Dear Member

Please find attached an Appendix to the New Zealand Forest Owners Road Engineering Manual, titled "Forest Roads for High Productivity Motor Vehicle with Two Drive Axle Log Trucks," prepared by Paul van der Voort from Forest Management NZ Ltd, and funded with support from the Forest Growers Levy Trust.

The original 2020 Forest Road Engineering Manual was developed to ensure that roads, water crossings, and related infrastructure in New Zealand's plantation forests are fit for purpose and adhere to high environmental standards. The manual includes sections on Road Planning (Section 3) and Pavement Design (Section 6). However, the design tables and specifications were created prior to the advent of High Productivity Motor Vehicles (HPMVs), which have different requirements compared to the older configurations.

The previous truck configuration featured an overall wheelbase of 16 metres, a length of 20 metres, and a gross weight of 44 tonnes. In contrast, the popular HPMV configuration today is a 9-axle truck with a maximum weights of 50, 54, and 58 tonnes Gross Combination Mass, and an overall length of 23 metres.

While these HPMVs can navigate the same turning circle, the trailer off track is greater and they face challenges on steeper terrain due to their heavier and longer loads in comparison to 20-metre length and 8 axle configurations.

This appendix provides guidance and commentary on planning and constructing in-forest roads to accommodate HPMV vehicles, addressing several key areas:

- **HPMV Configuration Options**: An explanation of the various configurations.

- **Curve Widening**: Updated design charts for curve widening to accommodate larger vehicles.

- **Curve Radius, Corner Gradient, Corner Radius, and Road Gradient Guidance**: Specific recommendations for designing roads to handle the increased demands of HPMVs.

- **Road Pavement Material**: Guidance on selecting appropriate surface materials for loaded travel.

- **Positive and Negative Camber**: Recommendations for road camber to ensure vehicle stability.

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- **Pavement Surface Compaction and Tightness**: Suggested maximum adverse (uphill) grade of 12.5% to ensure road usability by 90% of drivers in 90% of weather conditions.
- **Driver Skill and Decision Making**: Emphasis on the importance of skilled drivers and appropriate decision-making.
- **Pavement Design and Construction**: Discussion on Equivalent Standard Axle Loading and how it increases with HPMV usage.
- **Recommendations**: Acknowledgement that HPMV vehicles may not be suitable for all forest conditions and offering advice for specific scenarios.

This appendix aims to provide practical, up-to-date guidance to help forest road engineers and planners design roads that accommodate the new HPMV configurations safely and efficiently.

Yours sincerely

Elizabeth Heeg
CEO

Signatories to the Log Transport Safety Accord 2021 – A commitment to improve the health, safety, and wellbeing of Log Transport across the industry, while enhancing safety for all road users on public and private roads.

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New Zealand Farm Forestry Association
Oranga Rākau Aotearoa

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New Zealand Forest Road Engineering Manual Appendix:
Forest Roads For High Productivity Motor Vehicles (HPMV) with Two Drive Axles Log Trucks.

The New Zealand Forest Owners Association Road Engineering Manual (FEM) has 25 pages dedicated to the planning of roads and their layout in section 3, and pavement design in section 6. Principally this guidance is for road building for log trucks which will have trailer up for travel back to the forest harvesting site and a loaded truck towing a trailer out of the forest onto the public roads.

Nearly all of the available design tables and charts in the FEM use references applicable before the onset of the High Productivity Motor Vehicle (HPMV) era, where the overall truck wheelbase, first to last axle, was 16 metres and the overall truck and load length was 20 metres. Gross weights were 44 tonnes.

HPMV development was initiated by Transit NZ (the road controlling authority for New Zealand State Highways). A subsequent change now identifies them as NZ Transport Agency or Waka Kotahi.

As a brief historical progression of the HPMV inception.

- The original 44t combination required 16m from first to last axle and needed 7 or 8 axles.
- When the 9 axle 50max was introduced, the theory was a progression of gross weight from 46 to 50 tonnes depending on the distance from first to last axle, ie 19m GCM 48.5t and 20m GCM 50t
- The concept assumed no additional pavement wear by adding 1 axle to the combination.
- Gross weight or standard 44 t vehicles increased also, 7 axles to 45t and 8 axles to 46t.
- HPMV axle weights and groups were introduced to allow increased mass on standard combinations and on 9 axle combinations.
- Trucks with 8 axles could be HPMV permitted to 48t and 53t which included an increase weight on drive axle group from 15t to 16t.
- Allowance for 9 axle combinations at 50, 54, and 58t in either Class 1 axle groups or HPMV.

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- The key is 16t on drive axles on permitted routes with grade ability greatly improved at 16t on drive axles.
- 7 and 8 axle combinations performed well because gross weight on the truck is higher than the trailer.
- 50max Gross Combination Mass (GCM) is normally spread 50/50 and anything above, say 54t the split is 26t on the truck 28t on the trailer.
- 58t GCM is up to 27t on the truck and up to 32t on the trailer.
- A typical 9 axle logging combination swept path is often better than 8 axles as there is a trade off in shorter truck wheelbase to achieve maximum axle spacing on the 2 to 9 axles for weight allowance, add in the truck hitch position to piggyback a longer trailer, with the trailer having a shorter drawbar and longer chassis.
- Still, at 23m overall these truck and trailers take up significant road space.

The motivation for HPMV development was to reduce the numbers of trucks on the road by increasing the load that can be safely carried (increased productivity) for a given specification of vehicle. The standard increased weight vehicle with 9 axles became known as the 50 MAX vehicle. HPMV vehicles are issued with permits for individual trucks to increase gross combined mass (GCM) above 50 tonne and up to 62 tonne as general freight including logs. Transporters carrying harvesting equipment exceed these limitations and operate under a different permitting system.

The movement of these vehicles into forests roads was natural in the Central North Island and approved routes quickly expanded.

The HPMV truck is a specific design, requiring 9 axles and having a maximum overall length of 23 metres. This design of truck and trailer quickly became the normal configuration as new log trucks were built. Forest owners have seen these trucks move into forests as trucks approved for HPMV loads on the public roads get loaded in forest. This type of truck with the longer lengths and heavier loads present challenges for roads built on steep terrain. The truck will negotiate the same turning circle as before, so the minimum radius required to negotiate a corner remains at 13m for a 180-degree central angle corner.

The challenges for HPMV in forest are the curve widening required on the tight radius of the corners, the steepness of the roads and the different surfacing materials required for loaded travel.

Curve Widening.

Section 3.13 of the FEM outlines requirements for curve widening. Paragraph 3 mentions the requirement for calculations for vehicles which are of greater dimensions than those used for the chart calculation. Image 1 is an indicative chart for HPMV curve widening to be used to ensure there is enough pavement to cater for the trailer off track.

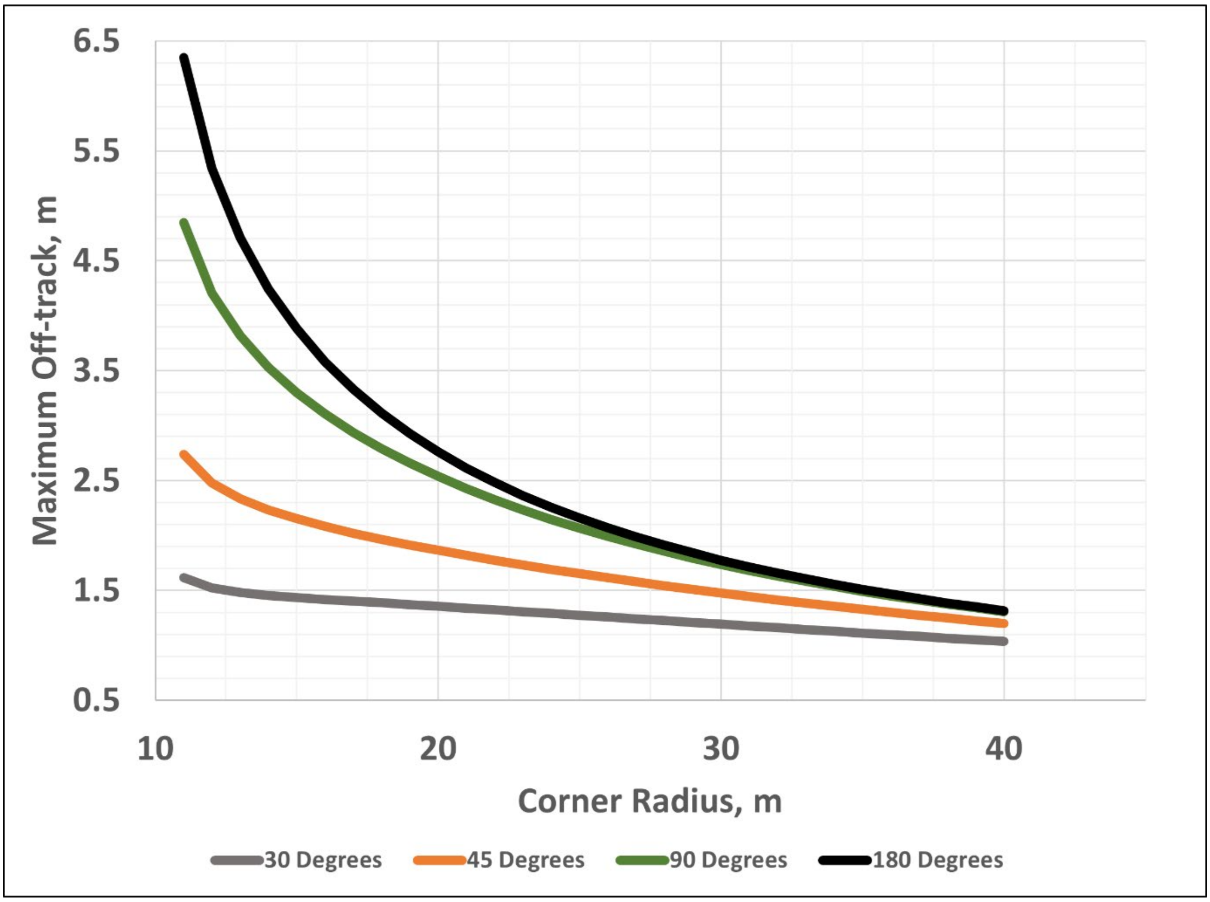

Image 1: Curve widening requirements for HPMV vehicle.

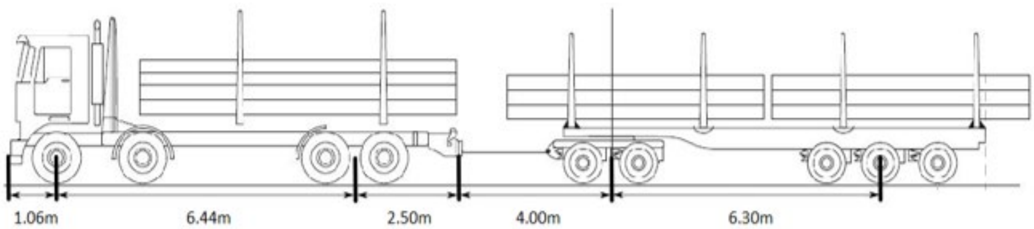

Image 2: Wheelbase of HPMV log truck.

Curve Radius.

Curve radius measurement and calculation is described on page 49 of the FEM, but an app is available from the App Store called **Radius Calc** which makes the measurement and automated calculation quick and easy.

Truck and Road Interaction.

On a flat road with a hard surface which does not deflect under the point loadings of the axle weights, the effort required to move the wheeled vehicle is minimal. As the adverse loaded grade increases from flat upwards, the effort required to move the mass increases. This effort is directed to the drive wheels of the unit and many other forces commence affecting the dynamics of the unit, such as:

The most critical dynamic is to maintain the traction effort from the drive tyres onto the road pavement surface. The truck drive line will allow the truck to climb steep gradients as long as the traction effort is maintained. Many factors have an effect on tractive effort and this is usually in combination with one or two other factors which may include:

Road gradient: For both conditions, adverse loaded or favourable gradients, the effort required from the vehicle increases. For a given weight, the steeper the road for adverse loaded travel, the more power is required to continue forwards momentum. For favourable gradients, the steeper the gradient the greater the braking capacity is required to oppose the acceleration effect of gravity.

Gross weight: As gross weight increases on adverse loaded road, the more power is required to continue forwards momentum. For favourable gradients, as gross weight increases, the greater the braking capacity is required to oppose the acceleration effect of gravity.

Gravity: Everything is affected by gravity, one suspects it is up or down the road but it is also sideways. On slow speed corners with super elevation to the inside of the corner, gravity will pull the trailer to the inside. Gravity affecting the trailer will affect the truck by lifting the weight off the outside drive tyres and pulling back on the truck. The weight on the truck can also lean inwards into the corner, all of which significantly affects tractive effort. This is not a new phenomenon as all trucks are affected the same, just HPMV GCM weight increases mean greater effects and therefore outcomes.

Positive and negative camber (super elevation): The steeper the gradient the more attention must be placed on corner design. The NZ-FOA FEM Manual indicates centreline maximum grades on corners on page 45 but, the design of super elevation has a huge impact on truck gradability. The steeper the (climbing) corner, the super elevation should be negative up to 3% which has the effect of shifting the weight of the load to the outside of the truck and keeping the tractive effort square on the pavement to oppose the rearward drag of the trailer weight, while also using gravity to encourage the trailer to follow the truck around outside alignment of the corner.

Corner radius. Trucks can negotiate a 13m radius as a minimum. This is best undertaken on a flat to very low-grade corner.

Corner Gradient: The steeper the road grade and the tighter the corner radius then the flatter corner gradients should be and in context with the super elevation as previously discussed. Roads with steep climbs will benefit from the corner grade being flatter than the road grade.

Road pavement material: This one factor that has the most impact on the truck gradability. The tighter the pavement and the more impervious to moisture it is, then the ability to successfully traffic steep grades increases considerably. The same is true for steep favourable grades. The ability to maintain traction because of pavement material is fundamental to heavy traffic passage. There are lots of road grades published that trucks have successfully negotiated, including some steep grades, but once a shower of rain falls, the ability to continue passage is stopped. The ultimate of course is to chip seal the steep roads (cost vs results), to provide the ultimate in traction.

The ability for the road to carry the weight and repetitive axle loading is part of pavement design. Poor wet subgrade can cause rutting to appear, as will pavement thickness being under designed. Rutting causes rolling resistance, the more axles the more rolling resistance.

Not all areas of NZ have good quality crushed quarry rock for building roads. Pavements are made of whatever product is available and different products react in different ways to the traffic of heavy trucks. Generalised grinding of softer rock creates fines, which also creates dust, or it can form as sludge with disastrous results, (just add water).

Automatic vs manual gearbox: Not necessarily an issue but drivers who leave the auto gearbox in auto rather than selected manual are leaving the truck to decide on gear change positions and while climbing hills, the change can occur at the most inappropriate time. It is the same with a manual gearbox and drivers changing gear on the wrong position in the road. On steep hill country roads, the gear selection to negotiate the road should be made at the start of the climb and stay that way until the truck reaches the top. Pulling gears will end up with power coming on in almost an emergency change and typically ends up with drive wheels spinning, potentially causing damage to the pavement.

Driver decision making: With the aging driver workforce and younger drivers entering the forest, some spectacular gear changes have been observed. Correct gear selection by an experienced driver is beneficial to all parties. Drivers need to be able to read the road requirements ahead and avoid the tendency to "point and drive".

Weather conditions: One of the largest impacts to maintain tractive efforts on unsealed pavements are weather conditions, particularly on roads which use poorer quality aggregate such as red metal, limestone and varying qualities of mudstone. These materials grind to dust under traffic and when mixed with rain can be very slippery and dangerous. This material can be best when its dry or when its heavy rain but it's the half dry- half wet period that makes everything tacky and slippery.

Pavement surface conditions: Every unsealed pavement which has constant traffic will suffer from corrugations and potholes. Bad corrugations can severely limit tractive effort and is known to affect gear retention under load. Bad corrugations on steep roads cause a rocking effect which then lifts weight off the respective driver tyres which further exacerbates the creation of corrugations.

Pavement surface compaction and tightness: As with the road pavement material type, the tighter the pavement, the less ability there is to pull up the surface and damage the pavement. The better the pavement in the steeper sections of road the trucks can negotiate these places successfully. In areas with loose gravel or rubble, the more difficult it is to maintain traction.

Due to driver competence factors as well as an inability to maintain some of the road parameters described above, the max adverse grade for building forest roads has been set at 12.5%. At this gradient there is an expectation that 90% of drivers will be able to traffic the road 90% of the time through 90% of the weather conditions.

We know that HPMV trucks can negotiate steeper flexible pavement roads but the percentage of time the road remains trafficable (and can be used freely) reduces dramatically as the loaded adverse gradient goes up.

Pavement design and construction:

The FEM has a complete section on subgrade preparation, pavement design and construction.

The basis of all pavement design is to enable point loading of axles to be supported as the load is passed across the road. All forest roads are flexible pavements and therefore will deflect as the load passes. The cohesive strength of the binding of the pavement aggregate provides support and strength for repetitive loading.

Forest pavement design relies on Equivalent Standard Axle (ESA) loading which is clearly described in Section 6 of the manual.

- A return trip for a 44 tonne GCM log truck impact on a road pavement is 4.33 standard axles.
- A return trip for a 50 max GCM log truck is 5.5 standard axles.
- A return trip for a 54 tonne GCM log truck is 6.5 standard axles.

The 54-t truck increases the impact and wear on the road pavement by 33 percent however, the change in requirements for pavement thickness is small and cannot be materially managed during construction to make savings from construction costs. The additional axle and the additional weights do affect the truck gradability to successfully negotiate roads, especially where the loaded adverse road grades are increased to 12.5% and aggregate used for surfacing has a tendency to create fines during the continual traffic use. As HPMV vehicles GCM weight increases, the weight increases on the trailer which creates a dynamic for the truck where it has a trailer with more gross weight than the truck which is the prime mover.

The additional axle on the configuration helps with lowering the impact on the pavement overall but it does create additional rolling resistance, especially where the pavement is wet and muddy or on adverse loaded grades.

All the factors must be assessed for impacts on truck gradability, and decisions made on the greatest risks which could have an impact on the daily access and safe passage of trucks.

A decision needs to be made on how to manage the risks, assuming all the construction techniques which have been used provide the best road alignment, shape, and surface.

Some considerations could be:

- Stopping cartage in the wet.
- Judicial use of traction coat aggregate spreads.
- Using products to tighten the surface of the road.
- Use of bitumen as the ultimate surface to provide constant traction.

With an increasing fleet of HPMV trucks pushing into the forests, at some point, there needs to be the ability to evaluate that HPMV trucks are may not be a suitable solution in every forest application.