Logging trucks on local roads – is forestry really having an unreasonable impact?

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Abstract

What impact does forestry have on local roads compared to other farming sectors? With a harvest cycle of approximately 30 years forestry can generate a large volume of traffic for a short period of time. This increased traffic can arguably cause a pavement to fail quickly compared to the traffic loading a pavement is more normally subjected to. The required rehabilitation of the pavement could be attributed to the forestry traffic but this fails to take account of the whole life cycle loading of the pavement. This paper examines the impact on the pavement life that forestry generated traffic has relative to other farming sectors for an example district. It concludes that forestry can generate significant traffic movements in a short timeframe, but when averaged over a 30 year period the production per hectare is fifty per cent greater than that of dairy farms. However, in addition to exported produce from farms, they import freight as well. These inwards movements of fuel, fertiliser, and stock need to be accounted for in the quantification of vehicle loading produced by the various farming sectors.

Introduction

Local or district roads have been designed or have evolved to carry the heavy vehicles generated by the farming sectors that they service. With a harvest cycle of approximately 30 years forestry can generate a large volume of traffic for a short period of time. This increased traffic can arguably cause a pavement to fail quickly compared to the traffic loading a pavement is more normally subjected to by the other farming sectors. The required rehabilitation of the pavement could be attributed to the forestry traffic but this fails to take account of the whole life cycle loading of the pavement. This paper uses an example district to study the impact on the pavement life that forestry generated traffic has relative to other farming sectors.

New Zealand Forest Owners' Association have produced a report entitled *A review of issues relating to the use of district roads for the transportation of forest harvest* (Frame Group 2003). The report is general in its nature and is not written specifically for individual districts; instead, it details the impacts that different farming modes have on vehicle movements. As such, the data in the report cannot be used directly to determine the relative contributions of each farming sector for a particular district.

This paper presents a methodology by which the influence of forestry generated traffic can be separated from the impact of other primary users on the local roads. It looks at the issue from a district based view and assumes that the vehicle movements generated by the various farming sectors originate in the region and are transported through the region to state highways. In doing so, it does not allow for vehicle movement generated outside of the district upon the local roads.

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Fundamentals of pavement design

Design of road pavements in New Zealand is performed according to the guides produced by Austroads (2010) and the New Zealand Transport Agency's Supplement to Austroads (Transit 2007). These documents identify the methods by which the design traffic and the pavement structure are determined. Based on the New Zealand Transport Agency's supplement a reliability factor of between 80% and 90% is considered appropriate for rural roads. This means that between 80% and 90% of the pavements designed and constructed according to the relevant standards will achieve a life in excess of the design.

Pavement life

Austroads (2010) does not define what is meant by pavement failure. A failed pavement is a subjective concept, with failure normally being determined by an experienced network manager. Failure can be attributed to combinations of numerous factors including, but not limited to, roughness, potholes, cracking of the pavement surface, edgebreak, rutting, loss of surface friction, and is influenced by the speed environment, traffic levels and public opinion. For a sealed pavement two commonly adopted determinants of failure are a rut depth greater than 20 mm and/or roughness in excess of 150 NASSRA.

Therefore, it must be recognised that pavement life as discussed herein is a theoretical construct and is a value of traffic loading beyond which most (as determined by the reliability factor) pavements are expected to perform satisfactorily.

Pavement design life

The design life is typically chosen as 25 years, however this is merely a period over which the expected traffic is calculated. The total design traffic loading may be applied earlier than 25 years if the design assumptions are not met and thus the theoretical life of the pavement will be less. Conversely, the pavement may not be subjected to the design traffic in the design period and the achieved life may theoretically be greater.

Design traffic

The design traffic is the product of a number of factors, the variables are typically the average daily traffic (averaged over a year this is known as the annual average daily traffic), the percentage of heavy vehicles, and the growth rate. For the rural roads other factors such as the design period, the average number of axle groups per heavy vehicle, lane distribution factor and the direction factor are typically constant.

Design traffic is calculated by equating all the loading from heavy vehicles into Equivalent Standard Axles (ESA). This is achieved by determining the allowable Standard Axle Repetitions (SAR) before expected failure, based on the ratio of the load on an axle group to the standard load for an axle group to the power of an exponent. This is expressed in equation 1 below,

[1] $$SAR = \left(\frac{L}{SL}\right)^m$$

where L is the load on the axle group,

SL is the standard load on the axle group, and

m is the damage exponent and is equal to 4 for granular pavements with thin bituminous surfacings.

The standard loads for an axle group have been determined to cause the same damage as a standard axle and are reproduced from AUSTROADS (2010) in Table 1 below.

Table 1 Axle group loads

Axle group type	Load (kN)
Single axle with single tyres	53
Single axle with dual tyres	80
Tandem axle with single tyres	90
Tandem axle with dual tyres	135
Tri-axle with dual tyres	181
Quad-axle with dual tyres	221

One ESA is the load applied by a single axle with dual tyres subjected to a load of 80 kN with an individual tyre contact area of 0.0267 square metres. Where the damage exponent of 4 is used in the equation above, then one ESA is equal to one SAR. Based on an exponent of 4 a doubling of axle load has a sixteen-fold increase on the damaged induced by the axle.

As an example a typical logging truck configuration when carrying 28.5 tonnes produces an ESA of 3.2 and when unloaded generates an ESA of 1.4.

The New Zealand Transport Agency (NZTA) publish an annual weigh-in-motion report, the latest of which (NZTA 2010) indicates that approximately 10% of heavy vehicles are overloaded, based on Equation 1 above the damage caused by these overloaded vehicles is almost 50% greater than the damage from vehicles that adhere to the loading limits.

A table below has been prepared that shows the Design Equivalent Standard Axles (DESA) expected in a 25 year period assuming 10% heavy vehicles (based on the values in RAMM), 1% growth and all other factors being the default factors with the exception of the ESA per heavy vehicle. The New Zealand Supplement to Austroads has a value of 1.44 ESA per heavy vehicle, however this value can vary throughout the country.

Table 2 Indicative design traffic loading for various average daily traffic volumes

Average daily traffic	DESA (with ESA per heavy vehicle=1.44)
50	3.71×10^4
80	5.94×10^4
100	7.42×10^4
250	1.86×10^5

Pavement structural design

The design methodology assumes that subgrade strength, of which the California Bearing Ratio (CBR) is a measure, and the design traffic over a period of 25 years determines the structure of the pavement.

Reproduced in Figure 1 is *Figure 8.4* from AUSTROADS (2010), from this it can be seen that for a design traffic of 10^5 ESA and a CBR of 5% then a total granular thickness of approximately 300 mm including a premium basecourse of 100 mm is required to achieve the design life. The design traffic value used in the example above has been chosen as the minimum design value allowed by *Figure 8.4* but is also representative of expected loadings on the example district’s rural roads.

Figure 1 Reproduction of Figure 8.4 from AUSTROADS (2010)

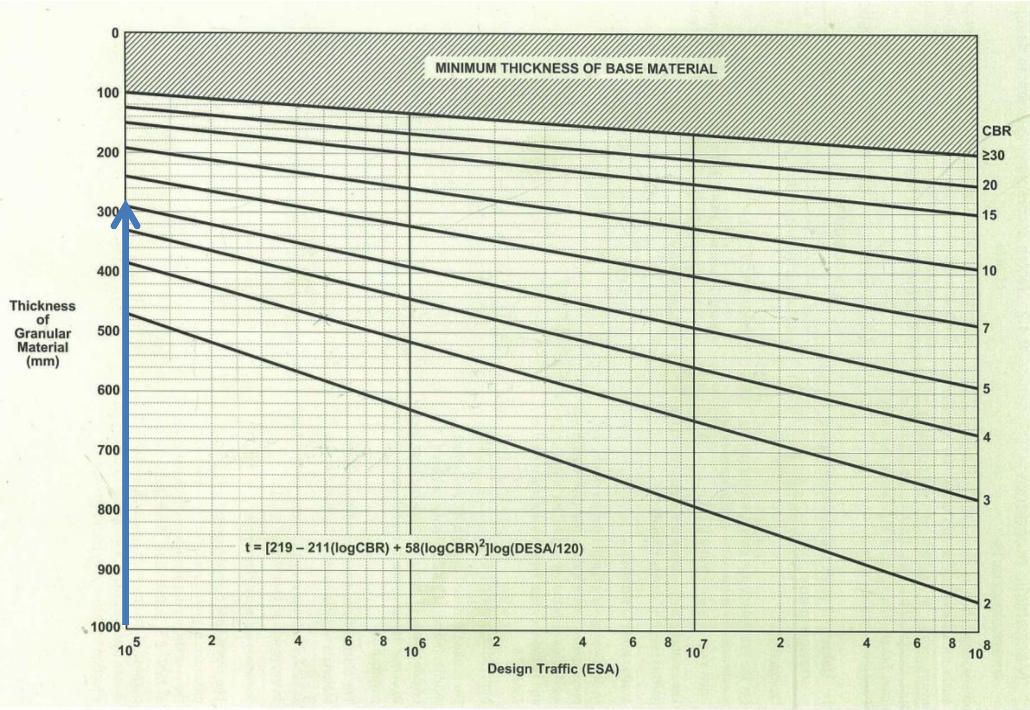

Figure 8.4 from Austroads can be redrawn with subgrade CBR as the ordinate, Figure 2 reproduced from Gribble and Patrick (2008) demonstrates the non-linearity of the design method. For example, for a design CBR of 5% the constructed pavement for a design traffic level of 10^5 ESA is approximately 292 mm while for a design traffic level of 10^6 ESA is approximately 400 mm. That is, a tenfold increase in traffic can theoretically be accommodated by a 35% increase in pavement thickness. Further discussions on the Austroads' design methodology can be found in Gribble and Patrick (2008).

Figure 2   Reproduction of Figure 8.4 in terms of CBR and total granular thickness

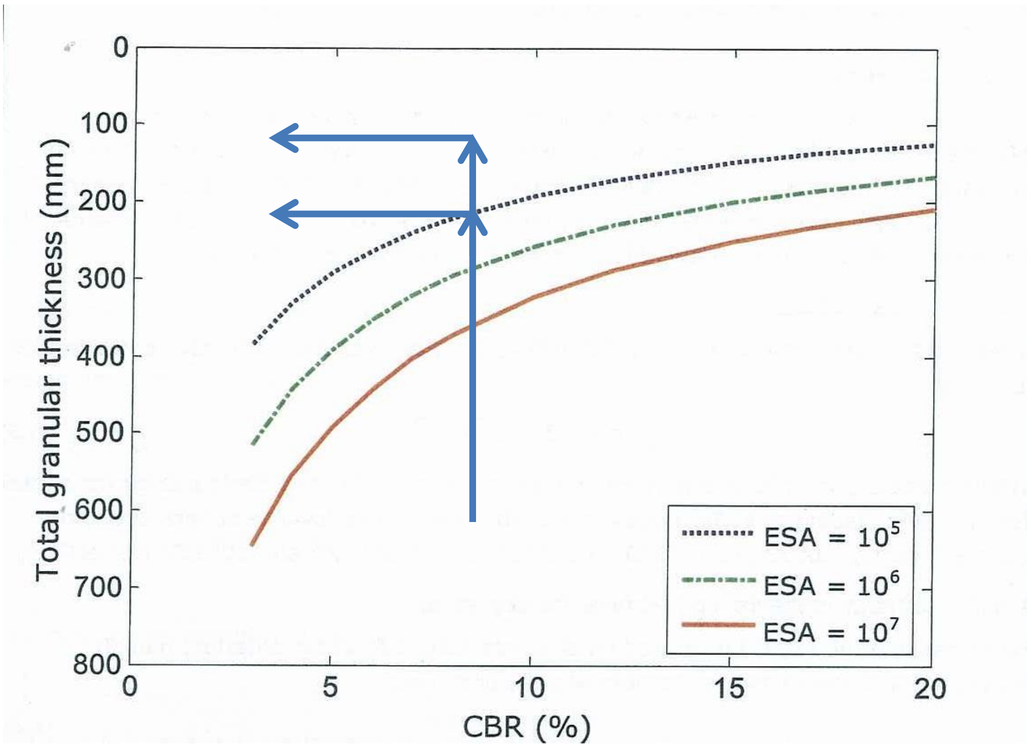

Figure 2 supports the New Zealand forest Owners' statement that the nonlinear behaviour of pavements under traffic loading allow significant increase in carrying capacity for a minimal increase in construction. However, typically these pavements have already been constructed, in most cases, many years ago so the opportunity for that additional structural capacity has been lost. A granular overlay is a potential strengthening option prior to any additional trafficking.

Pavement surfacing

The bulk of rural roads in districts where forestry is a significant industry will be either surfaced with a chipseal or be unsurfaced. Chipseal surfaces are not considered to contribute structurally to pavement strength; however, an intact chipseal prevents the ingress of water into a pavement with water having a negative impact on pavement performance, particularly the subgrade.

Pavement loading from heavy vehicles

Frame Group data

The Frame Group report makes a number of useful and significant comments in regard to the pavement loading from forestry generated traffic and other primary industries. Table 3 below is reproduced from the Frame Group (2003) report and demonstrates the yield from a number of farming sectors. It should be noted that dairy, kiwifruit and pip fruit farming all yield annual harvests, while forestry has a 30 year harvest period.

Table 3 Rural land production yield (tonne Ha^{-1} yr^{-1})

Dairy farming	9
Kiwifruit	17
Forestry	22
Pip fruit	40

Reproduced in Table 4 is data from the Frame Group (2003) report, using information from the Waikato District Council. These data indicate that, per year, forestry generates the same approximate number of truck movements per hectare as beef farming and less than half the number of movements from diary. What the table fails to account for is the loads carried by these truck movements. A forestry truck typically applies a pavement loading of 3.2 Equivalent Standard Axles loaded versus a 1.4 ESA unloaded. Cropping and livestock vehicles will typically apply a similar axle load while dairy tanker movements will progressively fill as it travels out from and returns to the milk factory, so the applied load will vary.

Table 4 Truck movements generated by various land uses (trucks Ha^{-1} yr^{-1}).

Sheep	0.02
Mixed sheep and beef	0.09
Forestry	0.8
Beef	0.81
Dairy farming	1.94

Indicative pavement performance

The impact of forestry traffic on a representative road was examined to determine a theoretical impact from forestry loading. Assuming a representative road has been designed for 10^5 ESAs over a 25 year period and a design subgrade CBR of 4% then the pavement will have 100 mm of basecourse material over 240 mm of subbase material. If the initial AADT is 340 and at 12.5 years the traffic increases by 40% to 476 then according to the AUSTROADS (2010) pavement design methodology the design life is reduced by approximately 2.5 years. If the increased traffic is applied to a new road from opening then the expected life is approximately 18 years. However, in both cases, using the Highway Design Manual roughness models as described in Gribble and Patrick (2008) the pavement has sufficient capacity for the increased traffic and the pavement will still theoretically achieve a life in excess of 25 years.

Productivity from different farming sectors

The productivity per hectare is determined for a number of farming sectors for an example district and these numbers are presented below. In generating these productivity values a significant number of assumptions have been made. Assumptions such as the finishing weight of animals need to be confirmed before the numbers can be relied upon. In addition these calculations do not take account of the movement of stock and materials onto the farms.

Dairy productivity

Dairy statistics have been obtained from New Zealand Dairy Statistics 2009-10 (DairyNZ 2010). The average number of dairy cows per hectare in the example district is 2.61 and the average milk production is 3930 L/cow/year. So production of approximately 10.3 tonnes per hectare per year is expected. Each tanker can carry a maximum of 26,300 litres of milk.

Based on these numbers, for a 30 year period, 11.7 tanker trips are generated per hectare by milk production.

Forestry productivity
Forestry statistics are taken from Moore and Associates (2009). Moore and Associates give a representative figure of 500 tonnes per hectare as a regional average. It is assumed that this is over a 30 year harvest period and each truck carries 28.8 tonnes

Based on these numbers, one hectare of forestry over 30 years generates 17.4 truck movements.

Sheep productivity
Leung-Wai (2011) indicate that the example district had 677,000 sheep. Beef and Lamb New Zealand indicate that the region has on average 9 live-stock units[2] per hectare. Assuming three years to achieve a sale weight of 55 kg, this implies that one hectare produces 165 kg per year and 15 kg of wool per year. Over 30 years one hectare would produce 5,400 kg of sheep live weight and generate 0.2 truck movements.

Beef productivity
Beef cattle only account for nine pecent of stock in the example district (Leung-Wai 2011). Then over 30 years for one hectare 270 live-stock units are available and assuming one beef cow requires seven live-stock units this implies the land can support 39 cattle. Assuming a four year finishing period and sale weights of 500 kg indicates that one hectare produces 4800 kg of beef stock and generates 0.17 truck movements over a 30 year period.

Local farm productivity values

A number of farms in the example district were asked to provide their production data, the results from six farms are reproduced in Table 5 below. While the final measure is called productivity (in tonnes per hectare in 30 years) it is more strictly movement of mass per hectare per year both into and out from the farms.

[2] It is the feed requirement used as the basis of comparison for different classes and species of stock. It expresses the annual feed requirements, equivalent to one 55 kg ewe rearing a single lamb. 1 LSU requires approximately 520 kg of good quality pasture dry matter per year. 1 hogget = 0.7 LSU; 1 Jersey cow = 6.5 LSU; 1 mature Red Deer stag = 1.5-2.0 LSU

Table 5 Self-reported farm productivity values for combined sheep and beef farms

Farm	**1**	**2**	**3**	**4**	**5**	**6**
Land area (Ha)	1800	650	400	1470	1500	1200
Wool (tonnes)	43.00	21.00	18.00	51.75	51.00	22.32
Cattle exported (tonnes)	52.50	Not supplied	2.20	1.45	122.00	111.40
Cattle and sheep imported (tonnes)	85.00	108.00	36.04	64.80	69.00	2.08
Sheep (tonnes)	221.00	103.25	127.92	342.00	270.00	133.60
Fertiliser (tonnes)	380.00	40.00	58.00	342.00	220.00	120.00
Fuel (tonnes)	6.00	3.60	6.00	Not supplied	Not supplied	10.10
Total production (tonnes)	787.5	275.9	248.2	802.0	732.0	399.5
Productivity (Tonnes per Hectare per year)	0.438	0.424	0.620	0.546	0.488	0.333
Productivity (Tonnes per Hectare in 30 years)	13.1	12.7	18.6	16.4	14.6	10.0

There are significant discrepancies between the measures calculated for sheep and beef productivity and that calculated in using local farm production values. The differences can be attributed predominantly to freight delivered to the farms such as fuel and fertiliser. Therefore, any allocation of productivity would need to account for these factors.

The productivity values from the sheep and beef sectors are significantly less than the productivity of the dairy and forestry sectors. There are some differences between the numbers calculated here and those presented in the Frame Group (2003) report and the reasons for these discrepancies need to be investigated.

Based on the data from the local farms the movement of freight on farms can have a significant impact on the total number of vehicle movements generated per hectare. These vehicle movement need to be considered when equating different farming productivities.

Discussion and Conclusion

Discussion

The tables in the New Zealand Forest Owners' Association as reproduced above in Table 3 and Table 4 are general in nature. As such, they do not accurately reflect the contribution of the different farming sectors to vehicle loadings in individual districts. The actual district production values need to be used to calculate the contribution of each industry to the vehicle loading on the road. It cannot be simply assumed that forestry yield is twice that of diary, therefore the damage generated is twice that of dairy farming.

Given the default pavement design life is 25 years then the increased loading generated by a five year forest harvesting period will potentially have a significant impact on the pavement life depending on when the loads are applied to the pavement in terms of its life cycle, particularly given the large increase of vehicle movements expected on individual roads.

Statistics New Zealand data has been used to determine the contribution of each farming sector to the vehicle loadings presented herein. A number of assumptions have been made in generating these data and further research is necessary to validate the assumptions.

The data used in these calculations are from various sources, the accuracy of these calculations could be confirmed through discussions with the different market sectors. The regional agricultural production values presented in this report are sourced from Statistics New Zealand data and make a number of assumptions regarding stock weight and annual numbers of stock exported from the farms. Of particular importance is establishing the level of traffic importing stock and materials to the farms. The values used in all these calculations should be verified.

Based on Gribble and Patrick (2008) the change in the expected life of a pavement designed for 10^5 ESAs has been estimated based on the AUSTROADS methodology and using a respected roughness model. AUSTROADS suggests an expected life reduction of between seven and two and a half years is indicated assuming the traffic increase occurs at the start and half way through the design lives. A roughness model examined by Gribble and Patrick suggested that there is sufficient capacity for the pavement to achieve a design life of 25 years. More sophisticated modelling has not been performed at this stage, however, additional modelling and monitoring of an actual pavement during the logging period is recommended.

The calculations of forestry generated traffic could be repeated for all of the roads that will experience forestry generated traffic. This could be combined with condition surveys and pavement test pit information to determine the expected consumption of pavement life from the forestry traffic.

Conclusion

Forestry can generate significant traffic movements in the short term. Based on the calculations presented in this paper when averaged over a 30 year period the production per hectare is fifty per cent greater that of dairy farms. However, in addition to exported produce farms import freight as well. These inwards movements of fuel, fertiliser, and stock need to be accounted for in the quantification of vehicle loading produced by the various farming sectors.

The productivity values from the sheep and beef sectors are significantly less than the productivity of the dairy and forestry sectors. There are some differences between the numbers calculated here and those presented in the Frame Group (2003) report and the reasons for these discrepancies need to be investigated.

Recommendation

The productivity values from the sheep and beef sectors are significantly less than the productivity of the dairy and forestry sectors. There are some differences between the numbers calculated here and those presented in the Frame Group (2003) report and the reasons for these discrepancies need to be investigated.

Representative roads should be selected that are expected to be subjected to forestry logging in the next five years. The condition of these roads should be assessed, including a visual inspection, recording of existing defects being mapped, prior to logging and after logging. Any maintenance work should be monitored and the traffic loading determined. This will allow more accurate maintenance costs and estimates of pavement deterioration to be established.

The monitoring of the pavement deterioration could be complemented by pavement deterioration modelling, using a traffic forecast based on logging volumes.

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