	12080	14427	16363	17890	19046	19892	20492	20904	21178
41580	3185	6332	9369	12193	14689	16773	18420	19655	20543	21154	21558	21812

Table 61. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 2.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
4158	23	36	39	38	36	32	29	26	24	21	19	17
8316	50	82	94	95	90	83	76	69	62	55	50	44
12474	82	138	164	169	164	153	140	127	115	103	92	82
16632	117	202	247	260	255	241	222	202	183	164	146	130
20790	155	273	341	367	365	347	322	294	265	238	212	188
24948	196	351	447	489	492	472	440	402	363	325	289	255
29106	239	434	562	624	637	616	576	528	476	425	377	331
33264	285	523	687	774	797	778	731	671	605	539	476	416
37422	332	616	820	935	974	957	904	832	750	667	587	511
41580	382	714	960	1108	1167	1155	1096	1010	911	809	709	615

Table 62. Lateral force (N) vs vertical load and slip angle for generic dataset 3.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
4629	826	1581	2221	2732	3128	3428	3654	3823	3951	4047	4119	4174
9258	1589	3033	4244	5205	5942	6499	6918	7234	7474	7656	7796	7903
13886	2243	4283	5997	7358	8405	9198	9797	10251	10596	10861	11064	11221
18515	2764	5294	7441	9168	10510	11535	12315	12907	13358	13703	13968	14173
23144	3147	6058	8571	10631	12261	13523	14490	15226	15786	16212	16536	16782
27773	3403	6589	9401	11762	13671	15172	16332	17217	17886	18390	18766	19047
32402	3549	6919	9961	12584	14756	16493	17845	18877	19651	20225	20644	20947
37030	3608	7081	10291	13133	15541	17499	19036	20205	21072	21702	22150	22461
41659	3601	7113	10433	13448	16060	18216	19916	21203	22144	22812	23271	23576
46288	3546	7049	10430	13574	16352	18673	20505	21881	22869	23549	23999	24282

Table 63. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 3.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
4629	25	40	44	43	40	36	33	29	26	24	21	19
9258	56	91	105	106	100	93	85	76	69	62	55	49
13886	91	153	183	189	182	170	156	142	128	115	102	91
18515	130	225	275	290	284	268	247	225	203	182	163	145
23144	172	304	380	409	406	387	359	327	295	265	236	209
27773	218	390	497	544	548	526	490	448	404	362	321	283
32402	266	483	626	695	709	686	642	588	530	474	419	368
37030	317	582	764	861	888	866	814	747	674	600	530	464
41659	370	686	912	1041	1085	1066	1007	926	835	743	653	569
46288	425	794	1069	1234	1299	1286	1221	1125	1015	901	790	685

Table 64. Lateral force (N) vs vertical load and slip angle for generic dataset 4.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
5198	928	1776	2493	3068	3512	3849	4103	4293	4436	4544	4625	4687
10395	1784	3406	4766	5844	6672	7298	7768	8123	8392	8597	8754	8874
15593	2519	4809	6734	8262	9438	10329	11001	11511	11898	12195	12424	12600
20790	3104	5944	8356	10294	11801	12953	13828	14493	14999	15387	15685	15914
25988	3534	6802	9624	11938	13768	15185	16270	17097	17726	18204	18568	18844
31186	3821	7399	10556	13207	15351	17037	18339	19332	20084	20649	21072	21387
36383	3985	7769	11185	14131	16569	18519	20038	21197	22066	22710	23181	23521
41581	4052	7951	11556	14747	17451	19650	21375	22688	23662	24369	24872	25222
46778	4044	7987	11715	15100	18033	20454	22363	23809	24866	25615	26131	26474
51976	3982	7915	11712	15242	18361	20967	23025	24570	25679	26443	26948	27266

Table 65. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 4.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
5198	29	44	49	48	45	41	37	33	30	26	24	21
10395	63	103	118	119	113	104	95	86	77	69	62	55
15593	102	172	205	212	205	191	175	159	143	129	115	102
20790	146	252	308	325	319	301	278	253	228	205	183	162
25988	194	341	427	459	456	434	403	367	332	297	265	234
31186	245	438	558	611	615	591	550	503	454	406	361	318
36383	299	543	703	781	796	770	721	660	596	532	471	414
41581	356	654	858	967	997	972	914	839	757	674	595	521
46778	416	770	1024	1169	1218	1197	1131	1040	938	834	734	639
51976	477	892	1200	1386	1459	1444	1371	1263	1139	1012	887	769

Table 66. Lateral force (N) vs vertical load and slip angle for generic dataset 5.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
5884	1050	2010	2823	3473	3976	4358	4645	4860	5022	5144	5236	5306
11768	2020	3855	5395	6616	7553	8261	8794	9196	9501	9733	9910	10046
17652	2851	5445	7623	9353	10684	11693	12454	13031	13470	13806	14064	14264
23536	3514	6729	9459	11654	13360	14664	15654	16407	16980	17419	17756	18016
29420	4001	7700	10895	13514	15586	17191	18419	19355	20066	20608	21020	21333
35304	4325	8376	11950	14952	17378	19287	20761	21885	22736	23376	23855	24211
41188	4511	8795	12662	15997	18757	20965	22685	23996	24980	25709	26242	26627
47072	4587	9001	13082	16694	19755	22245	24198	25684	26787	27587	28157	28552
52956	4578	9042	13262	17095	20415	23156	25317	26953	28149	28998	29582	29970
58840	4508	8960	13259	17254	20786	23736	26066	27814	29070	29935	30507	30867

Table 67. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 5.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
5884	32	50	55	54	50	46	42	37	33	30	27	24
11768	71	116	134	134	128	118	107	97	87	78	70	62
17652	116	195	232	240	232	216	198	180	162	146	130	116
23536	165	286	349	368	361	341	314	286	258	232	207	184
29420	219	386	483	519	517	492	456	416	375	336	300	265
35304	277	496	632	692	697	669	623	569	514	460	408	360
41188	339	614	795	884	901	872	816	747	674	602	533	468
47072	403	740	972	1095	1129	1100	1035	950	857	763	674	589
52956	470	872	1160	1323	1379	1355	1280	1177	1062	944	830	723
58840	540	1010	1359	1569	1651	1635	1552	1430	1290	1145	1004	871

Table 68. Lateral force (N) vs vertical load and slip angle for generic dataset 6.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
6570	1173	2245	3152	3879	4440	4866	5187	5427	5608	5744	5847	5925
13141	2255	4305	6025	7388	8434	9225	9820	10269	10609	10868	11066	11218
19711	3184	6080	8512	10445	11931	13057	13907	14551	15041	15416	15705	15928
26282	3924	7515	10563	13013	14918	16374	17480	18320	18961	19451	19827	20117
32852	4467	8598	12166	15091	17404	19196	20568	21612	22407	23012	23472	23821
39422	4830	9353	13344	16696	19405	21537	23183	24438	25389	26103	26638	27036
45993	5038	9821	14140	17863	20945	23411	25331	26795	27894	28708	29303	29733
52563	5122	10051	14608	18641	22060	24840	27021	28680	29911	30805	31441	31883
59134	5112	10097	14810	19089	22797	25857	28270	30097	31433	32381	33033	33466
65704	5034	10005	14805	19267	23211	26505	29106	31059	32461	33427	34066	34467

Table 69. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 6.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
6570	36	56	62	60	56	51	46	42	37	33	30	26
13141	79	130	149	150	143	132	120	109	98	88	78	70
19711	129	218	259	268	259	241	221	201	181	163	145	130
26282	184	319	390	411	404	381	351	320	288	259	231	205
32852	245	431	539	580	577	549	509	464	419	376	335	296
39422	309	554	706	772	778	747	696	636	574	513	456	402
45993	378	686	888	987	1006	973	911	834	753	672	595	523
52563	450	826	1085	1222	1260	1229	1155	1060	957	852	752	658
59134	525	974	1295	1478	1540	1513	1429	1314	1185	1054	927	808
65704	603	1128	1517	1752	1844	1825	1733	1597	1440	1279	1121	972

Table 70. Lateral force (N) vs vertical load and slip angle for generic dataset 7.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
7355	1313	2513	3528	4342	4970	5447	5806	6075	6278	6430	6545	6632
14710	2525	4819	6744	8270	9442	10327	10993	11495	11876	12166	12388	12558
22065	3564	6806	9529	11692	13355	14616	15568	16289	16837	17257	17580	17830
29420	4392	8412	11824	14567	16700	18329	19568	20508	21225	21774	22195	22520
36775	5001	9625	13619	16893	19483	21488	23024	24193	25083	25760	26275	26666
44130	5407	10470	14938	18689	21722	24108	25951	27357	28420	29221	29819	30264
51485	5639	10993	15828	19996	23446	26206	28356	29995	31225	32136	32803	33283
58840	5733	11252	16352	20867	24694	27806	30247	32105	33483	34484	35196	35690
66195	5722	11303	16578	21368	25519	28945	31646	33691	35187	36247	36977	37462
73550	5635	11200	16573	21568	25983	29670	32582	34768	36337	37419	38134	38583

Table 71. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 7.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
7355	40	63	69	68	63	57	52	47	42	37	33	30
14710	89	145	167	168	160	147	134	122	109	98	88	78
22065	145	244	290	300	289	270	248	225	203	182	163	145
29420	207	357	436	461	452	426	393	358	323	290	259	230
36775	274	483	604	649	646	615	570	520	469	420	374	332
44130	346	620	790	864	871	836	779	712	642	575	510	450
51485	423	768	994	1105	1126	1090	1020	934	843	752	666	585
58840	504	925	1215	1368	1411	1376	1293	1187	1071	954	842	737
66195	588	1090	1450	1654	1724	1694	1600	1471	1327	1180	1038	904
73550	675	1262	1698	1961	2064	2043	1940	1787	1612	1431	1255	1088

Table 72. Lateral force (N) vs vertical load and slip angle for generic dataset 8.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
8336	1488	2848	3999	4921	5633	6173	6580	6885	7115	7288	7418	7516
16671	2861	5462	7643	9373	10700	11704	12459	13028	13459	13788	14039	14232
25007	4040	7713	10799	13251	15136	16565	17643	18460	19082	19558	19924	20208
33342	4978	9533	13400	16509	18926	20773	22176	23242	24055	24677	25154	25522
41678	5668	10909	15435	19145	22080	24353	26093	27419	28427	29194	29778	30221
50014	6128	11866	16929	21181	24618	27323	29411	31004	32210	33116	33795	34299
58349	6391	12459	17938	22662	26572	29700	32136	33994	35389	36421	37176	37721
66685	6498	12752	18532	23650	27986	31513	34280	36385	37947	39081	39888	40449
75020	6485	12810	18788	24217	28921	32804	35865	38183	39878	41080	41907	42457
83356	6386	12693	18783	24444	29447	33626	36926	39404	41182	42408	43218	43727

Table 73. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 8.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
8336	46	71	78	77	71	65	59	53	47	42	38	34
16671	101	164	189	191	181	167	152	138	124	111	99	89
25007	164	276	329	340	328	306	281	255	230	206	185	164
33342	234	405	494	522	512	483	445	405	366	328	293	260
41678	310	547	684	736	732	696	646	589	532	477	424	376
50014	393	703	895	980	987	947	882	807	728	651	578	510
58349	480	870	1127	1252	1276	1235	1156	1059	955	853	755	663
66685	571	1048	1376	1551	1599	1559	1466	1345	1214	1081	954	835
75020	667	1235	1643	1875	1953	1919	1813	1667	1504	1338	1176	1025
83356	765	1430	1925	2222	2339	2316	2198	2025	1827	1622	1422	1233

Table 74. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 9.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
9316	1663	3183	4469	5500	6296	6900	7354	7696	7952	8145	8291	8401
18633	3198	6104	8542	10476	11960	13081	13924	14561	15043	15410	15691	15907
27949	4515	8621	12070	14810	16917	18514	19719	20632	21327	21859	22269	22585
37266	5564	10655	14977	18452	21153	23217	24786	25977	26885	27580	28114	28525
46582	6335	12192	17251	21398	24678	27219	29163	30645	31772	32629	33282	33777
55898	6849	13262	18921	23673	27515	30538	32872	34652	36000	37013	37771	38335
65215	7143	13925	20049	25329	29699	33195	35918	37994	39552	40706	41550	42159
74531	7262	14252	20713	26432	31279	35221	38313	40666	42412	43680	44581	45208
83848	7248	14317	20999	27067	32324	36663	40085	42675	44570	45914	46838	47452
93164	7137	14187	20993	27320	32912	37582	41271	44040	46028	47397	48303	48872

Table 75. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 9.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
9316	51	80	88	86	80	73	66	59	53	47	42	38
18633	113	184	211	213	202	187	170	154	139	124	111	99
27949	183	309	367	380	367	342	314	285	257	231	206	184
37266	262	452	553	583	572	540	498	453	409	367	327	291
46582	347	612	765	822	818	778	722	658	594	533	474	420
55898	439	786	1001	1095	1103	1059	986	902	814	728	646	570
65215	536	973	1259	1399	1426	1380	1292	1183	1068	953	844	741
74531	638	1172	1538	1733	1787	1742	1638	1503	1356	1209	1066	933
83848	745	1381	1836	2095	2183	2145	2027	1863	1681	1495	1315	1145
93164	855	1599	2151	2484	2614	2588	2457	2264	2042	1813	1590	1379

Table 76. Lateral force (N) vs vertical load and slip angle for generic tyre dataset 10.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
10395	1855	3551	4987	6136	7025	7699	8206	8587	8873	9088	9251	9373
20790	3568	6811	9531	11689	13344	14595	15537	16247	16784	17194	17508	17748
31185	5038	9619	13467	16524	18875	20657	22002	23021	23796	24390	24847	25200
41580	6208	11889	16711	20588	23602	25905	27655	28985	29998	30773	31369	31828
51975	7068	13604	19248	23875	27535	30370	32540	34193	35451	36407	37135	37688
62370	7641	14798	21112	26414	30701	34073	36677	38664	40167	41298	42144	42773
72765	7970	15537	22370	28261	33137	37038	40076	42393	44132	45419	46361	47040
83160	8103	15902	23111	29493	34901	39299	42749	45375	47323	48737	49743	50442
93555	8087	15975	23430	30200	36066	40908	44726	47616	49730	51229	52261	52946
103950	7964	15829	23423	30483	36722	41933	46049	49139	51356	52885	53895	54531

Table 77. Aligning moment (Nm) vs vertical load and slip angle for generic dataset 10.

Vertical load (N)	Slip angle (degrees)											
	1	2	3	4	5	6	7	8	9	10	11	12
0	0	0	0	0	0	0	0	0	0	0	0	0
10395	57	89	98	96	89	81	73	66	59	53	47	42
20790	126	205	236	238	226	208	190	172	155	139	124	110
31185	204	345	410	423	409	382	350	318	287	257	230	205
41580	292	505	617	651	638	602	555	506	456	409	365	325
51975	387	683	853	918	913	869	805	735	663	594	529	469
62370	490	877	1117	1222	1231	1181	1100	1006	908	812	721	637
72765	598	1085	1405	1561	1592	1540	1441	1320	1191	1063	941	827
83160	712	1307	1717	1934	1994	1944	1828	1677	1513	1349	1190	1041
93555	831	1540	2049	2338	2436	2394	2261	2079	1875	1668	1467	1278
103950	954	1784	2400	2771	2917	2888	2741	2526	2278	2023	1774	1538