Back

OPTIMISING LOG TRUCK CONFIGURATIONS

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Abstract

Over time heavy vehicle configurations evolve in response to changes in the operating environment. Because of the evolutionary nature of this process there is no guarantee that, at any time, the currently preferred vehicle configuration is optimal. Even the notion of optimality is not absolute as different stakeholders have different objectives. In New Zealand the government has developed the New Zealand Transport Strategy (NZTS) which defines five objectives for transport policy. Thus, for the government the optimum vehicle is the one that delivers the maximum gains in relation to these five objectives.
This study was commissioned by the users of log transport services whose focus is on delivering the lowest cost transport. However, the interests of the other stakeholders cannot be ignored. Any design that requires size and weight concessions from the government needs to consider the objectives of the NZTS. Furthermore no size and weight concession can succeed without the support of the transport operators, who are very focussed on safety.

Keywords: Heavy vehicles, Performance-based standards, Truck size and weight.

Résumé

Les configurations de poids lourds évoluent au fil du temps pour s'adapter aux conditions d'exploitation. Dans un tel processus évolutif, rien ne garantit qu'à tout moment la configuration retenue soit optimale. En outre la notion même d'optimum n'est pas absolue puisque différents acteurs peuvent avoir des objectifs différents. En Nouvelle-Zélande le gouvernement a mis au point la stratégie du transport de Nouvelle-Zélande (NZTS) qui définit cinq objectifs en politique du transport. Ainsi, pour le gouvernement le véhicule optimal est celui qui apporte le gain maximum par rapport à ces cinq objectifs.
Cette étude a été commanditée par les clients de services de transport de bois ronds dont le but est d'assurer le transport au prix le plus bas. Cependant, les intérêts des autres acteurs ne peuvent pas être ignorés. Toute conception qui demande des concessions sur les poids et dimensions de la part du gouvernement doit prendre en compte les objectifs du NZTS. En outre aucune concession sur les poids et dimensions ne peut être accordée sans le soutien des opérateurs de transport, très préoccupés par la sécurité.

Mots-clés: Poids lourds, normes de performance, poids et dimensions des camions.

1. Introduction

Over time heavy vehicle configurations evolve in response to changes in the freight task, in size and weight regulations and taxes and other charges. Because of the evolutionary nature of this process there is no guarantee that, at any time, the currently preferred vehicle configuration is optimal. Even the notion of optimality is not absolute. For the operator the optimum vehicle is the one that produces the greatest profit while, for the transport user the optimum vehicle is the one that results in the lowest cost. In New Zealand the government has developed the New Zealand Transport Strategy (NZTS) (Ministry of Transport 2002) which defines five objectives for transport policy. These are:

- Assisting economic development,
- Assisting safety and personal security,
- Improving access and mobility,
- Protecting and promoting public health,
- Ensuring environmental sustainability.

Thus, for the government the optimum vehicle is the one that delivers the maximum gains in relation to these five objectives. The NZTS does not resolve the question of tradeoffs between the objectives.

This study was commissioned by the users of log transport services and so the focus is on delivering the lowest cost transport. However, this does not mean that the interests of the other stakeholders can be ignored. Any design that requires size and weight concessions from the government needs to consider the objectives of the NZTS and requires the support of the transport operators to have any chance of success. Log transport in New Zealand in the past had a poor safety record. Over the last ten years substantial improvements have been achieved through a number of initiatives driven primarily by operators. The operators are not prepared to consider any changes in vehicle configuration that might erode the safety benefits that have been achieved.

2. Defining the Problem

2.1 The Current Log Transport Fleet

The Parliamentary Inquiry into Truck Crashes (Transport Committee 1996) identified log trucks as an area of particular concern because of their high rollover crash rate. Following on from this a study was undertaken to characterise the performance of the log transport fleet. At that time (1997) the on-highway log transport fleet was estimated to consist of approximately 650 combination vehicles. A survey obtained data on 430 of these vehicles.

A summary of the mix of vehicle configurations in the 1997 fleet is shown in Table 1. The dominant configuration was the truck and trailer which made up 91% of the fleet. The trucks and trailers used each had either three or four axles, which means that there are four possible combinations. All four were well represented in the fleet with the 3-axle truck and 3-axle trailer combination being a little less favoured than the other three options. This mix of truck and trailer configurations is interesting because it implies that no configuration had a significant economic advantage over the others.

One of the reasons that the log truck crash rate was of such concern in 1996 was that the log harvest was forecast to more than double between 2000 and 2005. Because the additional harvest was expected from forests that are more remote and are not serviced by private forestry roads, the log transport task was expected to grow by much more than 100%.

Since the 1997 study a number of things have happened that have influenced the makeup of the log transport fleet.

- The Log Transport Safety Council (LTSC) (de Pont et al, 2006) implemented a number of initiatives to reduce the rollover crash rate including: improved vehicle design for better rollover stability and better dynamics and obtaining an overall vehicle length concession allowing 22m instead of 20m. This enables mid-length logs to be double-bunked thus improving rollover stability for these loads.
- Transit New Zealand undertook the Heavy Vehicle Limits project (Transit New Zealand 2001), which investigated two scenarios for increasing size and weight. Scenario A proposed an increase to 50 tonnes GCW on the entire network while scenario B proposed increases to 62.5 tonnes GCW on specified routes. Although neither of these scenarios has been implemented, the transport industry has been "future-proofing" itself by selecting vehicles that could utilise a 50 tonnes GCW limit should it be introduced.
- The Vehicle Dimensions and Mass Rule in 2002 (de Pont et al, 2004) introduced a minimum rollover stability requirement for all large heavy vehicles.

Current estimates put the on-highway log transport fleet at about 1450 vehicles. The LTSC conducted a survey of its members in May 2006. The response rate was 34% and the respondents reported owning a total of 652 trucks. The proportion of the different vehicle configurations in 2006 is shown in Table 1.

Table 1 – Changes in vehicle configurations between 1997 and 2006.

Configuration	Percentage in 1997	Percentage in 2006
3-axle truck with 3-axle trailer	18.4%	3.1%
3-axle truck with 4-axle trailer	23.7%	12.3%
4-axle truck with 3-axle trailer	24.7%	18.9%
4-axle truck with 4-axle-trailer	24.0%	58.4%
B-train	5.1%	1.4%
Semi-trailer (Bailey bridge)	4.2%	1.2%
Others (incl. jinkers)		4.8%

The predominant configuration is still the truck and trailer which makes up 93% of the fleet. However, the vast majority of these truck and trailer combinations are now 4-axle trucks and 4-axle trailers. The 4-axle truck and 3-axle trailer combination is less popular than it was but is still reasonably widely used. The 3-axle truck and 4-axle trailer combination is about half as popular as it used to be, while the 3-axle truck and 3-axle trailer has almost disappeared from the fleet. B-trains and semi-trailer proportions have also declined.

Currently 72% of trailers are multi-bolster units compared to 40% in the 1997 survey. Multi-bolster trailers have four bolsters and are able to carry two packets of shorter logs at once. The 652 vehicles in the survey travelled 72.64 million kilometres giving an average annual distance of 111,400km per truck. The LTSC administers the approval process for 22m length concession and currently some 916 vehicles have permits representing about 63% of the fleet. 10.8% of trips undertaken were in the 22m configuration. The 22m exemption only applies to multi-bolster trailers and only comes into effect when the logs are between approximately 4.2m and 5.2m long. If the logs are less than 4.2m most vehicles can double-bunk them within the standard 20m length limit. If the logs are longer than about 5.2m most vehicles cannot double-bunk them at all and so they must be carried as a single packet load.

As well as the changes in the mix of vehicle configurations in the fleet there have been significant changes to the vehicles themselves. One of the early initiatives taken by the LTSC was to identify the key vehicle parameters that influence safety performance. The performance measures considered were Static Roll Threshold (SRT), Dynamic Load Transfer Ratio (DLTR) and Rearward Amplification (RA). The key vehicle parameters that affect these performance measures are tyre track width, centre-of-gravity height, vehicle roll stiffness, trailer wheelbase and hitch offset. Thus to produce a safer vehicle we should aim for a wider tyre track width, a lower centre-of-gravity, high roll stiffness suspension, long trailer wheelbase and a shorter hitch offset. These concepts have been incorporated into current log truck design.

Another change that has occurred over the period is that there has been a substantial increase in engine power. In 1998-99 the typical engine power was 450hp while in 2006 it was 550-630hp. There has been no increase in GCW over this period so it is not clear what is driving this power increase other than the increased availability of these higher powered engines.

2.2 The Log Transport Task

In some ways it is remarkable that the log transport fleet is so homogeneous. With the range of log lengths that are transported and the range of road environments in which the vehicles operate one might expect to see more dedicated vehicles specialising in specific transport tasks. This does occur to some extent in the off-highway environment but for on-highway transport flexibility appears to be an overriding consideration. The optimum log truck should be able to carry all the standard log lengths as safely and efficiently as possible.

To define the task, data was collected from all the major processors and exporters on the volume and lengths of logs. Export logs are considered separately because the packets of logs are generally of a single uniform length. Figure 1 shows the current distribution of export log lengths. The three most common lengths are 3.8m, 3.9m and 5.1m which together make up 48% of the total. The remaining 52% span a wide range of lengths from 3m up to 12m.

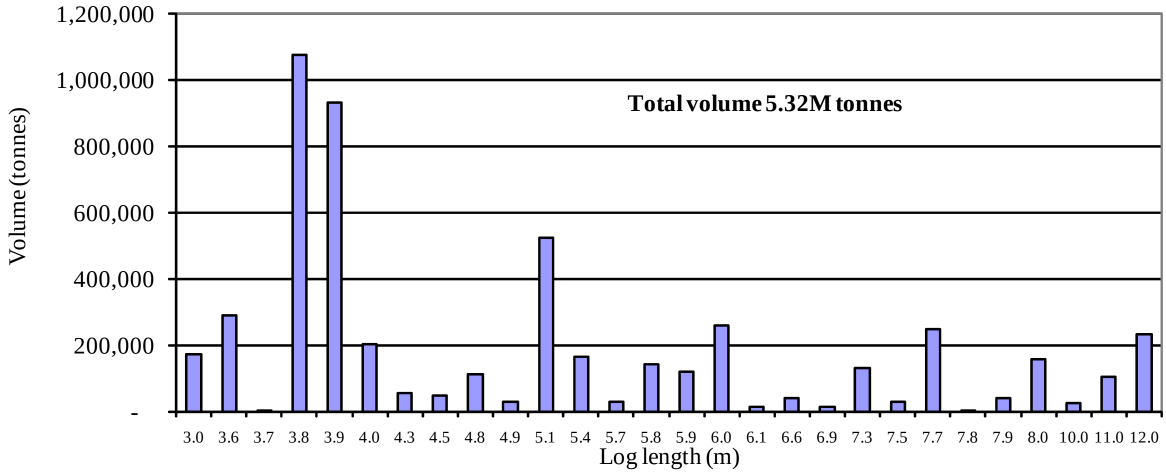

Figure 1 – Distribution of log lengths for export logs.

Data on domestic log lengths were collected by region and for saw logs and pulp logs separately. Typically log packets span a range of lengths, for example, 4.9m-6.1m rather than a single length value and different processors use different and overlapping length ranges. From the log transport point-of-view the length of the longest log in the packet is a key parameter. This determines whether or not the packet can be double-bunked on a trailer which has a significant effect on the load height and hence the rollover stability of the vehicle. Using this concept we can consolidate the length data by grouping together all the length categories with the same maximum value. Some further consolidation is possible if we group log lengths that are within 0.1m of each other. The national distribution of log lengths after consolidation is as shown in Figure 2 and Figure 3.

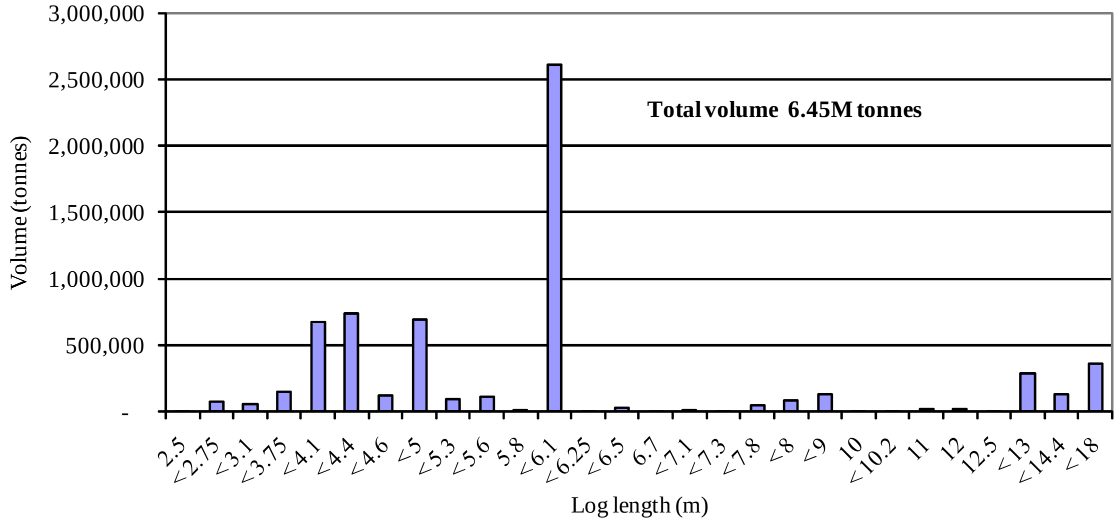

Figure 2 – Distribution of log lengths for domestic sawlogs.

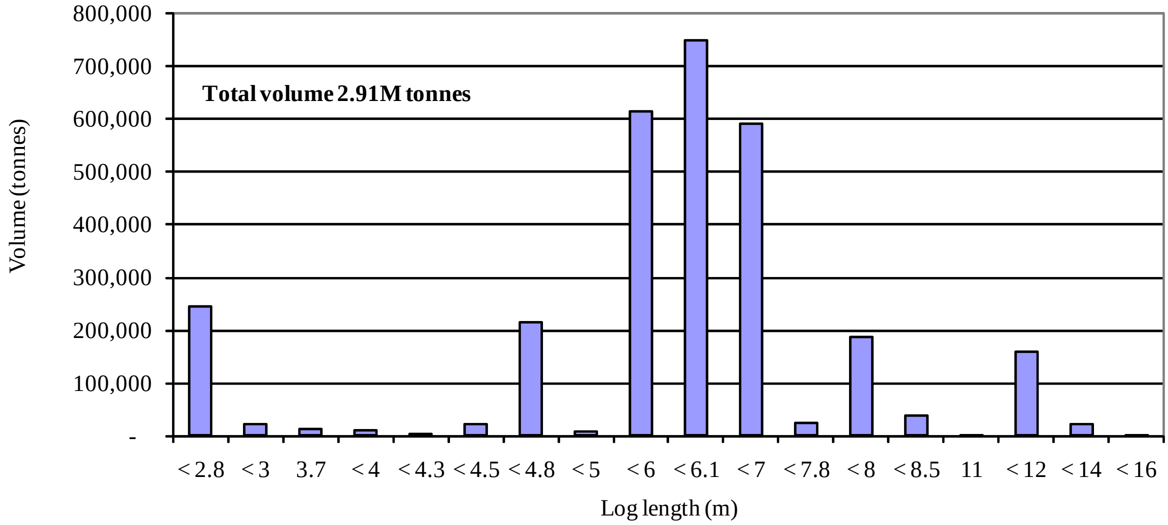

Figure 3 – Distribution of log lengths for pulplogs.

The most striking characteristic of this distribution is the large proportion of logs in packets with a maximum length of 6.1m or thereabouts. With current log truck dimensions these log lengths can only be carried as a single packet load. However, if these logs could be carried as a double packet load on the trailer, the load height reduction and rollover stability improvement would be substantial. This opens up the possibility of carrying more weight without any loss of rollover safety performance. To achieve this would require the length of the load space on the trailer to be about 12.3m. This would also enable the most common export logs (3.8m-3.9m) to be triple-bunked which again would enable the weight to be increased without a reduction in rollover stability. In fact, depending on the level of weight increase, there could well be a stability improvement.

2.3 Road User Charges and Other Constraints

The purchasers of log transport services want to reduce costs and one might expect that this would be achieved by increasing payload to the maximum amount possible. However, in New Zealand, heavy vehicles pay weight-distance based Road User Charges (RUCs) rather than a diesel tax. RUCs are designed to recover the cost of the road network and include a pavement wear component based on the fourth power relationship with load. Thus RUCs increase much faster than vehicle weight and there is a point where the cost increases are greater than the productivity gains. Because of RUCs most large combination vehicles in New Zealand have more axles than they need to comply with axle group weight limits. Thus in most cases it is possible to increase the GCW significantly without violating axle group limits.

Height and width constraints are considered inviolable. In New Zealand the maximum allowable width is 2.5m and the maximum allowable height is 4.25m. New Zealand also has a rollover stability requirement that all large heavy vehicles must achieve a minimum SRT of 0.35g. For log trucks, the SRT requirement generally means that the maximum achievable load height is less than 4.25m so the maximum height restriction does not add a further constraint. Although increasing vehicle width could improve rollover stability there is a great reluctance by the Road-Controlling Authorities to consider this as an option.

The minimum SRT requirement of 0.35g is specified by law. However, in addition to this any proposed size and weight concessions need also to be supported by transport operators in order to be considered by the government. Over the past 10 years, log transport operators in New Zealand have achieved substantial improvements in safety particularly in relation to rollover crash rates. As a group they will not support any size and weight concessions that could potentially result in less safe vehicles. Thus the SRT cannot be significantly worse than current vehicles. For many log lengths it would have to be substantially higher than 0.35g.

There is also a schedule of axle weight and spacing limits (commonly known as the “bridge formula”) that applies. Scenario A of the Heavy Vehicle Limits project proposed increases to the “bridge formula” which appeared to be manageable and so there is the possibility of some increases in this regard. Current maximum dimension and weight vehicles are 20m long and 44 tonnes GCW and are close to the limits imposed by the current “bridge formula”

3. Performance Analysis of Options

Vehicle configuration options were modelled using the Yaw-Roll (Gillespie 1982) multi-body simulation software developed by the University of Michigan Transportation Research Institute. Performance measures relating to three key aspects of vehicle safety performance were considered. For comparison a well-designed modern log truck meeting current size and weight limits was analysed as the "reference vehicle". This vehicle was a 4-axle truck and 4-axle full trailer combination illustrated in Figure 4. Although the legal GCW limit is 44 tonnes, a weighing tolerance of up to 1.5 tonnes applies and thus 45 tonnes is a typical operating GCW. The vehicle was loaded to give a gross weight of 25 tonnes for the truck and 20 tonnes for the trailer. This loading arrangement gives good safety performance but is not the most economically efficient because of RUCs. Most operators would put more of the load on the trailer. Its safety performance will be above average for the current log transport fleet.

3.1 Steady Speed Rollover Stability

Steady speed rollover stability performance was characterised using SRT. A summary of the SRT performance of the reference vehicle with different loads is shown in Table 2 below. In two of the loading cases the critical vehicle for rollover is the truck rather than the trailer. This is because of the higher truck weight as noted earlier. Making the truck the less stable vehicle in the combination enhances safety because the driver gets better feedback from the truck. Shifting more payload onto the trailer would make the trailer the critical vehicle for rollover but the overall level of SRT would remain good.

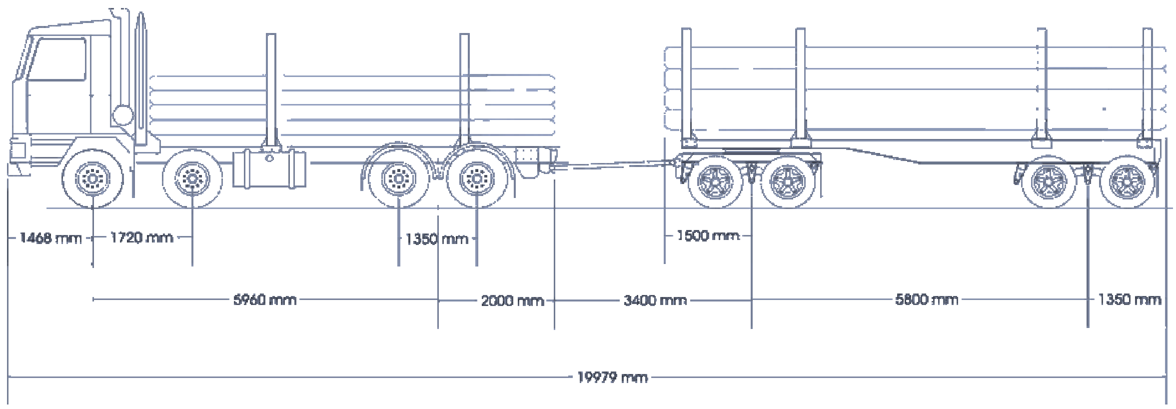

Figure 4 – Modern 20m log truck configuration.

Table 2 - Rollover stability performance of a good modern log truck

Configuration	SRT
Reference vehicle – 45t 3.8m logs	0.43g truck rolls
Reference vehicle – 45t 5.1m logs	0.47g trailer rolls
Reference vehicle – 22m, 45t, 5.1m logs	0.48g truck rolls

3.2 Evasive Manoeuvre Performance

Evasive manoeuvre performance was characterised by three performance measures. These were Rearward Amplification (RA), Dynamic Load Transfer Ratio (DLTR) and High Speed Transient Off-tracking (HSTO). The standard manoeuvre used for all three measures was the SAE lane change manoeuvre (Society of Automotive Engineers, 1993). The evasive manoeuvre performance of the reference vehicle is shown in Table 3. Generally acceptable performance is considered to be RA < 2, DLTR <0.6 and HSTO < 0.8m, so the vehicle has good performance characteristics.

Table 3 - Evasive manoeuvre performance of a good modern log truck

Configuration	RA	DLTR	HSTO (m)
Reference vehicle – 45t 3.8m logs	1.14	0.37	0.254
Reference vehicle – 45t 5.1m logs	1.17	0.45	0.260
Reference vehicle – 22m, 45t, 5.1m logs	1.14	0.33	0.248

3.3 Low Speed Manoeuvring

The performance measure used to characterise this behaviour was Low Speed Off-tracking (LSO). This is the additional width that a vehicle requires to execute a low speed 90° turn. In New Zealand the standard turn used is 9.8m radius and generally acceptable performance is considered to be less than 4.2m. A typical 20m B-train has an LSO value of about 4.2m. The LSO values of the reference vehicle are shown in Table 4.

Table 4 - Low speed manoeuvring performance of a good modern log truck

Configuration	LSO (m)
Reference vehicle – 45t 3.8m logs	3.246
Reference vehicle – 45t 5.1m logs	3.243
Reference vehicle – 22m, 45t, 5.1m logs	3.242

The reference vehicle has quite a long trailer wheelbase compared to many existing vehicles and therefore will have a higher LSO than many current log trucks.

4. Standard Dimension Log Truck and Trailer at 50 tonnes GCW

The first configuration considered was increasing the GCW of existing vehicles to 50 tonnes. This vehicle aligns itself with the Scenario A proposal in the heavy vehicle limits project and so there has been considerable analysis of its feasibility. Its main advantage is that it is geometrically identical to existing vehicles and thus will have no difficulties accessing the entire road network that is currently accessible by logging trucks.

In general, increasing the load on an existing log vehicle means that the load height will increase and consequently that the rollover stability will reduce. It has been shown that the relative rollover crash risk increases dramatically as SRT becomes low. However, for higher SRT values the changes in crash risk are small. It was therefore proposed that the weight concession of up to 50 tonnes GCW should be limited to the cases where the trailer SRT is greater than 0.4g. This will effectively limit the concession to longer log lengths where the load height is kept low. The minimum truck SRT would be kept to 0.35g on the basis that the driver receives direct feedback on the truck's stability performance and will drive accordingly. It is relatively rare for a truck to roll without the trailer rolling first.

Table 5 - Performance of a good modern log truck at 50t GCW.

Configuration	SRT	RA	DLTR	HSTO (m)	LSO (m)
Reference vehicle – 50t 3.8m logs	0.42g truck rolls	1.18	0.50	0.299	3.219
Reference vehicle – 50t 5.1m logs	0.39g trailer rolls	1.24	0.68	0.339	3.215
Reference vehicle – 50t 22m, 5.1m logs	0.48g truck rolls	1.17	0.42	0.282	3.216

A summary performance of the reference vehicle at 50 tonnes gross combination weight is shown in Table 5. It is clear that increasing the load to 50 tonnes without increasing length generally degrades rollover stability. The exception is the 22m vehicle with 5.1m logs where the stability of the truck is the critical factor. With the loading assumptions used the load on the truck does not increase and so the stability remains the same. Under the proposed criteria of a minimum trailer SRT of 0.4g, this vehicle would not be able to carry 5.1m logs as a single packet load at 50 tonnes although it could handle 48 tonnes.

5. 52 tonnes 24m Log Truck and Trailer

An analysis of the current log loads carried show two dominant sizes. For the export market 3.8m and 3.9m sawlogs are the predominant size together making up some 38% of the total weight. For the domestic market, 41% of the total weight is made up of mixed length packets up to 6.1m long. These 6.1m lengths cannot be double-bunked within the existing dimension limits and so increasing the load on the trailer will reduce rollover stability. The obvious solution to this is to increase the combination length so that 6.1m packets on the trailer can be double-bunked. By choosing the dimensions carefully we can configure the same vehicles so that 3.9m logs can be triple-bunked on the trailer and double-bunked on the truck. The effect of this would be that for the most common log lengths, the vehicle could carry 52 tonnes but be more stable than current 44 tonne combinations carrying the same log size. To achieve this loading the overall combination length needs to be 24m with a maximum trailer length of 13.5m (as allowed under the 22m concession). The front overhang on the trailer needs to be allowed to increase to 2.4m (compared to 2m allowed under the 22m concession). The reason for this is that the trailer wheelbase is restricted to about 7m maximum because of the need to piggy-back the trailer when empty and so it is not possible to distribute the load properly without the additional front overhang.

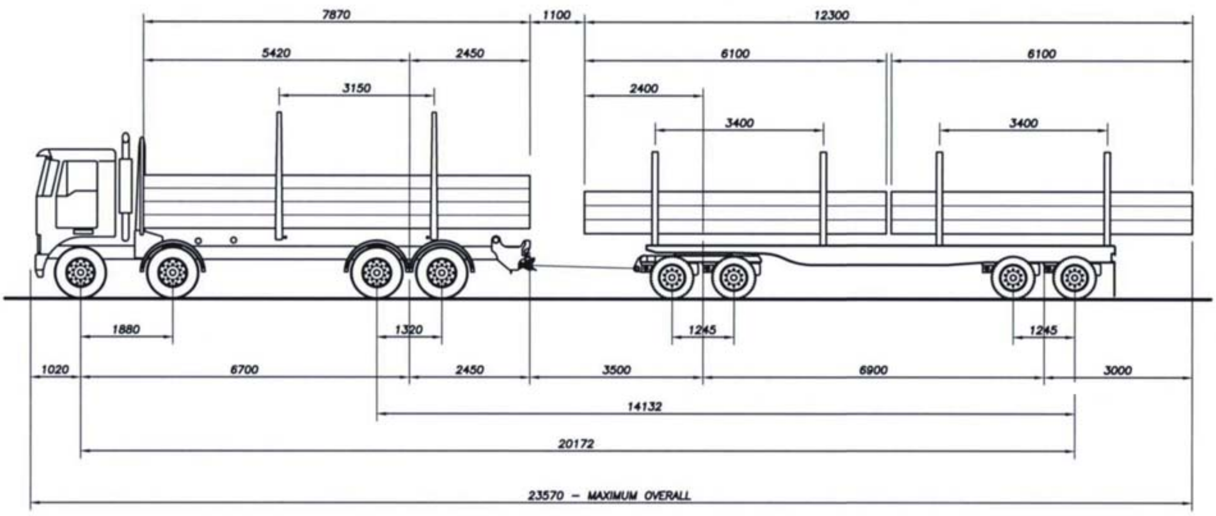

Figure 5 - Possible 24m 52 tonnes log truck.

A comparison of the performance of this vehicle with that of the reference vehicle carrying 6.1m logs is summarised in Table 6. Both the rollover stability and the dynamic performance of this longer vehicle are similar to that of the reference vehicle even though it is carrying substantially more payload. The obvious aspect of vehicle performance that would be expected to be compromised by the additional length is low speed offtracking (LSO) and to a degree this occurs. The 24m vehicle requires 0.67m more swept width than the reference vehicle for the standard manoeuvre. However, the LSO is still less than the 4.2m LSO of current 20m B-trains and 18m semitrailers.

Other performance issues that arise from extra length are overtaking time, intersection clearance time and the proximity of railway crossings to intersections. Overtaking time consists of the sum of three components; the time to pull out, the time to pass and the time to pull in. Only the second of these is affected by vehicle length. Although increasing the vehicle length from 20m to 24m increases the passing time by 20% the overall effect on overtaking time is much less. In evaluating the routes where this vehicle would be used it is necessary to consider the level of other traffic on the route and the availability of passing lanes. Generally log trucks have relatively powerful engines and intersection clearance time is not an issue. The issues of railway crossings should be considered when evaluating routes.

Table 6 – Comparison of the proposed longer vehicle with the reference vehicle.

Configuration	SRT	RA	DLTR	HSTO (m)	LSO (m)
Reference vehicle – 45t 6.1m logs	0.51g trailer rolls	1.37	0.4	0.25	3.24
Longer log vehicle – 52t 6.1m logs	0.52g truck rolls	1.41	0.38	0.27	3.91

6. Summary

During this study the Ministry of Transport initiated a review of size and weight. They asked industry to submit proposals for concessions that would deliver significant economic benefits while not compromising the other objectives of the NZTS. The New Zealand Forest Owners Association submitted a proposal which included the two log truck configurations analysed above. The proposal was that the 24m combination would be used wherever possible between forests and processing facilities and ports while the 20m vehicle at 50 tonnes would be used in areas where the road geometry was not suited to the longer vehicle.

These proposals were included in a paper prepared for the Minister of Transport and are currently under consideration by cabinet. A decision will be made early in 2008.

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