REVIEW OF TRUCK AND DOG TRAILER OPERATIONS OVER 42.5 TONNES GROSS VEHICLE MASS

Barry Hendry Senior Project Manager, National Road Transport Commission, Level 5/326 William Street, Melbourne, Victoria, Australia 3000, Website: www.nrtc.gov.au, Email: hendryb@nrtc.gov.au

Brendan Coleman Systems Engineer, Roaduser Systems Pty Ltd, 76-80 Vella Drive, Sunshine Melbourne, Victoria, Australia, 3020, Website: www.roaduser.com.au, Email: brendan@roaduser.com.au

ABSTRACT

In Australia, the national Road Transport Reform (Mass and Loading) Regulations 1995 only allow operation of truck and dog trailers to 42.5 tonnes gross combination mass (GCM) and a mass ratio of 1:1. However, many jurisdictions allow higher mass limits/mass ratios and operation up to 50 tonnes GCM on their general road network.

The Australian National Road Transport Commission (NRTC) has proposed a scheme (based on a Performance Based Standards (PBS) approach) which provides specific dimensional limits for truck-trailer combinations above 42.5 tonnes and up to 50 tonnes GCM with the options of providing separate evidence that showed compliance with a performance-based formula or a full PBS assessment.

While the most common usage for truck-trailers in Australia appears to be for transportation of quarry products, there is a growing application in logging and other sectors (such as fuel transportation) where stability factors are of concern.

The objective of the NRTC review was to develop appropriate performance-based controls for the design and operation of truck trailers at higher mass limits to deliver a consistent road safety performance. A national policy is considered desirable to:

- *improve consistency;*
- *introduce a common set of conditions;*
- *facilitate cross jurisdiction operations even though the percentage of interstate operation is expected to remain low; and*
- *ensure a consistent on-road safety performance for the truck trailer fleet.*

This paper will outline the various approaches taken in developing the operational conditions for general access operation of truck and dog trailers above 42.5 tonnes GCM and the process in obtaining agreement by operators, regulators and truck/trailer manufacturers to the proposal.

The policy development has not been completed and will need to align with the Performance Measures and Standards developed as part of the NRTC's Performance Based Standards (PBS) Project. The views expressed in the paper are those of the authors.

INTRODUCTION

The range and variety of regulatory frameworks under which Australia's road transport industry was required to operate was contrary to the very idea of competitiveness. This was recognised by the Special Premiers Conference in 1991 which led to the establishment of the National Road Transport Commission (NRTC). Initially, the Commission was set up with responsibility only for Heavy Vehicles (defined as greater than 4.5 tonnes Gross Vehicle Mass (GVM)). This responsibility was expanded in 1992 to also include Light Vehicles.

The mission of the National Road Transport Commission (NRTC) is:

> ***To contribute to Australia's economic, social and environmental future by playing the lead role in developing and co-ordinating road transport reform in Australia.***

Working in close partnership with the road freight transport and road passenger transport industries, governments and their agencies, police, community interest groups, unions and other organisations, the NRTC aims to develop and implement policies, practices and laws that:

- make road transport and road use more innovative, efficient and safe;
- introduce greater national transport uniformity and consistency;
- reduce the environmental impact of road transport; and
- reduce the costs of administration of road transport.

BACKGROUND

The national Road Transport Reform (Mass and Loading) Regulations 1995[1] limit the total mass of a combination (other than a road train or B-double) including load to 42.5 tonnes and also require that the loaded mass of the dog or pig trailer must not exceed the loaded mass of the towing vehicle, ie a 1:1 mass ratio. These limits are less, in most cases, than the sum of axle mass limits for the six, seven and eight axle truck and trailer combinations. Additionally, the general access overall length limit for these combinations is 19m. Figure 1 shows a typical three axle truck and four axle dog trailer with maximum overall length of 19m.

Operators in a variety of industry sectors, including quarry operations, sand, gravel, grain cartage and brick cartage, have expressed strong interest in using truck and dog trailer combinations at higher gross mass limits to improve productivity. Figure 2 shows a typical three axle truck and three axle dog trailer used in quarry operations.

Although most jurisdictions have implemented the national Mass & Loading Regulations, some jurisdictions allow truck trailers to operate at mass limits higher than 42.5 tonnes under special conditions that were developed by jurisdictions in conjunction with the NRTC in 1996-97 (Refer Annex A).

REVIEW OBJECTIVE

The review of the Truck and Dog Trailer mass limits is an initiative of the NRTC's Second Heavy Vehicle Reform Package, recognising that various schemes for these combinations already exist in most jurisdictions.

The objective of the review is to develop appropriate performance-based controls for the design and operation of truck trailers at higher mass limits to deliver a consistent road safety performance.

A national policy is considered desirable to:

- improve consistency;
- introduce a common set of conditions;
- facilitate cross jurisdiction operations even though the percentage of interstate operation is expected to remain low; and
- ensure a consistent on-road safety performance for the truck trailer fleet.

INITIAL POLICY DEVELOPMENT

In 1996, the Roads and Traffic Authority of New South Wales (RTA) commissioned ARRB Transport Research Limited (ARRB) to investigate the effects of higher mass (greater than 42.5 tonnes) on a range of vehicle safety and performance issues for truck and dog trailer combinations.

The testing conducted by ARRB covered dynamic stability, braking, high speed off-tracking and other criteria for vehicles with different wheelbases, axles and suspensions. On-road trials under permit conditions were also conducted for evaluation in New South Wales and Victoria by the RTA and VicRoads in conjunction with their respective operators and industry groups.

Based on the field testing of truck and dog trailer combinations in 1996 with gross combination mass (GCM) above 42.5 tonnes and on-road trials conducted under permit in Victoria and New South Wales (NRTC 1997), a preliminary set of general operating conditions as outlined in Annex A covering suspension type, axle spacing and vehicle capability were developed for the operation of truck-trailers above 42.5 tonnes GCM.

Figure 3 shows the four axle truck and three axle dog trailer testing conducted by ARRB Transport Research at Armidale, Australia in 1996.

These conditions were based on the results of testing by ARRB (NRTC 1997) that indicated that increasing the mass ratio from 1:1 to 1:1.4 is unlikely to compromise road safety for vehicles fitted with air suspensions. This means from a stability point of view, a three axle truck and a four axle trailer could have a gross combination mass limit of 54 tonnes. However, from a bridge perspective, the general access limit in Australia is generally 50 tonnes. Each of the State and Territory jurisdictions currently allow truck-trailers to operate above 42.5 tonnes as shown in Table 1 subject to special conditions. The mass increases do not exceed existing legal axle mass limits[2].

INDUSTRY CONCERNS

In July 1998, the Australian Trucking Association (ATA) expressed concern over the prospect of higher mass limits for six and seven axle truck-trailer combinations. This concern emanated principally from:

- computer simulation work, indicating stability problems for certain truck-trailer combinations (particularly with high centres of gravity and short truck wheelbases);

[1] Available on NRTC Website: www.nrtc.gov.au

[2] Steer Axle 6t, Tandem Axle Dual Tyred 16.5t (17t Road Friendly Suspension), Triaxle Dual Tyred 20t (22.5t Road Friendly Suspension)

- anecdotal reports of stability problems with these higher mass combinations; and
- the potential fleet conversion from more stable vehicles, eg 6 axle articulated vehicles to truck-trailer combinations (because of the higher payload).

As a result, the NRTC contracted Roaduser International Pty Ltd (now Roaduser Systems Pty Ltd) to undertake an assessment. Roaduser Systems interacted with a small group of jurisdictional representatives in undertaking its contract and the analysis involved the application of performance criteria for on-road stability, based on computer simulations.

The Roaduser Systems report (NRTC 1999), indicated in part, that the stability performance of truck-trailer combinations is dependent on the Centre of Gravity (CoG) of the trailer (predominantly), longitudinal dimensions and the tow coupling rear overhang.

Additionally, the report indicated that:

- truck-trailer combinations with high CoG remain of concern;
- acceptable stability can be achieved by adjusting critical design dimensions;
- the most common usage for truck-trailers appears to be for transportation of quarry products and these seem to possess adequate stability (low CoG);
- only limited details on accidents involving truck-trailers at the higher mass limits were found; and
- there is no evidence of significant fleet conversion at this stage.

A range of options on how to proceed were considered by the NRTC. The NRTC was attracted to controlling CoG (or a surrogate) through regulation, coupled with the possible provision of a Technical Guide prepared by the regulators in conjunction with industry. The surrogate selected was the centroid of the load space as detailed in Annex B.

This approach was considered suitable to deliver an operating regime that maintains productivity improvements and a comparable stability performance to that of the existing fleet. However, a final position was dependent on consultation with the jurisdictions and industry.

It appears that the stability problems raised by the ATA may occur with the less common Truck and Dog combinations with a high CoG when loaded. Moreover, the analysis suggests that design relationships are available to adjust critical dimensions to ensure that a consistent level of on-road stability is achieved.

PROPOSED APPROACH

In February 2000, the NRTC proposed a three level scheme (based on a Performance Based Standards (PBS) approach) which provided specific dimensional limits for truck-trailer combinations above 42.5 tonnes and up to 50 tonnes with the options of providing separate evidence that showed compliance with a performance-based formula or a full PBS assessment.

A performance-based simulation analysis was conducted by the consultant (mainly in relation to stability of the combination (Load Transfer Ratio)) to derive control conditions and performance formulae for truck and dog trailer combinations operating above 42.5 tonnes GCM and up to 50 tonnes GCM.

For combinations operating at GCM's of 42.5 tonnes (the current legal maximum mass limit) or below, no change in existing conditions was considered necessary.

However, for combinations operating above 42.5 tonnes GCM and up to 50 tonnes GCM, a three level approach for approval of their operation was proposed as shown in Table 2.

Although there was general support for the three level approach concern was expressed by jurisdictions and industry in that:

- the core dimensions in Level 1 were too onerous and alternatives should be considered;
- a significant percentage of existing vehicles would be outside the core dimensions in Level 1, particularly for the three axle dog trailer;
- on-road safety problems are not being experienced to warrant such a restriction of the existing fleet; and
- trailer load height may be difficult to enforce and/or prosecute because some loads (eg gravel) do not have a level upper
- surface.

Jurisdictions were then requested to:

- consult further with industry on the proposed 3 level approach;
- quantify how many vehicles in the existing fleet may not comply; and
- provide information to justify alternative core dimensions.

Feedback from this round of consultations with jurisdictions resulted in advice to the NRTC that it should consider dividing Level 1 into a further two levels with appropriate conditions to cover:

- truck and trailer combinations that transport quarry and other related 'high density' commodities/products ie, low Centre of Gravity (COG) vehicle combinations; and
- all other commodities/products transported by truck and trailer combinations.

Overall, the formal responses received indicated general acceptance of the three level concept even through many considered it overly complex, cumbersome from an enforcement viewpoint and emphasised that many vehicles in the existing fleet may not comply especially with the Level 1 dimension limits. Additionally, some debate occurred on the selection of 0.8 as the value for Load Transfer Ratio (LTR) in the assessments and performance formulae (Refer Annex D).

A summary of the comments and views received on the revised Truck and Dog Trailer Proposal indicated that:

- there appears to be little evidence of a large scale problem;
- some outliers can occur based on short wheelbase truck;
- appropriate conditions that are not too complex for on-road enforcement are required;
- policy needs to be relatively simple to be enforceable in on-road situations;
- operators and industry know suitable configurations for their tasks;
- stability can be achieved by good design and proper selection of equipment;
- correct loading/unloading sequence based on industry best practice is important;
- generally air suspension drive axles have better roll stiffness than mechanical drive axles. (However, there are large variations between makes and types.); and
- four axle trailers handle better overall, they have better braking and a longer wheelbase than a three axle trailer.

REVISED PROPOSAL - CIRCA 2001

The revised proposal (See Annex B Part A, B and C) now caters for the two scenarios at the Level 1 dimensional limits:

Level 1	any commodity; and
Level 1A	commodities with a density greater than 1 tonne/m^3 for 3 axle trailers and 0.45 tonne/m^3 for 4 axle trailers.

As with the original submission, the revised dimensional requirements are a coarse selection generally based on the simulation work and are within the range of key variables used in the performance formulae.

Although this revised proposal retains some of the complexity of the initial submission (ie in relation to trailer load height, the new 'high density' provision should be more aligned with the existing dimensions for the relatively low COG 'high density' product quarry) fleet.

To clarify the range and type of commodities covered by the proposed new Level 1A, a specific guideline (for both operators and enforcement staff) listing examples of the densities of various commodities may be necessary for the implementation stage of this policy proposal. An example of such a document is at Annex E.

As with the initial submission, the use of the Level 2 performance formulae and the Level 3 full PBS assessment still allows a more sophisticated alternative process if a specific truck and trailer combination does not meet the Level 1 criteria.

If an existing truck and trailer combination does not comply and if vehicle modification action on the combination is not financially feasible or practical, grandfathering options may need to be considered as part of the implementation phase.

BASIC PREMISE FOR PERFORMANCE FORMULAE - LOAD TRANSFER RATIO

The load transfer ratio (LTR) is defined as the proportion of vertical load imposed on the tyres on one side of a vehicle unit that is transferred to the other side of the vehicle during a standard lane change manoeuvre (NRTC 2002). When the load transfer ratio reaches a value of 1, rollover occurs.

The policy development work to date by Roaduser Systems has been based on a LTR of 0.8. However, as provided at Annex D, there are different viewpoints on the appropriate value for LTR for Truck Trailer combinations.

The NRTC Performance Based Standards (PBS) project has been developing performance measures and standards over the last few years and indications are that the Load Transfer Ratio may not be selected as a PBS measure in the final analysis. In the report *Performance Characteristics of the Australian Heavy Vehicle Fleet* (NRTC 2002) LTR is shown as being highly correlated with *static rollover threshold* and *rearward amplification*. Additionally, the in-field determination of LTR is apparently costly and complicated and maybe prohibitive at this stage.

ADDITIONAL CONDITIONS FOR TRUCK TRAILER COMBINATIONS

In December 2000, following representations regarding a non-air RFS from Industry and VicRoads, additional research work was commissioned by the NRTC to determine the suitability of a non-air drive axle road friendly suspension in a Truck and Dog Trailer combination. Roaduser Systems conducted the work and they were also required to detail the values of the significant suspension characteristic values used in previous research and project reports for the NRTC on Truck and Dog Trailers.

The Roaduser Systems report for the NRTC, 'Performance Criteria for Non-Air Road Friendly Suspensions (RFS) in Truck and Dog Trailer Operations above 42.5 tonnes and up to 50 tonnes' of February 2001 (unpublished)[3] found that:

- the influence of the type of drive axle (ie, air or non-air) on the dynamic stability of the trailer is minimal; and
- the combination of the roll stiffness and roll centre height of the trailer suspension is a significant parameter for the overall combinations dynamic stability and performance.

Based on this report and from a performance based standards aspect, additional conditions covering trailer suspension characteristics are considered warranted for both Level 1 and 2 situations. The proposed condition is:

> The 'Total Roll Stiffness per axle' and 'Roll Centre Height' values for the Trailer suspension should satisfy the requirements of Figure C1 in Annex C Part A (Figure C1 is based on Figure 14 in the Roaduser Systems report). Basically the intersection point of the Roll Centre Height and Roll Stiffness should be in the Acceptable Zone of the chart.

Also, the *Coupling Rear Overhang* (CROH) dimension condition was expanded to include '35% of Truck Wheelbase' as an additional alternative limit to the 1.8m CROH requirement.

INDUSTRY INVOLVEMENT IN POLICY DEVELOPMENT AND CONSULTATION

A number of workshops and teleconferences with industry representatives and jurisdiction representatives have been held at each stage of the development of the policy. Transport media has also been utilised to broaden the coverage of the policy proposals.

During the course of the policy development, some operators have started to use the performance formulae to check their existing fleets and in developing their replacement fleet vehicle specifications.

REGULATORY IMPACT STATEMENT FOR TRUCK TRAILER COMBINATION POLICY

A Regulatory Impact Statement (RIS) for the proposal is being prepared (NRTC 2001). In Australia, a RIS must be developed for all proposals for regulatory changes that are to be submitted to the Transport Ministers for vote. Proposals for regulatory change are 'measures which, when implemented, would encourage or force businesses or individuals to pursue their interests in ways they would not otherwise have done'. The RIS considers alternatives and conducts a cost benefit assessment.

The objective of the Truck and Dog Trailer RIS is to:

- provide a clear definition of the problem;
- evaluate the need for government action in relation to Truck Trailer combinations operating at mass limits above the existing statutory limit of 42.5 tonne - specifically, the need to develop appropriate controls (using a performance based approach) for the design and operation of truck trailers at higher mass limits to deliver a consistent road safety performance; and
- assess the relative costs and benefits of the proposed policy.

The RIS evaluates the impact, cost and benefits of the NRTC proposal compared to the existing permit schemes operating currently in jurisdictions. Over ten years, the proposal would result in additional costs of $18.7* million relative to the base case. The cost impact would be $2.5* million on an annualised basis.

Table 3 shows the initial summary of impacts of the regulatory proposal outlined in the draft RIS:

The regulatory proposal would need to reduce the number of truck-trailer related fatalities by approximately 1.5 annually (or by 10%) in order to cover its costs[4]. While the potential of the regulatory proposal to achieve this safety improvement is conjectural, its costs of $2.5 million annually are relatively low and would be at least partially ameliorated for affected operators by a suitable grandfather provision. The alternative, of body specific

[3] Prepared by Brendan Coleman, Peter Sweatman and Scott McFarlane of Roaduser Systems Pty Ltd.
[4] The average cost per fatal accident is $1.7 m* (BTE 2000).
* Australian Dollars

mass limits, has costs nearly four times those of the regulatory proposal which would be unlikely to be offset by savings in accident costs. It would also have a more significant environmental impact than the regulatory proposal.

While expected to reduce truck-trailer fleet productivity (albeit by a small margin over all), the regulatory proposal responds to professional advice and industry concern that these vehicles may be unstable in some configurations and under some loading conditions.

The RIS concludes that assessment of the regulatory proposal is influenced by the degree to which operators and manufacturers will incur suspension related costs. Were those costs found not to be necessary (because in-service and on market suspensions were compliant with the requirements of the regulatory proposal), the regulatory proposal would appear on balance to be worthwhile given (1) its low costs; (2) the finding that most truck-trailers will not be affected; and (3) the greater assurance it would provide as to the safety of the truck-trailer fleet.

The possibility that operators and manufacturers may incur suspension related costs would make the assessment more marginal given the higher costs, the wider range of operators expected to be affected, and the uncertainty associated with the suspension-related cost estimates. Annual costs would increase from $2.5* million to between $3.6* million and $3.9* million, and the breakeven reduction in fatalities attributable to truck trailers would need to increase to between 13% and 17% before the costs of the regulatory proposal could be covered.

AXLE MASS SPACING SCHEDULE (BRIDGE FORMULAE) IMPACT

General access vehicles are permitted to travel over virtually all parts of the road network. The axle spacing mass schedule (ASMS)(Bridge Formulae) for general access vehicles is based on the formulae:

- up to 42.5 tonnes (L= 10 metres), **M = 3L + 12.5 tonnes**; and
- from 42.5 tonnes to 50 tonnes, a formula of **M = L + 32.5 tonnes**.

where M tonnes is the mass allowed on all axle groups within L metres (measured to the outer axles of any two groups).

Truck trailer manufacturers and operators cannot in some jurisdictions achieve the full 50 tonnes (ie meet **L + 32.5**) within an overall length limit of 19m due to construction allowances for front and rear overhangs. Although this project has not addressed this issue, it is considered an issue for individual jurisdictions to decide whether truck trailers that are at maximum extreme axle spacing (ie 16.5m in the 19m overall length) to have 50 tonnes GCM instead of the 49.5 tonnes as per the current ASMS or allow the extra 0.5 tonne as a special truck-trailer allowance. This would give vehicle designers and manufacturers additional flexibility and achieve the maximum general access mass limit within the 19m overall length limit.

Some vehicle designers/manufacturers have recently had the opportunity to present their viewpoint regarding a relaxation or adjustment of the Bridge Formulae for Truck and Dog Trailers to the Austroads[5] Bridge Committee.

FUTURE ACTION

Pending the outcomes of the performance measures and the values of the performance standards from the NRTC Performance Based Standards project, the truck and dog trailer policy will need to be further developed to enable a proposal to be prepared for submission to the Australian Transport Council.

The NRTC is committed to developing a consistent policy to address the potential stability problems for certain Truck-Trailer combinations and to reduce the uncertainty for industry in relation to Truck and Dog Trailer operation above 42.5 tonnes in jurisdictions. Accordingly, to enable further development of the proposal for submission to ATC, the following is still to be resolved:

- the suitability of the NRTC proposal and the relevant package of conditions;
- the likely enforcement issues related to in-field assessment of the 'trailer load height' measurement;
- a possible clearer definition for the commodities/products covered by Level 1A;
- adjustment of the axle spacing mass schedule to enable full achievement of the 50 tonnes GCM; and
- finalisation of the Regulatory Impact Statement.

This case study raised several issues relevant to a PBS approach, including the need for staged approaches, the difficulty in removing productivity gains on the grounds of safety risk and the potential complexity of PBS approaches.

CONCLUSION

The regulatory proposal is an early initiative in the NRTC's performance-based standards program which aims to improve the performance, safety and productivity of the national heavy vehicle fleet. In this particular initiative, the productivity gains of earlier decisions by jurisdictions to grant higher mass limits for truck-trailers are likely to

[5] Austroads is the national association of Australian and New Zealand road transport and traffic authorities.

be pulled back in order to secure greater assurance of safety. A relatively small proportion of the truck-trailer fleet is expected to be affected.

Most vehicles have dimensions and load characteristics that will allow them to retain those productivity gains while still operating safely. The overall safety of the Australian truck-trailer fleet should be improved as a consequence of the regulatory proposal.

This project has provided a useful example of the potential for a Performance Based Standards approach. In part, it suggests that traditional assessment techniques have potential shortcomings that may now be better addressed through a complete PBS approach. The opportunity may also arise for further research on developing an appropriate low cost, in-field test method of determining Load Transfer Ratio for vehicle combinations.

ANNEXES

A. Proposed Operating Conditions 1996-97
B. Proposal and Additional Design Requirements 1998
C. Proposed Operating Conditions 2000/2001
D. Load Transfer Ratio Issues
E. Draft Typical Commodity Densities Document

REFERENCES

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NRTC (1997). *Assessment of Truck/Trailer Dynamics*. Technical Working Paper No. 31. Prepared for the National Road Transport Commission by ARRB Transport Research Pty Ltd (Rod George, Brendan Gleeson, Matt Elischer, Euan Ramsay): Melbourne, Vic. December 1997.

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TABLES & FIGURES

Table 1 - Truck-Trailer Mass Limits

Jurisdiction	**3-axle truck**		**4-axle truck**	
	3 axle dog trailer	**4-axle dog trailer**	**3-axle dog trailer**	**4-axle dog trailer**
New South Wales	48	50	50	50
Victoria	45	50	45	Not approved
Queensland	45	50	45	50
South Australia	45	49.5	45	50
Western Australia	48	55.5#	53#	60.5#
Tasmania	48	55.5#	53#	60.5#
Northern Territory	48	55.5#	53#	60.5#
Australian Capital Territory	48	50	45	50

Concessional loading, sum of axle limits and restricted access schemes

Table 2 - GCM 42.5 tonnes to 50 tonnes

Level 1	The existing or proposed combination is required to meet the specific dimension limits and a general set of control conditions **derived from the performance-based simulation analysis.

Level 2	If an existing or proposed combination is outside the proposed performance-based controls in Level 1 above, then an assessment against the performance formulae** developed as part of this review is required.

Level 3	If an existing or proposed combination does not meet the performance formulae in Level 2 above, then a full performance-based assessment is required.

** The control conditions and performance formulae in Levels 1 and 2 cover a range of key dimensional variables.
See Annex C, Part B and C

Table 3 – RIS Benefits/Costs

Jurisdiction	**Agency costs**	**Road wear costs**	**Vehicle certification costs**	**Vehicle operating costs**	**Total costs**	**Annualised costs**
	($m)*	($m)*	($m)*	($m)*	($m)*	($m)*
TOTAL	2.447	-1.264	1.012	16.531	18.726	2.544

* Australian Dollars

Figure 1 – Typical Three Axle Truck and Four Axle Dog Trailer
Maximum Overall Length 19 m

Figure 2 – Typical Three Axle Truck and Three Axle Dog Trailer
Maximum Overall Length 19m

Figure 3 – Four Axle Truck and Three Axle Dog Trailer Testing, Armidale, Australia, 1996, ARRB Transport Research

ANNEX A

Proposal Circa 1996-97

PROPOSED OPERATING CONDITIONS FOR TRUCK AND DOG TRAILER COMBINATIONS GREATER THAN 42.5 TONNES AND UP TO 50 TONNES GROSS COMBINATION MASS (GENERAL ACCESS)

1. GROSS MASS LIMIT

Maximum gross mass for truck and dog trailer combinations operating without route restrictions.

3 Axle Dog Trailer		
(a)	3 axle rigid truck towing a 3 axle trailer (provided extreme axle spacing of trailer is at least 3.8m)	= 45t
(b)	4 axle rigid truck towing a 3 axle trailer (provided extreme axle spacing of trailer is at least 3.8m)	= 45t
(c)	3 axle rigid truck towing a 3 axle trailer (provided extreme axle spacing of trailer is at least 4.3m)	= 48t
4 Axle Dog Trailer		
(a)	3 axle rigid truck towing a 4 axle trailer.	= 50t
(b)	4 axle rigid truck towing a 4 axle trailer.	= 50t

2. DIMENSION LIMITS

Dimension limits are the same as for other general access combinations:

- length of combination not to exceed 19.0 metres.
- height not to exceed 4.3 metres.
- width not to exceed 2.5 metres.

3. VEHICLE CAPABILITY AND EQUIPMENT RATINGS

All vehicles, components and couplings used in the truck and dog trailer combination must have a manufacturer's rating and GCM appropriate to the maximum gross mass of the combination. (See Note: 1)

4. AXLE SPACING/MASS SCHEDULE

All truck and dog trailer combinations exceeding 42.5 tonnes GCM must comply with the 1994 Austroads recommended axle spacing/mass schedule (bridge formulae) for general access vehicles, ie '3L + 12.5' tonnes to 10m spacing (42.5 tonnes) and then 'L + 32.5' tonnes to 17.5m (50 tonnes).

5. SUSPENSIONS

Truck and trailers must be fitted with air suspension (except for the steer axle(s) of the truck).

6. MASS RATIO

The loaded mass of the dog trailer must not exceed the loaded mass of the truck by more than 25%, ie mass ratio of 1:1.25 under any loading condition.

Note: 1 Although a preference for a requirement that combinations should be capable of maintaining 70km/h on a 1% grade has been raised by jurisdictions, the requirement could be covered by ensuring that the combination has a suitable GCM rating by the manufacturer for the combination/load to be carried.

ANNEX B

Proposal Circa 1998

ADDITIONAL DESIGN REQUIREMENTS/INITIAL PERFORMANCE FORMULAE GENERAL ACCESS TRUCK AND TRAILER COMBINATIONS – 19M LONG

50 tonnes Combinations R12-T22

Trailer(&Truck) CoG Height	Requirement
Less than 2m	No additional requirements
Greater than 2m and less than 2.2m	(TkWb + TrWb) ÷ 2 > or = to CROH + 3.4m
Greater than 2.2m	TrWb + 1.24 TkWb – 3 CROH – 14.1 TrCoG > -25.0

48 tonnes Combinations R12-T12

Trailer(&Truck) CoG Height	Requirement
Less than 1.9m	No additional requirements
Greater than 1.9m and less than 2m	TrWb > or = to CROH + 2.8m
Greater than 2m	4.8TrWb + 2.0 TkWb – 4.95 CROH – 19.0 TrCoG > -15.1

45 tonnes Combinations R12-T12

Trailer(&Truck) CoG Height	Requirement
Less than 1.9m	No additional requirements
Greater than 1.9m and less than 2m	TrWb > or = to CROH + 2.4m
Greater than 2m	4.8TrWb + 2.0 TkWb – 4.95 CROH – 19.0 TrCoG > -16.8

CROH = Coupling Rear Overhang
TkWb = Truck Wheelbase
TrWb = Trailer Wheelbase
TrCoG = Trailer Centre of Gravity

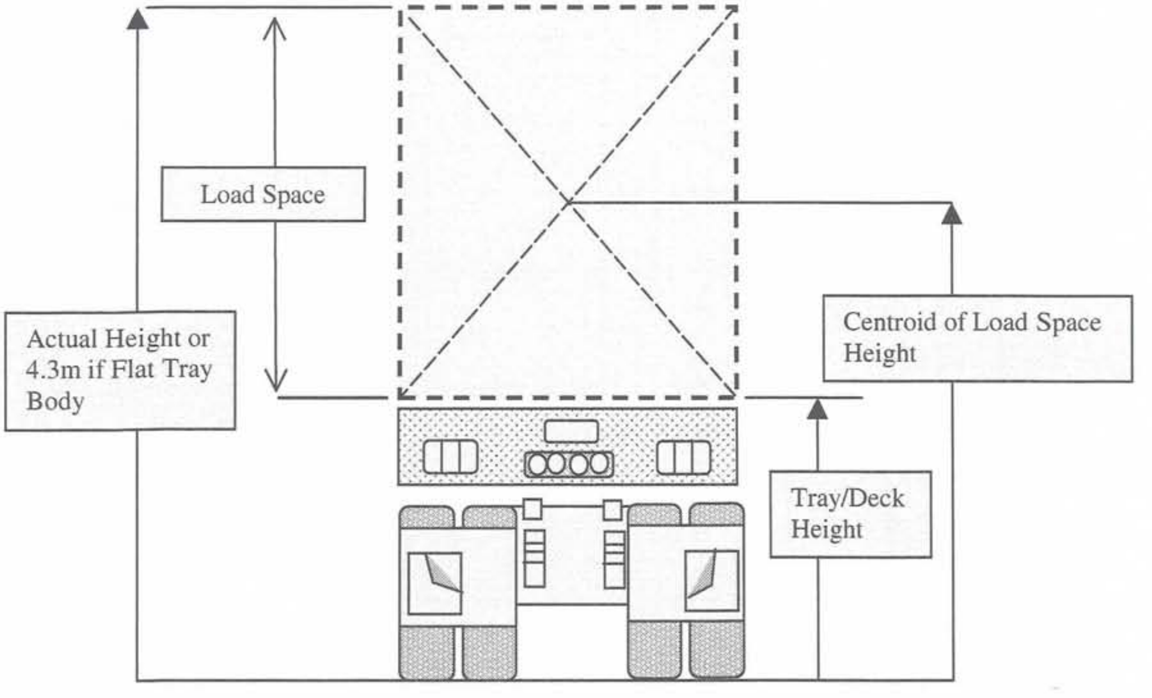
ANNEX C

DESIGN CONDITIONS GENERAL ACCESS TRUCK AND TRAILER COMBINATIONS - 19M LONG

Centroid Height Of Trailer (Centre of Gravity Control)

The centroid height from ground level of the imaginary or actual load space must be below 2.2m for all combinations

50 tonnes	**Combinations**	R12-T22
48 tonnes	**Combinations**	R12-T12
45 tonnes	**Combinations**	R12-T12



CONFIGURATIONS OUTSIDE ABOVE NOTICE DIMENSIONS
If a proposed configuration for a Truck and Dog Trailer is outside the above dimensions then an Engineering Certificate covering a dynamic assessment to show the LTR is below 0.8 will be required.

ANNEX C PART A

Proposal Circa 2000/2001

TRUCK AND DOG TRAILER - MASS LIMITS REVIEW (OPERATIONS OVER 42.5 TONNES)

Revised Proposal

The revised proposal now caters for two scenarios at the Level 1 dimensional limits:

- Level 1 — any commodity; and
- Level 1A — commodities with a density greater than 1 tonne/m^3 for 3 axle trailers and 0.45 tonne/m^3 for 4 axle trailers

Level 1 & 1A

	3 axle Truck and 3 axle Trailer 45t	**3 axle Truck and 3 axle Trailer 48t**	**4 axle Truck and 3 axle Trailer 50t**	**3 & 4 axle Truck and 4 axle Trailer 50t**
Truck Wheelbase (TkWB)	4.3m	4.3m		4.3m
Trailer Wheelbase (TrWB)	3.2m	3.7m		7 4.5m

Level 1

(Any commodity)

Trailer Load Height limit	3m (evidence that load is below height limit required)	3.8m

Level 1A

(No overall height limit* depending on Density of load)

No overall Trailer Load Height limit* if density of load	7 1t/m^3 (Evidence required of load density (dry, wet))	7 0.45t/m^3

* Other than normal 4.3m legal maximum overall vehicle height limit

General Conditions

Coupling Rear Overhang	1.8m or 35% of TkWB (if 35% of TkWB is >1.8m)
Overall Dimension Limits.	Length 19.0m, Width 2.5m, Height 4.3m (unless indicated differently)
Suspension	Truck and trailer must be fitted with a Road Friendly Suspension (except for steer axle(s) of truck). Also, see required additional Trailer Suspension Characteristics.
Mass Ratio Limit	The loaded mass of the dog trailer under any loading condition must not exceed the loaded mass of the truck by more than the following ratio/percentage. • 45 tonnes 1:1 or 0%; • 48 tonnes 1:1.15 or 15%; and • 50 tonnes 1:1.25 or 25%.
Axle Spacing Mass Schedule (ASMS)	Compliance with the applicable Austroads Axle Spacing Mass Schedule is required for the combination.
Vehicle Capability, Braking and Equipment Ratings	All vehicles, components and couplings used in the truck and dog trailer combination must have a manufacturer's rating and GCM appropriate to the maximum gross mass of the combination and axle loads.

Trailer Load Height	* The distance from ground level to the top of the load in/on the trailer. Trailer Load Height **excludes** all load restraint systems/attachments, eg load tarps/covers. Applies when combination load is between 42.5 tonnes and 45, 48 or 50 tonnes as applicable. (normal 4.3m maximum overall vehicle height applies)

Note 1: The control conditions and performance formulae are based on the assumption that the loading condition of the combination is such that the truck has maximum allowable axle loads.

Additional Condition
<u>**Trailer Suspension Characteristics**</u>

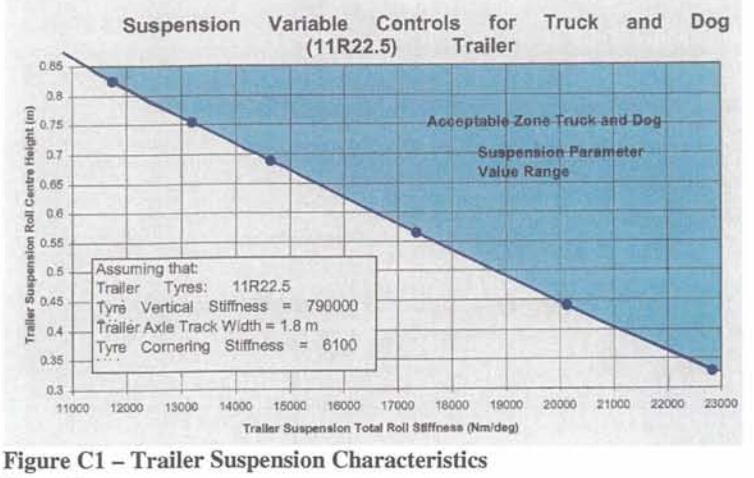


Figure C1 – Trailer Suspension Characteristics

Examples:

1. if trailer suspension Roll Centre Height is 0.36m, then Roll Stiffness should be greater than 22000 Nm/deg
2. if trailer suspension Roll Centre Height is 0.57m, then Roll Stiffness should be greater than 17000 Nm/deg

ANNEX C PART B

CONFIGURATIONS OUTSIDE ABOVE NOTICE/GAZETTE DIMENSIONS

As an alternative, if a proposed or existing configuration for a Truck and Dog Trailer is outside any of the Level 1 dimensions then either:

- Level 2 - evidence is required that the combination meets the performance formulae developed by Roaduser Systems as outlined at Annex C, Part C; or
- Level 3 - a full performance-based assessment of the proposed combination is required using 0.8 as the value for Load Transfer Ratio (LTR) or the performance measures and values developed and selected in the NRTC PBS Project.

ANNEX C PART C

LEVEL 2

PERFORMANCE FORMULAE

The performance formulae for the 3 axle truck and 3 or 4 axle trailer combinations below are detailed in the reports NRTC 'Performance-Based Controls for Truck and Dog Trailer Combinations, May 1999 and Roaduser Systems 'Truck and Dog Combination Issues, December 1999(NRTC unpublished) and cover the listed range of key vehicle dimensional variables.

3 Axle Truck and 3 or 4 axle trailers

Extract from Performance-Based Controls for Truck and Dog Trailer Combinations, May 1999.

8.1 Performance Formulae

8.1.1 Key Variables

Trailer COG height affects the tendency of the trailer to rollover in response to lateral acceleration. It also affects the tendency of the trailer to damp out lateral oscillations. It can also affect the rearward amplification mechanism, making the trailer lateral accelerations greater than the truck lateral accelerations.

Trailer wheelbase affects the rearward amplification mechanism and can affect the ability of the trailer to damp out lateral oscillations.

Truck wheelbase affects the rearward amplification mechanism.

Coupling rear overhang affects the rearward amplification mechanism.

8.1.2 Formulae

Performance formulae have been developed using the above variables, and are designed to ensure that the LTR will be no greater than 0.80. Allowance has been made for the fact that, although the most important variables are explicitly present in the formulae, other factors do have some influence on LTR.

The performance formula for 3-axle dogs is valid for the following ranges of key variables:

- Truck wheelbase: **4.1 m*** - 5.3 m
- Coupling rear overhang: 1.5 m to 2.1 m
- Dolly drawbar length: 3.0 m to 4.5 m
- Trailer wheelbase: **3.2 m*** to 5.0 m
- Trailer COG height: 1.6 m to 2.4 m.

The performance formula for 4-axle dogs is valid for the following ranges of key variables:

- Truck wheelbase: **4.1 m*** - 6.1 m
- Coupling rear overhang: 1.6 m to 2.6 m
- Dolly drawbar length: 3.0 m to 4.5 m
- Trailer wheelbase: 4.6 m to 7.0 m
- Trailer COG height: 1.6 m to 2.4 m.

*Extended range for application of performance formulae.

Within these ranges of key variables, the performance formulae are able to reproduce the simulation results to an accuracy of better than 1 % on average, and the largest error relative to the simulations is 6 %.

The performance formulae assume that:

- The truck and trailer have air suspension; air suspensions can vary significantly and average value were assumed
- LTR varies linearly with each of truck wheelbase, trailer wheelbase, coupling rear overhang and trailer COG height
- Uncontrolled influences, including variations in the truck air suspension, may increase LTR by a total of 0.05.

8.1.2.1 Four Axle Dogs

The most general form of the performance formula for the truck and dog with 4-axle dog trailer at 50.0 tonnes GCM is given by:

$$\mathrm{TrWB} + 1.24\,\mathrm{TkWB} - 3\,\mathrm{CROH} - 14.1\,\mathrm{TrCOG} > -25.0 \qquad \{2\}$$

where	CROH	=	coupling rear overhang (m)
	TrCOG	=	trailer centre of gravity height (m)
	TrWB	=	trailer wheelbase (m)
	TkWB	=	truck wheelbase (m)

and an alternative form of the performance formula, where the trailer COG term is not explicit, is given by:

$$\mathrm{TrWB} + 1.24\,\mathrm{TkWB} - 3\,\mathrm{CROH} > \mathrm{TDS} \qquad \{3\}$$

where TDS is a **Truck and Dog Stability** parameter which is a function of trailer COG height, as given in Table 4.

Table 4 Values for truck and dog stability parameter TDS (4-axle dogs at 50.0 tonnes GCM)

Trailer COG Height	Typical Corresponding Body Type	TDS
1.7	Tipper	-1.1
1.8	Low-COG Tanker	0.3
2.2	Conventional Tanker	6.0
2.4	General Freight	8.8

8.1.2.2 Three-Axle Dogs

The most general form of the performance formula for the truck and dog with 3-axle dog trailer at 48.0 tonnes GCM is given by:

4.8TrWB + 2.0 TkWB – 4.95 CROH -19.0 TrCOG > - 15.1 {4}

where	CROH	=	truck rear overhang (m)
	TrCOG	=	trailer centre of gravity height (m)
	TrWB	=	trailer wheelbase (m)
	TkWB	=	truck wheelbase (m)

And the analogous formula for the truck and dog with 3-axle dog trailer at 45.0 tonnes GCM is given by:

4.8TrWB + 2.0 TkWB – 4.95 CROH -19.0 TrCOG > - 16.8 {5}

An alternative form of the 48.0 tonne 3-axle dog performance formula, where the trailer COG term is not explicit, is given by:

4.8TrWB + 2.0 TkWB – 4.95 CROH > TDS {6}

where TDS is a truck and dog stability parameter which is a function of trailer COG height, as given in Table 5.

Table 5 Values for truck and dog stability parameter TDS (3-axle dogs at 48.0 tonnes GCM)

Trailer COG Height	Typical Corresponding Body Type	TDS
1.7	Tipper	17.2
1.8	Low-COG Tanker	19.1
2.2	Conventional Tanker	26.7
2.4	General Freight	30.5

And an alternative form of the 45.0 tonne 3-axle dog performance formula, where the trailer COG term is not explicit, is given by:

4.8TrWB + 2.0 TkWB – 4.95 CROH > TDS {7}

where TDS is a truck and dog stability parameter which is a function of trailer COG height, as given in Table 6.

Table 6 Values for truck and dog stability parameter TDS (3-axle dogs at 45.0 tonnes GCM)

Trailer COG Height	Typical Corresponding Body Type	TDS
1.7	Tipper	15.5
1.8	Low-COG Tanker	17.4
2.2	Conventional Tanker	25.0
2.4	General Freight	28.8

4 Axle Truck and 3 or 4 Axle Trailers

Although specific performance formulae have not been developed by Roaduser Systems for the 4 axle truck combinations, the 3 axle truck performance formulae above could also be applied to 4 axle truck combinations.

- For R22T22 use R12T22 formulae
- For R22T12 use R12T12 (48 tonne) formulae

Note: The performance formulae may give a more conservative outcome, ie more restrictive than if a specific performance formulae were developed for the 4 axle truck combination.

Reference: Roaduser Systems Report: 00-583-01 Truck and Dog Combination Issues: Twin Steer

Hauling Units, 4 February 2000 (unpublished by NRTC).

ANNEX D

LOAD TRANSFER RATIO

The following extracts from the referenced reports illustrates some of the various views on LTR over the life of the project.

Extracts from pages 19 and 21 of Performance-Based Controls for Truck and Dog Trailer Combinations, May 1999. (NRTC 1999).

LTR is the ultimate stability performance measure for truck and dog combinations because, in addition to combining the influences of static roll stability and rearward amplification in one measure, it concentrates on the tendency of the trailer to roll over, and this is the greatest risk for these combinations in dynamic situations.

The Load Transfer Ratio (LTR) is a meaningful measure of the dynamic stability of truck and dog combinations, along with other multi-articulated configurations. It combines notions of the inherent resistance of the trailer to roll over with notions of the tendency of the vehicle combination to "crack the whip" and thereby amplify the lateral acceleration occurring in the trailer during emergency avoidance manoeuvres.

It is known that LTR values vary widely between vehicle configurations with the same body type (and therefore similar COG height); for maximum-weight, medium-COG vehicles, such LTR values range from 0.5 to values close to 1.0. For a given configuration, LTR is significantly affected by COG height and other dimensions. For vehicle configurations whose rear unit (not roll-coupled to its towing unit) is relatively short, COG height increases can readily take the LTR to a value of 1.0. Such vehicles cluster at the LTR value of 1.0 because it is not possible for LTR to exceed 1.0, even though some of these LTR = 1.0 vehicles are still "worse" than others.

The load transfer ratio is one of the few engineering performance measures which has been linked to accident risks. Such relationships have been developed in the US, where both the quantity and quality of truck accident data, pertaining to fatal crashes, is sufficient to support the necessary analysis.

Research by UMTRI (Francher, Campbell, Blower 1989) found increased fatal rollover accident involvement for doubles operating on interstates and rural primaries when the combination vehicles' rearward amplification exceeded a value of approximately 1.6. During the FHWA Comprehensive Truck Size and Weight Study, the UMTRI relationship between accident involvement ratio and rearward amplification was converted to a relationship between accident involvement ratio and LTR. This was done because LTR is an absolute measure of dynamic stability, while rearward amplification is an intermediate measure with regard to dynamic stability (rearward amplification has had significant use historically in the US because it is relatively easy to measure in the field, while LTR is difficult to measure).

Figure 1 shows the relationship between relative risk of being involved in a fatal rollover accident and the LTR of the vehicle, based on the UMTRI rearward amplification relationship (Francer, Campbell, Blower 1989). This shows that accident risk increases significantly when LTR exceeds a value of approximately 0.80. The vehicles involved in the UMTRI study were 5-axle short doubles combinations comprising a 2-axle prime mover, single axle semi-trailer and two-axle full trailer, with GCM up to 36.3 tonnes. This relationship gives credence to the idea that an LTR target of 0.6 is conservative, and that a target of approximately 0.8 will protect against increased accident risks related to dynamic instability.

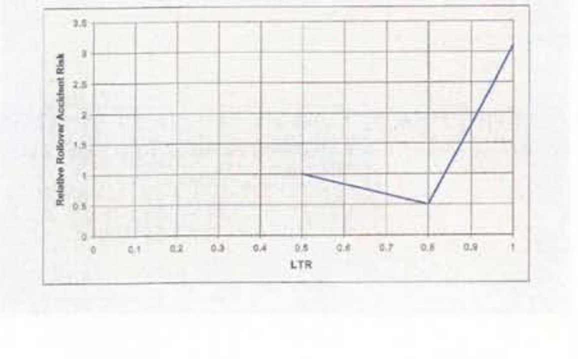


Figure 1D - Relative accident risk versus Load Transfer Ratio

Extracts from pages 34 and 35 of NRTC (2001)

Load transfer ratio is a well-established performance measure that is highly correlated with both static roll stability and rearward amplification within a given class of vehicle configuration (Winkler and Bogard, 1993; McFarlane et al, 1997; Mueller, de Pont and Baas, 1999; Winkler et al, 2000).

Load transfer ratio can have a value in the range 0 to 1. Lower values indicate comparatively better performance; high values imply high probabilities of rollover.

The same method for evaluating rearward amplification using the standard SAE lane change is used to determine load transfer ratio. However, it is important to note that unlike static rollover threshold and rearward amplification, load transfer ratio has never been measured[6] (McFarlane et al, 1997) and it is calculated using computer-based simulation. Nevertheless, it has been recognized as a useful means of distinguishing between the performance of roll coupled and non-roll-coupled multi-unit vehicles (Winkler et al, 2000).

For load transfer ratios much above 0.6 most trucks are highly susceptible to rolling over (Clarke and Wiggers, 1998). However, according to Sweatman, Woodrooffe and Blow (1998), *"there appears to be some evidence that accident risks begin to increase for load transfer ratio values above 0.75 and are significantly higher 'above' 1.0"*.

The generally accepted performance level for load transfer ratio is 0.6, which is supported by the work of Mueller, de Pont and Baas (1999) and recommended by Land Transport Authority (2000) and Austroads (2000). However, for logging trucks in New Zealand a performance level of 0.75 has been chosen and is used in combination with a slightly relaxed performance requirement for static roll threshold of 0.3g (Land Transport Safety Authority, 1991; Land Transport Safety Authority, 1997).

Extract from page 3 of Truck and Dog Trailer Combinations Issues, Roaduser Systems Pty Ltd, December 1999. (NRTC unpublished)).

It is true that, for a specific vehicle configuration, there is a strong correlation between LTR, RA and SRS. Determination of this correlation for truck-trailers with 3-axle and 4-axle dog trailers was not included in the brief for the subject report (NRTC 1999). This may be a useful exercise, although it would be necessary to specify both LTR and RA in order to calculate the equivalent SRS.

Considering the SRS information that is now available for the subject report, it could be noted that:

- For a 3-axle dog of moderate COG height (2.0 metres) and benchmark dimensions, its LTR of 0.80 corresponds to a SRS of 0.34 g
- For a 4-axle dog of moderate COG height (2.0 metres) and benchmark dimensions, its LTR of 0.67 corresponds to a SRS of 0.46 g.

The amenability of LTR to measurement in the field is a relevant issue in the application of PBS. Rearward amplification may be measured in a reasonably straightforward manner; this could be combined with a measured SRS value to estimate the LTR, provided that a correlation equation (between LTR, RA and SRS) is available *for the specific vehicle configuration.*

References:

AUSTROADS (2000). *Performance Measures for Evaluating Heavy Vehicles in Safety Related Manoeuvres.* AUSTROADS Publication AP-147. Austroads: Sydney, NSW.

CLARKE, R.M. and WIGGERS, G.F. (1998) Heavy Truck Size and Weight and Safety, 5th International Symposium on Heavy Vehicle Weights and Dimensions, March 29-April 2, Maroochydore, Queensland.

FANCHER PS, CAMPBELL, KL and BLOWER, DF (1989) Vehicle design implications of the Turner Proposal. SAE 892461.

LAND TRANSPORT SAFETY AUTHORITY (1991). *Policy for 44 Tonne A-Trains.* Road and Traffic Standards Information, No. 6(1), March 1991. LTSA, Wellington, New Zealand.

LAND TRANSPORT SAFETY AUTHORITY (1997). *Logging Vehicle Load Safety Measures (Part Two).* Factsheet, 24 October 1997. Land Transport Safety Authority, Wellington, New Zealand.

[6] This should not be interpreted to mean that it cannot be measured but that the cost and time required to develop and test the necessary equipment is at present prohibitive.

LAND TRANSPORT SAFETY AUTHORITY (2000). *Land Transport Rule (draft): Vehicle Dimensions and Mass (Rule 41001).* Land Transport Safety Authority, Wellington, New Zealand.

McFARLANE, S., SWEATMAN, P.F., DOVILE, P. and WOODROOFFE, J.H. (1997). *The Correlation of Heavy Vehicle Performance Measures* SAE Technical Paper 973190. In Special Publication SP-1308 – Heavy Vehicle and Highway Dynamics. Society of Automotive Engineers: Warrendale, PA, United States.

MUELLER, T.H., DE PONT, J.J. and BAAS, P.H. (1999). *Heavy Vehicle Stability Versus Crash Rates.* Prepared by TERNZ for the Land Transport Safety Authority, New Zealand.

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WINKLER, C.B., BLOWER, D., ERVIN, R.D. and CHALSANI, R.M. (2000). *Rollover of Heavy Commercial Vehicles*. SAE Research Report. Society of Automotive Engineers, Inc.: Warrendale, PA, United States.

ANNEX E

TYPICAL COMMODITY DENSITIES (kg/m^3) [7]

(Extract)

The purpose of these tables is to reconfirm and set out density tables that are typical and representative of selected common loads. As the development of the policy framework moves towards performance based standards, an understanding of basic issues such as load densities will help to assist operators and enforcement people identify the products that have a greater likelihood of causing a load to become overweight or reduce the rollover threshold.

An example of Loose Dry Bulk Commodities

Fertilisers	kg/m^3
Ammonium Nitrate.........................	721 - 993
Ammonium Sulphate..................	930 - 1010
Gypsum, (granulated)..................	913 - 960
Gypsum...................................	1100
Mono Ammonium Phosphate.........	975 - 1030
Potassium Chloride....................	1150
Sulphate of Ammonnia (granulated)	860 - 914
Superphosphate & or Lime............	1180 - 1300
Triple Superphosphate.................	1240
Urea.......................................	550 - 820

Grain & Produce	kg/m^3
Barley (feed)............................	380
Barley (malting)........................	360
Cotton Seed (meal)....................	560 - 640
Distillers Grains (wet).................	640 - 800
Linseed..................................	800 - 929
Maize.....................................	752 - 760
Oats.......................................	480 - 650
Rice (hulled)............................	720 - 784
Sugar (powdered)......................	800 - 960
Sugar (raw)..............................	975 - 1030
Wheat.....................................	720 - 768

Quarry Materials	kg/m^3
Aggregate (dry).........................	1700
Aggregate (wet).........................	2000
Building Rubble........................	1300 - 1500
Cement (bulk)...........................	1200
Clay (moist).............................	2000
Coal (hard)...............................	720 - 900
Coke	481 - 561
Concrete (ready mix)..................	1800 - 2000
Gypsum...................................	1100
Sand (dry)................................	1600
Sand (wet)................................	2100
Slurry.....................................	993

[7] *Prepared by Ian Wright & Associates, for the National Road Transport Commission, March 2001*