SAFETY IMPROVEMENTS FOR INCREASED WEIGHTS AND DIMENSIONS IN NEW ZEALAND

Peter H. Baas

David M. White

Department of Scientific and Industrial Research, Auckland Industrial Development Division, New Zealand.

ABSTRACT

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- improved braking standards
- standards for drawbars and drawbeams
- standards for fifth wheels and king pins
- improved load securing standards for load anchorage points

The vehicle safety standards have been developed on an industry committee basis with vehicle operators, regulatory authorities, equipment manufacturers, and researchers all being actively involved. The new vehicle dimensional requirements have drawn on current international thinking in terms of vehicle stability and manoeuvrability. A number of refinements will be possible once legislation is in place. The industry in particular wants the following issues explored:

- self-steering axles and bogies
- special-purpose A-trains which meet performance criteria
- alternative dollies
- truck-trailer combination requirements improved to be the same as for B-trains.
- loadings on the fifth wheel assemblies of B-trains

This paper explains the rationale behind the standards and vehicle specifications, and the need for international harmonisation while still catering for specific local needs.

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1. INTRODUCTION

Along with many other countries, New Zealand is grappling with the delicate balance between improved road safety, improved road transport efficiency, and political expediency. A vehicle which is ideal for interstate container transportation in Australia, USA, or Canada will be very different from the vehicle required for milk collection in the hilly, narrow roads of rural New Zealand. New Zealanders typically have a strong "do-it-yourself" approach with individuals insisting on their right to construct trailers and to extensively repair or modify vehicles. This has led to a few very innovative ideas, some very good, others dangerous. There has also been an attitude of "if it comes from overseas it must be good".

One unique innovation which has grown from New Zealand's extensive social welfare system is a "no fault" accident compensation system. This is administered by a State owned enterprise known as the Accident Compensation Corporation (ACC). The unique feature of this system is that if you have an accident for what ever reason ACC will pay the medical costs and you cannot sue or be sued for injury damages. You will be paid even if you injure yourself while robbing a bank. You cannot sue for the injuries caused by faulty products but you can sue for property damage, etc.

One result is that people are less safety conscious, including a stronger feeling that it "won't happen to me".

With this background very little emphasis has been placed on vehicle safety standards until recently. Only a few years ago a load was legally secure until it had fallen off, it did not matter how unstable it looked. The first author was involved in a Court case in 1984 involving a load of sawn timber which had fallen off a truck onto an oncoming car seriously injuring the occupants. The cause of the accident was grossly inadequate load securing strops and tie down rails. The heavy vehicle operator claimed with some justification that his system was common industry practice. He was fined the maximum penalty of $NZ 200 (approx $US 130) His insurance company would have paid for damage to the car and the load, but not the cost of the injuries.

The legislation regarding heavy vehicle brakes was even more vague. In effect an operator had to demonstrate that the vehicle could stop in a specified distance in the empty state.

In 1984 the transport industry made submissions to Government regarding an increase in gross combination mass (GCM) from 39 tonne to 44 tonne. Government responded with a number of prerequisite safety improvements listed below. The body of this paper comments on a number of these safety issues, and highlights the influence other country's standards or their lack have on a small country like New Zealand.

2. SAFETY IMPROVEMENTS

Brakes	Improvement of brake performance is seen as being of paramount importance. Vehicle combinations for which approval to operate in excess of 39 tonnes is sought will be required to comply with an interim code until the full code is completed. It is intended that eventually all vehicles over 3.5 tonne will comply with the new code.
Drawbars, couplings etc.	All heavy trucks and trailers will be required to have certified towing connections. Certification by a Registered Mechanical Engineer or other approved person is required.
Load Anchorage Points	All vehicles wishing to take advantage of the new weights and dimension regulations will need to meet the requirements of NZ Standard 5444.
Fifth Wheels, King Pins	Compliance with NZ Standards 5450 and 5451 is required.
Tyres	Tyres carrying loads in excess of the tyres manufacturers ratings will become illegal.
Chassis and axle ratings	A vehicle must not be loaded above the ratings certified for certain components approved by the manufacturer or approved engineers.
Trailer Weight Ratio	The gross weight of full trailers towed by rigid trucks will be limited to a maximum of twice the gross weight of the truck.
Load sharing axle groups	Approved load sharing suspensions must be fitted.
Tandem Drive	The prime movers of all combinations over 39 tonne must be fitted with tandem drive axles.
Other weight limitations	The following vehicle types will be kept to existing weight limitations • those with self-steering axles • A-trains • Truck-trailer combinations except with 8x4 trucks are restricted to 42 tonnes gross, and must have a truck wheel base of at least 4.25m.

3. BRAKES

The requirement for improved heavy vehicle brake performance has proved to be the most complex of all the safety improvements. The major complicating factor has been the diverse range of vehicles imported into New Zealand's relatively small transport fleet. Prime movers are imported mainly from Europe, USA, and Japan, all having their own particular brake requirements. Trailers are manufactured locally using imported components such as suspensions and brake systems. In addition, the transport industry frequently interchanges prime movers and trailers. The result has been brake INCOMPATIBILITY! The only simplifying factor is that brake components are not manufactured locally.

A series of tests were undertaken by DSIR (including tests to SAE J1505) to determine the behaviour of European, Japanese, and US sourced prime movers in tractor-semitrailer, A-train, and truck-trailer combinations[1]. The combinations were found to have brake imbalance of up to 300% for fully laden vehicles. Grave deficiencies were found in the total brake effort of each vehicle (eg. trailers overbraked) and in the brake balance within each vehicle (eg. too much drive axle braking relative to the front axle).

There are at least three factors which contribute to the poor prime mover braking performance:

- the brakes are balanced to the country of origin's weight regulations, eg. 20 tonne on tandem axles rather than NZ's 15 tonne.
- the U.S. practice of no or small front brakes
- manufacturers respond to local vehicle regulations and customer needs. For example, European sourced vehicles sold in New Zealand would not be legal in Europe. We tend to get the "jungle country" version.

It was decided that improved brake performance required a clear and realistic design code, improved maintenance standards and effective enforcement. These various aspects are now being addressed. The design code is in an advanced state and is due for general release in the near future. The design code aims to fulfil the following objectives:

- improve brake performance and stability in the laden state
- create a good understanding in the NZ transport industry of the factors affecting brake performance of vehicle combinations and the influence of suspension properties on this, and thereby;
- pave the way for the introduction of internationally compatible regulations which address the main issue of brake balance in all states of loading in the more distant future.

The heart of the design code is contained in its appendix 1 and is based on the establishment of brake performance through calculation. It is derived from annex 10 of ECE 13 and ADR 38.

The following are two of the issues which may be of interest.

3.1 ADHESION UTILISATION REQUIREMENTS

The braking system must conform to specific adhesion utilisation versus rear service coupling pressure requirements. Adhesion utilisation is defined as the brake force developed by an axle divided by the vertical force exerted by the tyres of that axle on the ground. This requirement is aimed at ensuring stability of the vehicle during braking. Factors which can affect adhesion utilisation include brake torque, weight transfer, and brake reactivity.

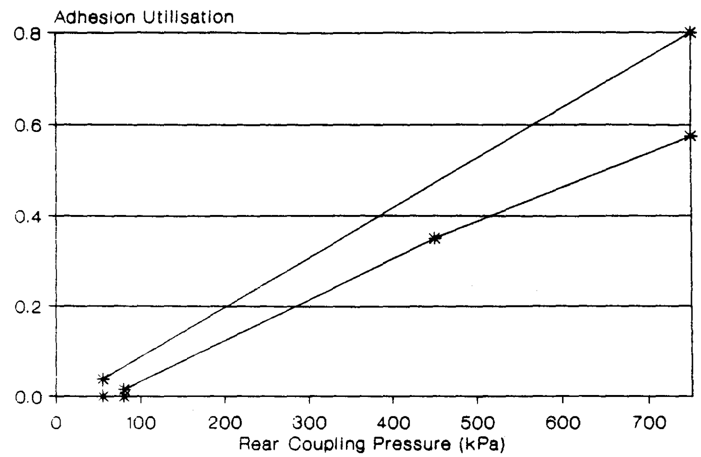


Figure 1a. Trucks and Trailers

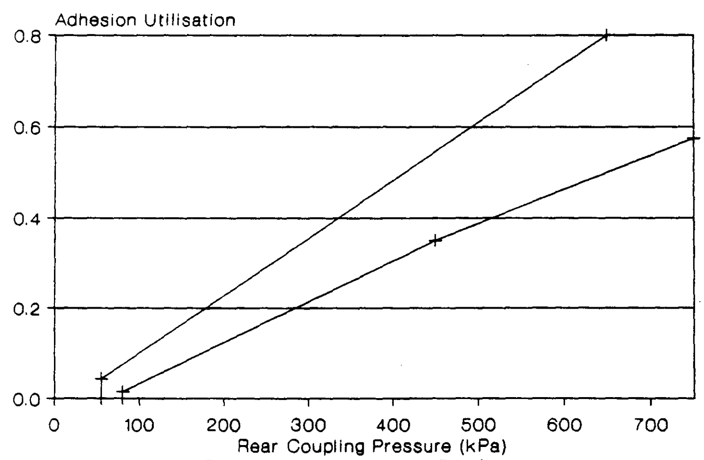


Figure 1b. Tractor Units

3.2 LOW BRAKE PRESSURE COMPATIBILITY

Nearly all brake applications occur at low level brake pressures, severe braking being fortunately a relatively rare event. Consequently low level braking is largely responsible for brake wear, vehicle instability during braking on slippery surfaces, and driver perception of brake compatibility. The Australians have undertaken some excellent work in this area, and have proposed appropriate criteria which we have incorporated in the code. One of the requirements is for braking to commence at rear service coupling pressures between 55 kPa and 80 kPa (50 to 85 kPa for rear couplings of trailers equipped to tow other trailers). Braking is deemed to have commenced when a brake torque of at least 100 Nm is generated at the wheel. This requirement is determined by hanging a weight attached to a rope wound around the perimeter of a raised wheel while monitoring coupling pressure and wheel rotation.

4. DRAWBARS

The development of a design code for drawbars and drawbeams started in the late 1970's following a particularly high number of fatalities due to drawbars failing in service. To develop the code the NZ Truck Trailer Manufacturers Federation established a transport industry Committee consisting of manufacturers, operators, and engineers. One of the first undertakings of the Committee was to determine whether any of the overseas Standards could be adopted directly. There are a number of such Standards in use, but they differ substantially. In addition to selecting the most appropriate code there was concern that NZ's conditions would necessitate special requirements.

Of particular concern was:

- the practice of mixing trucks and trailers irrespective of their manufacture, age, or rating;
- NZ's hilly terrain and narrow windy roads.

It was for these reasons that testing was carried out. The test programme, undertaken by DSIR, involved the measurement of both longitudinal and transverse drawbar loads on approximately ten truck-trailer combinations. These were largely chosen at random with the intention of surveying as many different types of operation as possible, such as various types of drawbar, vehicle configurations, terrain, and speeds as well as yard manoeuvres and braking. The measurements were made using strain gauges attached to the towing eye of the drawbar and the data recorded on 8-track instrumentation tape recorders. The recordings were analysed to determine specific loadings as well as fatigue history.

The main findings were:

- the mean tractive effort of the prime mover was largely irrelevant with respect to fatigue damage of the drawbar;
- peak forces were usually due to high-speed one-off events such as striking a bridge expansion joint;
- the greatest longitudinal forces were compressive;
- gear changes up hill were significant with respect to fatigue damage;
- transverse loadings were relatively low during normal driving, but could be high during yard manoeuvres.

Consequently transverse loading has been dealt with as a static loading state rather than fatigue. Fatigue analysis of the longitudinal loads typically showed two peaks.

- one at intermediate loads corresponding to the continual pounding motion between truck and trailer. Although well damped, this occurred at frequencies of up to approximately 5 Hz. It is suspected that these loadings form the basis of the concept of the "D" value;

- additional damage at large loads. These tend to be random and dynamic caused by events such as striking bridge expansion joints, road works, etc.

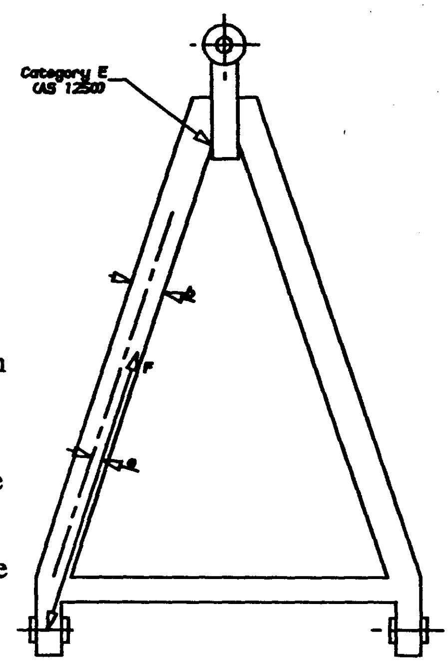
The Committee decided to develop a code based as much as possible on existing codes [2]. Components complying with DIN, SMS and AS standards are acceptable as is. The drawbar and drawbeam structures and the attachment of components must be designed and certified by a Registered Mechanical Engineer. This approach was preferred because of the large range of existing drawbars making fatigue testing a very expensive and restrictive option. It was decided to relate design loads to trailer weight rather than "D" value.

This decision was made because it was found that:

- both static and dynamic (fatigue) values were required
- the code would be easier to administer. (It was not necessary to know which prime mover would tow the trailer)
- the experimental results showed no compelling reason to use the "D" value.

The code covers design, manufacture, and maintenance. It specifies particular welding requirements and calls for certified welders. It also specifies acceptable material properties such as minimum charpy impact values. This requirement arose because it had been found that some imported RHS steel had very poor toughness, resulting in the potential for unexpected and catastrophic failure. This property had not been specified in the past and steel suppliers were in the main ignorant as to its importance for mechanical structures. For fatigue calculations it assumed 20 load or force occurrences per hour giving 20 million cycles in an expected lifetime. If the intended use is limited, the designer can design for a limited life but must endorse the certificate accordingly (as every trailer must be fitted with a hubometer, trailer life can be legally related to distance travelled). The standard draws attention to the considerable influence even small geometric offsets have on the design stresses. Refer to Figure 2.

Most drawbars and drawbeams in NZ have now been certified by Registered Mechanical Engineers to the standard or its earlier drafts. To the authors knowledge there have been no fatalities due to towing connection failure over the past few years.



Axial Stress $\sigma_A = F/A$

Bending Stress $\sigma_B = F.e.y/I$

If $e \approx 1/3\ b$ $\sigma_A = \sigma_B$

Figure 2. Stresses due to geometric offset

5. LOAD SECURING

Load securing requirements have been developed through a number of discrete stages:

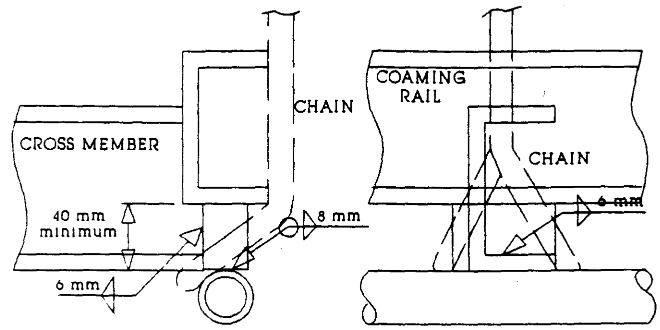
- log load securing
- sawn timber transportation and storage
- general load securing requirements for webbings and fittings
- logging truck cab guards
- load anchorage points

Load securing first became an issue approximately 8 years ago following some well publicized fatal accidents involving logging trucks. This led to the formation of an industry committee which consisted of logging truck operators, trailer manufacturers, transport engineers, researchers, and regulatory authorities.

Extensive trials were undertaken by DSIR to determine the forces and stresses on typical on-highway and off-highway vehicles. As well as forming the knowledge base for detailed requirements, the measurements confirmed the applicability of the generally accepted international requirements which are now the basis of all NZ load securing requirements. These requirements state that the load securing system must be capable of preventing movement of the load under four particular conditions:

- forward deceleration under emergency braking conditions when the combined restraining forces must be at least equal to the payload weight (ie. a deceleration of 1.0 g)
- rearward deceleration when braking during reversing when the combined restraining forces must be at least 50% of the payload weight (ie. 0.5g)
- lateral acceleration when cornering when the combined restraining forces must be at least 50% of the payload weight (ie. 0.5g)
- appropriate vertical acceleration
- These requirements are based on in-service accelerations - they do not attempt to restrain loads during impact conditions, as would be encountered during a road crash. The above has formed the underlying basis of all the load securing requirements. With this approach, novel load securing systems can be used provided that their compliance can be demonstrated.

Examples of acceptable methods of securing typical loads are also given in the various codes and standards. Although they have been based on accepted industry practice a significant improvement in load securing systems has been necessary. For example, typical load anchorage points will be 200-300% stronger than some existing arrangements. Figure 3 shows a typical standard design for a load anchorage point [3].



RAIL: 25mm NOMINAL BORE MEDIUM BLACK MILD STEEL PIPE
(OD 33.8 mm ID 27.4 mm)
DROPPER: 50x25 MM RHS (MINIMUM WALL THICKNESS 2.6 mm)

RATED STRENGTH ▪ 7.5 tonne

Figure 3. Load anchorage point design

Cab guards are fitted to logging trucks to protect the cab during loading, and the driver in a roll over, or from sudden movement of logs in an emergency stop. Pressure to decrease cab guard weight led to a review of the standard design that has been used for the past 15 years. A series of 15 cab guards were tested by NZAEI resulting in a proposed performance requirement which reflects the need for energy absorption as well as strength. The test represents approximately the effect of a one tonne log sliding forward 2.5m in line with the driver's head during emergency braking, before striking the frame. The frame is required to deflect no more than about 200mm in stopping the log, and its method of attachment to the truck must be able to satisfactorily withstand the resulting forces.

More specifically the provisional requirement states that

When progressively loaded by a horizontal force applied to one upright of a cab guard at a height of 1.6m above the top of the chassis rail, the following requirements shall be met:

(1) the maximum load supported by the frame shall exceed 55000 Newtons;

(2) loading shall continue until the energy absorbed exceeds 9000 Joules;

(3) at the point when the energy absorbed equals 9000 Joules, the force must not be less than 0.95 Fmax where Fmax is the maximum force so far recorded;

(4) the method of fixing the frame to the truck must be demonstrated in the test to withstand the loads generated by the frame.

6. KINGPINS AND FIFTH WHEELS

NZ Standards 5450 [4] and 5451 [5] were drafted to raise the standard of installation of fifth wheels and kingpins. Vehicle manufacturers, operators, engineers and regulatory authorities were represented on the drafting Committee. Unlike the drawbar standard, there had not been a significant history of fatal fifth wheel coupling failures. The main benefits of the Standards should be the enhanced ease of interchangeability between tractors and semitrailers, due to the positional requirements. While there is minimal international movement of heavy vehicles from New Zealand, the requirements have been devised with existing overseas standards in mind.

The following table compares New Zealand requirements with other standards.

Table 6.1 - International Coupling Position Requirements

All dimensions in mm	NZS	AS2174	ISO1726	UK(IRTE)
height	1320±25	1270±50	1300±50	1280±60
coupling to back of cab min	2100	2050	2120	2090
tail arc max	2200	2150	2200	2000
semi-trailer				
front overhang max	2000	1900	2040	1600
landing legs swing radius min	2300	2200	2300	2300

Fifth wheel mounting is to be in accordance with the heavy vehicle manufacturer's instructions. Where they are unavailable or incomplete, the Standard gives guidelines based on the Australian Standard AS 1771-1987. No force or moment measurements have been undertaken for New Zealand combinations. Such tests are planned, particularly for the second coupling in a B-train, where experience indicates coupling loads are significantly higher than at the tractor-semitrailer connection.

7. STABILITY AND MANOEUVRABILITY

Much of the recent development in heavy vehicle size and weight legislation has been based on factual or imagined stability differences between various combinations. For example, stability is the principal reason given by the Ministry of Transport for not increasing GCM for A-trains or units with self-steering axles. When the size and weight changes were proposed to the industry, the only basis for decisions on stability matters were overseas research findings. In fact, early proposals included phasing out of A-trains altogether! Industry sources were critical of research results based on foreign vehicle dimensions and axle loads.

Using vehicle dynamics software obtained from UMTRI, analyses of typical New Zealand vehicles has been undertaken by DSIR. Target values and methodology used by UMTRI in the RTAC study [6] have generally been employed, primarily to enable comparison with the RTAC results. Figures 4 to 6 summarise the stability results for typical New Zealand vehicles operating at the new size and weight limits. Despite our 2.5m width limit, New Zealand vehicles compare favourably with the Canadian results in the transient high-speed manoeuvre. However, a Static Roll Threshold of 0.35g is considered to be a more reasonable target for New Zealand vehicles (compared with 0.40g used in the RTAC review).

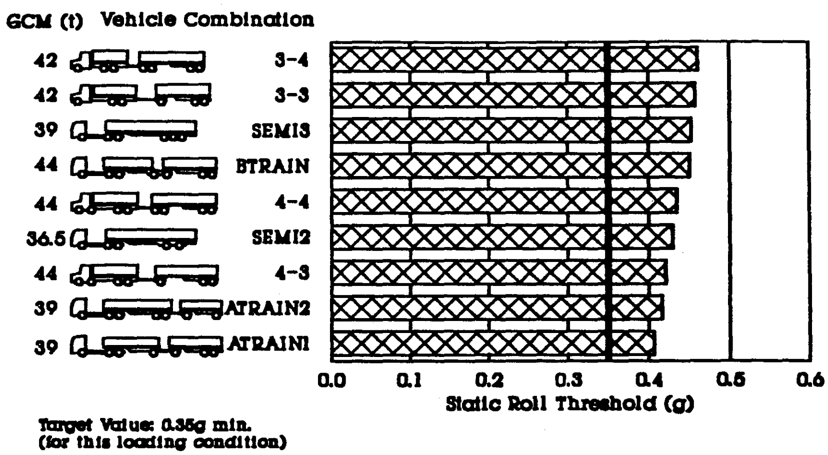


Figure 4. Static Roll Threshold results, typical NZ vehicles

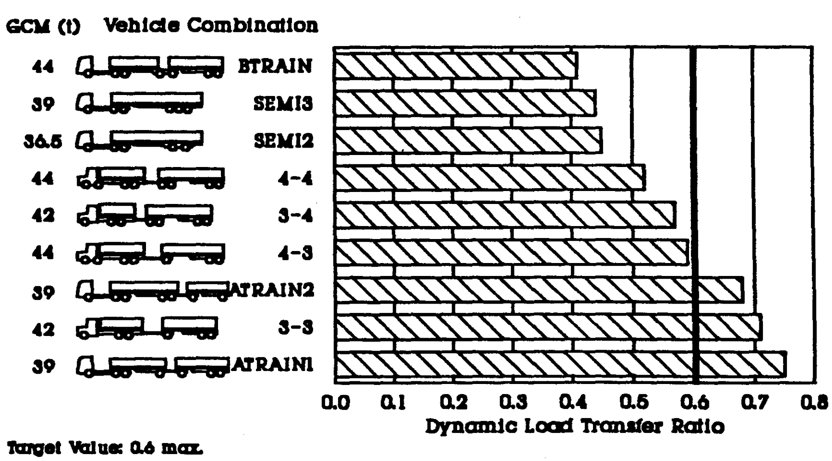


Figure 5. Dynamic Load Transfer Ratio results

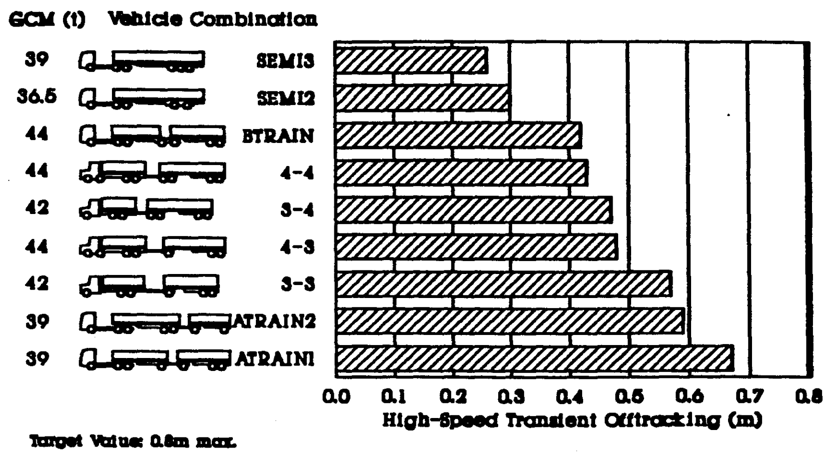


Figure 6. High-Speed Transient Offtracking results

Sloshing of liquid loads is a factor we would like to take into account. Since most of our tankers are not circular, it is not a trivial problem.

Certain industry sectors wish to convince the Ministry of Transport that their primary vehicle configuration is worthy of relaxed mass and dimension limits. It is encouraging that the Ministry is prepared to consider such proposals, and judges them according to the stability and economic arguments presented. Thus far, Ministry officials have accepted RTAC target values as providing guidelines for acceptable stability performance.

Dairy companies generally require A-trains for milk collection because of their superior manouevrability in negotiating restricted farm accesses. Some dairy companies are keen to be permitted 44t on A-trains. Stability analysis by computer simulation reveals that 44t A-trains are inappropriate for general cartage. In "constrained designs" such as tankers, however, where the centre of gravity height is fixed by the tank height, it is possible by careful design to achieve acceptable stability. That careful design is necessary is indicated by the fact that none of the existing milk collection A-trains which were simulated met the dynamic stability targets [7].

Clearly, then, road safety would be enhanced if new vehicles were required to meet these performance targets. Other operators, in general transport, are interested in investigating alternative dollies as a means of improving their A-train stability, in order to qualify for 44t, too.

Operators of 3-4 units (3-axle trucks and 4-axle trailers) similarly wish to be permitted 44t (up from 42t). Investigations indicate that their stability performance at 44t is acceptable and on a par with 4-3 units (which are already allowed 44t). Economic analyses of the benefits and costs to the nation of these proposed changes were undertaken by a consultant team to support the technical arguments to the Ministry of Transport. Significant net transport cost savings could be realised if the changes were approved in the case of 3-4 truck-trailer units. For milk collection vehicles, however, increased gross weights were determined to be:

"a less fruitful avenue to cost savings than scientific vehicle design using up-to-date technology".[8]

Switching to tractor-semitrailer units where feasible and designing vehicles with attention to minimising tare mass were identified as better methods to reduce milk collection costs.

3-3 units at 42t seem to be the only aberration in the new weight limits. With hindsight, it appears that they should have been restricted to 39t.

A minimum truck wheelbase of 4.25m for 3-axle trucks in a combination exceeding 39t has been introduced. This was not a clear requirement from stability considerations, although handling performance was found to be degraded as truck wheelbase was shortened. The 4.25m dimension was agreed to by the Ministry of Transport and New Zealand Road Transport Association as a desirable minimum.

Until the investigation into the performance of self-steering axles and bogies is completed, combinations which have these devices are restricted to their old mass limits. Manoeuvrability requirements assume that B-trains, which have been used in New Zealand since 1978, have acceptable low-speed turning performance. Other combinations are required to have manoeuvrability performance equal to or better than B-trains.

From a stability analysis viewpoint, the target values suggested by UMTRI in the RTAC study appear reasonable. The dynamic stability thresholds in particular, are proving to be good indicators of the stability performance of New Zealand combinations.

However, the best vehicle dynamics simulation packages are of no value without accurate data to mathematically represent the actual components that comprise the complete vehicle configuration. UMTRI have contributed heavily to this body of knowledge and made it publicly available, particularly via various SAE papers [9-11], the Factbook [12], and in the RTAC Study. This is to be commended and encouraged, as is the contribution of other institutions in the field.

We suggest that the international community of heavy vehicle dynamics researchers would benefit from greater exchange of information on heavy vehicle component mechanical properties.

CONCLUSIONS

The lack of international harmonisation has resulted in reduced safety in countries such as New Zealand. We are very dependent on imported prime movers and components. Although standards such as SAE, DIN, and ISO are invaluable, they do not address the overall performance issue.

It is suggested that moves be made towards accepted overall vehicle performance standards or at least targets.

As a starting point it is suggested that the following be considered:

- UMTRI/RTAC stability and manoeuvrability requirements
- Mechanical structural design criteria for vehicles which would include guidelines on issues such as fatigue requirements, safety factors, etc.
- Load securing requirements
- Brake performance

These requirements must also allow improvements in vehicle technology and must be able to be tailored to local needs. Not a simple task, but an important one.

ACKNOWLEDGEMENTS

Thanks are due to all the individuals and organisations who have contributed towards the improved heavy vehicle safety requirements. The process of developing the requirements has been very enjoyable, the outcomes are realistic and workable.

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