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FURTHER INVESTIGATIONS INTO THE FEASIBILITY OF HEAVY TRANSPORT ROUTES IN NEW ZEALAND

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1. ABSTRACT

New Zealand's economy relies heavily on its roading network to move its primary produce to ports for shipping to overseas consumers. The transport and export industry sectors have called for a review of current vehicle weights and dimension limits in an effort to increase transport productivity.

This paper reports on the second stage of a project to investigate the safety, feasibility, and economic viability of increasing weight and dimension limits, either on selected routes or on all roads in New Zealand. A previous paper covering the first stage of the project was presented to the 4th Symposium in June 1995 held at AnnArbor, Michigan, USA.

The methodology has included information gathering from transport operators to select routes for detailed study; adopting a range of vehicle sizes and weights; determining physical restraints (e.g. bridge, pavement, geometric); consideration of vehicle safety issues; and economic analysis of benefits and costs to New Zealand. The work has been performed in two stages using engineering and transportation consultants.

Preliminary results have indicated that the potential benefits of raising axle weight limits nationwide do not outweigh the likely costs incurred in meeting the increased limits. This result also extends to specific routes evaluated to date. The paper elaborates on both these findings and their potential impact.

In relation to increasing the allowable length of truck and trailer combinations, initial investigations have revealed that the recommended amount of seal widening on curves may need to be increased by at least half a metre. The potential implications of introducing such changes are examined in the paper for the rural state highway network utilising available road geometry data.

The paper concludes by outlining the next areas to be considered and identifies the outstanding issues yet to be addressed. The most recent and critical results will be discussed in the symposium presentation.

The views expressed in this paper are entirely personal and should not be relied upon as representing those of Transit New Zealand or Government policy.

2. INTRODUCTION

New Zealand's national economy relies on its road network to deliver primary products (e.g. timber, dairy, meat and wool) from rural areas to markets and export ports. During the last 15 years there has been a noticeable increase in the number and use of heavy vehicles on the road network.

A thorough review of the structural capacity of the network in 1988 resulted in the adoption of the 44 tonne gross weight limit. However, single axle, tandem, and tridem (triaxle) weight limits still lie somewhat below those of many countries. This has the effect of limiting the competitiveness and productivity of the road transport industry. The current legal weight limits appear in Tables 1 and 2 of this paper.

3. THE EXISTING ROAD NETWORK

New Zealand has 92,600 km of roads of which 10,677 km form the national state highway system. This roading network has to be supported by a population of only 3.45 million people whose resources are already stretched to provide other essential services such as health and education to a population dispersed over a land area roughly the size of the United Kingdom. However, the economy still has a large rural component which is almost entirely dependent on road transport, so the roading infrastructure has to be preserved.

Much of New Zealand's roading terrain is hilly or mountainous which requires considerable bridging, costly maintenance and construction, and can severely constrain geometric standards.

To meet its roading challenge within the funding limitations, New Zealand has relied on thin flexible pavements and light bridge structures, and acceptance of geometric standards which can sometimes be less than those commonly seen in other countries.

4. OUTCOMES FROM STAGE 1 OF THE PROJECT

Transit New Zealand (Transit) first initiated this research project in 1992, in response to requests from the road transport industry. The work has been conducted in two separate stages, each with their own objectives. The results of Stage 1 were reported in 1995 (Reference 1).

Stage 1 set out to identify the currently used heavy transport road routes, develop an evaluation methodology, and then evaluate a pilot route.

On the pilot route some remedial work would be required by the geometric constraints in order to accommodate the eight vehicle types evaluated. The pavements are already being trafficked by heavy vehicles without any sign of distress. The maximum gross vehicle weights determined for the pilot route did not imply significant increases in axle weights. Pavement strength was therefore not regarded as a constraint on the vehicle weights which were being considered.

The chief finding of Stage 1 was that the bridges on the pilot route could accept significant increases in the current legal gross vehicle weights for the vehicle types considered. The increases ranged from 12% to 25%.

For some of the vehicle types considered in the study the capacity increases would require increases in legal axle weights of up to 20%.

5. GENERAL APPROACH FOR STAGE 2

5.1 Objective for Stage 2

The objective of Stage 2 has been to investigate the possibilities of an increase in the statutory weight and dimension limits of heavy vehicles operating on public roads in New Zealand.

Economic costs and benefits would be identified and quantified for various load limits so that optimum limits can be determined.

The original purpose of Stage 2 was to evaluate the economic benefits of developing some heavy transport routes, based upon the results of Stage 1. When embarking on Stage 2 Transit recognised that there would be practical difficulties in reintroducing a roading hierarchy based on different weight limits. Hence the approach with Stage 2 has been to examine both the concept of designated heavy transport routes and an overall increase in legal weight limits applying to all roads.

It was intended that Stage 2 would be performed in three phases, beginning with the economic analysis. This paper reports in detail on the first phase which was completed at the end of 1996. The two subsequent phases have been placed on hold while Transit considers how best to address the outcomes of the first phase.

5.2 Literature Review

This included examination of previous studies of weight and dimension limits conducted in South Africa, Australia, United Kingdom, Finland, Canada, USA, and New Zealand. The main points emerging from the review were then used to develop the detailed methodology.

5.3 Current Weight and Dimension Limits

The weight limits applying in various countries are summarised in Tables 1 and 2. This information was used as background material to assist in discussions with New Zealand's road transport industry on the choice of limits to be evaluated.

Table 1: Comparative axle weight limits (tonnes)

Country	Single tyred steering axle	Twin tyred axle	Tandem twin tyred axle	Tridem twin tyred axle
Canada[1]	5.5	9.1	17.0	21.0-24.0[4]
USA[2]	?	9.1	15.4	19.1-20.4[4]
UK	10.0	10.0 (10.5[3])	20.3	22.5
EC Directive	10.0	10.0 (11.5[3])	11.0-18.0[4]	21.0-24.0[4]
Australia	6.0	9.0	16.5	20.0
New Zealand	6.0	8.2	14.5-15.5[4]	15.5-18.0[4]

NOTES 1 MOU limits. Some provinces have higher limits.
2 Most common limits. Some states have higher limits.
3 Drive axle
4 Depends on axle spread

Table 2: Comparative gross vehicle weight limits (tonnes)

Country	Truck and full trailer		Truck and full trailer		Tractor & semi-trailer		B-train	
	4 axle	5 axle	6 axle	7 axle	5 axle	6 axle	6 axle	8 axle
Canada[1]	32.8	39.5	48.6	53.5	39.5	46.5	48.6	62.5
USA[2]	37.3	36.3	36.3	36.3	36.3	36.3	36.3	36.3
UK	35.0	35.0 (38.0)	35.0 (38.0)[5]		38.0	38.0[5]		
EC Directive	38.0	40.0[5]	40.0[5]		40.0[5]	40.0[5]		
Australia	33.0	40.5	42.5	42,5	40.5	42.5	48.0	59.0
New Zealand	30.6	37.4	42.0[6]	42.0[6]	36.5[7]	39.0[7,8]	44.0	44.0

NOTES 1 MOU limits. Some provinces have higher limits.
2 Most common limits. Some states have higher limits.
5 44.0 tonnes for combined transport, eg containers transported by rail then road.
6 Limited to 42.0 tonnes by TrafficRegs.
7 At maximum axle spread on semi-trailer and 1.3 m tandem spacing on tractor.
8 Limited to 39.0 tonnes by TrafficRegs.

It was concluded that there is a significant range of gross vehicle weight limits between countries for equivalent classes of heavy vehicles, and that New Zealand tends to be at the lower end for both these and axle weights. It could be inferred from this that there are potential net benefits to be gained in New Zealand by raising the legal load limit. New Zealand's dimension limits as shown in Table 3 below are comparable with those in the other countries described. This appeared to indicate that dimension limits would not be a controlling factor.

Table 3: Comparative vehicle length limits (metres)

Country	Truck	Full trailer	Truck and full trailer	Tractor & semi-trailer	A-train	B-train	C-train
Canada	12.5	12.5	23.0	23.0	23.0	23.0	23.0
USA	10.7-18.3		16.9-25.9	16.8-25.9			
UK	12.0	12.0	18.35	16.5			
EC Directive	12.0	12.0	18.35	16.5			
Australia	11.0		17.5	17.5		23.0	
New Zealand	11.0	11.0	19.0	17.0	20.0	20.0	

6. DETAILED METHODOLOGY FOR STAGE 2

6.1 Development of Proposed Load Limits

From discussions which took into consideration bridge loading effects, the viewpoint of the New Zealand road transport industry, and overseas practice, three load limit options were chosen for evaluation. When expressed as ratios of New Zealand's current highway and bridge design load standard (known as HN) these are 0.93 HN, 1.00 HN and 1.15 HN. Since 1972 bridges have been designed to 0.85 HN. When expressed as the limitations then imposed on vehicles of various size and configuration, these load limits are detailed in Tables 4 and 5 below.

Table 4: Existing and Proposed Axle and Group Load Limits (tonnes)

Axle Type	Wheelbase	Current	0.93HN	1.00HN	1.15HN
Single tyred axle		6.0	6.0	6.0	6.0
Twin tyred axle		8.2	9.0	9.0	9.0
Twin steer axle group		10.8	11.0	11.0	11.0
Tandem	1.0 to 1.3 m 1.3 to 1.8 m 1.8 to 2.0 m	14.5 15.0 15.5	15.4 15.9 16.4	16.0 16.5 17.0	16.5 17.0 17.5
Tridem	2.0 to 2.4 m 2.4 to 2.5 m 2.5 to 2.8 m 2.8 to 3.0 m	15.5 17.5 18.0 ***	17.3 18.1 18.4 19.1	18.6 19.5 19.8 20.5	20.5 21.7 22.0 22.9

Table 5: Existing and Proposed Gross Load Limits (tonnes)

Vehicle Type	Axles	Current	0.93HN	1.00HN	1.15HN
Truck	3	21.0	21.9	22.5	23.0
Truck/trailer	4	30.3	33.0	33.0	33.0
	5	37.4	39.9	40.5	41.0
	6	42.0 [1]	46.8	48.0	49.0
	7	42.0 [1]	53.1	55.5	57.0
	8	44.0 [3]	55.4	59.0	62.0
	8	42.0 [1]	52.0	55.8	62.0
	9	42.0 [1]	53.4	57.3	65.4
	9	42.0 [1]	53.7	57.6	65.6
	9	44.0 [3]	54.6	58.3	66.0
	9	44.0 [3]	54.9	58.6	66.4
Semi-trailer	5	36.5	37.8	39.0	40.0
	6	39.0 [2]	40.3	42.3	45.0
A-train	6	39.0 [2]	48.9	49.5	50.0
B-train	7	44.0	53.7	55.5	57.0
	8	44.0	55.9	58.8	62.0
	9	44.0	55.0	58.9	67.0
	9	44.0	55.3	59.3	67.0

NOTES
1. Limited to 42.0 tonnes if single steer, by Reg 48B(v) of Traffic Regs 1976
2. Limited to 39.0 tonnes by Reg 48B(p)(ii) of Traffic Regs 1976
3. Twin steer
4. All vehicles are satisfactory for bridge loading. Handling characteristics have not been rigorously checked, but are believed to be satisfactory by comparison with overseas vehicles

6.2 Proposed Vehicle Dimensions

Existing width and height restrictions on vehicles were not changed. However, length restrictions were altered to match the chosen gross vehicle weights. It was decided to adopt the same vehicle length change for all proposed load limits for each vehicle type. The dimensions chosen were as shown in Table 6 below.

Table 6: Existing and Proposed Overall Vehicle Lengths (metres)

Vehicle Type	Existing	Proposed
A-train	20 m	25.6 m
B-train	20 m	26.6 m
Semi-trailer	17 m	19.1 m
Truck and trailer	19 m	25.6 m

6.3 Vehicle Benefits

The benefits of an increase in load limits arise from increased efficiencies associated with the transport of larger loads. These gains are measured as a reduction in freight charges per tonne-km. There are also additional costs associated with operating vehicles at higher weight limits.

6.3.1 Evaluation of Freight Tonne-Km

The evaluation of the total freight tonnes-kilometres carried was made using the following data sources:

- Road User Charge records (which detail the weight and distance licences obtained for all trucking operations); and

- the National Traffic Database (which gives the results of roadside surveys of vehicle numbers and weights and covers approximately 125,000 road sections).

The results from these two sources were combined, and then distributed by vehicle type and commodity group using the results of an earlier study commissioned by the road transport industry.

6.3.2 Uptake to Heavier Vehicles

This was determined is consultation with the New Zealand Road Transport Association. It was recorded by type of commodity involved, and by the extent to which the load increase is determined by volume or weight.

6.3.3 Evaluation of the Vehicle Benefits

Vehicle freight rates were determined from vehicle operating cost models for existing and new vehicles. A significant factor here was the assumed distance travelled each year. In consultation with the transport industry this was finally set at an average value of 80,000 km/year. Vehicle benefits were then calculated by determining total freight transport costs with and without the change to heavier vehicles.

6.4 Pavement Costs

The National Traffic Database was used to determine the existing road demand in equivalent design axle-kilometres per year. The increase in road demand resulting from the additional axle loadings was then applied across the road network including sealed and unsealed roads. The change in the pavement rehabilitation cycle for sealed roads resulting from these additional axle loadings was then evaluated.

For sealed roads the pavement costs were then found by combining the higher vehicle operating costs and the pavement rehabilitation costs. For the unsealed roads the costs were found from an assessment of the increase inremetalling costs resulting from the additional surface wear.

6.5 Bridge Costs

Data is currently held for all bridges on state highways. This was manipulated to give an estimate of the costs of upgrading the bridges to any chosen load level. This was not the case for local authority bridges where it was not possible to obtain a comprehensive inventory.

Instead the state highway data was extrapolated to include local authority bridges by measuring a number of typical characteristics for each group of bridges.

Some typical data held on New Zealand's bridge stock in 1994 is shown in Table 7 below.

Table 7: Data on New Zealand's Bridge Stock

Category	State Highways			Local Authorities		
	No	Length in metres	% of total length	No	Length in metres	% of total length
Total Bridges	3272	127320	100.0	12902	217889	100.0
Bridges built since 1972	579	36641	28.8	3095	67965	31.2
One lane bridges	197	12978	10.2	9195	136965	62.9
Restricted bridges	25	1715	1.3	531	12929	5.9
Timber bridges	20	843	0.7	1399	15770	7.2

Costs for strengthening of main members and decks of state highway bridges were determined in detail. Then local authority costs were estimated by extrapolation.

6.6 Geometric Constraints

The geometric constraints on a route arise from limitations on curvature, width, grade, and vertical clearance. The cost of upgrading sharp bends and narrow lanes will depend primarily on the terrain. In addition to the geometrics of the road itself, there is the constraint of vehicle accessways and roundabouts.

Swept paths were generated for the proposed vehicle types using the VPATH™ computer software package (**See footnote**). The B-train had the largest swept path and was therefore identified as the critical vehicle. Increase in path width per lane ranged from 0.5 m to 1.25 m.

For the purposes of geometric evaluation, roads were characterised according to the surrounding terrain, namely *Mountainous*, *Rolling* and *Flat*. The National Traffic Database was used for this purpose.

The average number of critical bends per kilometre was then determined from interrogation of vector files, and costs calculated based on known formation costs.

It was decided to exclude the costs for access improvements and roundabouts from the exercise at this stage. It was felt that these costs were difficult to assess over the whole network, and would be best estimated at the specific route level in subsequent work. Also excluded were the costs for additional passing lanes that may result from the introduction of much longer vehicles.

The total cost of geometric improvement per kilometre by terrain type based on bend improvements was then estimated and distributed over the network of roads in proportion to the total length of each terrain.

6.7 Safety Issues

No evaluation was made of net costs or benefits of safety issues. It was decided that safety considerations would be considered once the economic viability of the increased weight limits had been demonstrated.

6.8 Economic Evaluation

Economic viability was determined by evaluating a benefit/cost ratio for the proposal, where the benefit is the net freight cost savings and the cost is the sum of bridge and roading costs (all expressed as present value totals). The benefit/cost ratio was then evaluated for the change to the three load limits considered in the study.

6.8.1 Total Costs

Total costs for the three weight limits are given in Table 8 below. These use the mid-point of estimates where a range has been evaluated. Note that the costs of corner widening are the same in each case as the same vehicle dimensions have been assumed.

The bridge costs calculated are capital costs only. The strengthening method envisaged would entail some additional maintenance costs, and these have not been quantified.

These costs have been discounted to present value totals, making the assumption that the road network would be upgraded over a five year period with the benefits following over a similar period. The pavement costs are assumed to be distributed in the same proportions as the benefits, except that they occur one year earlier. Bridge and corner widening costs are assumed to be distributed evenly over the first five years.

Table 8: Present Value Total Costs(All Roads)

Item	**Present Value Total Cost ($ million)**		
	Weight Limit 1	**Weight Limit 2**	**Weight Limit 3**
Pavements	161.3	207.5	251.7
Bridges	31.8	48.3	82.1
Corner Widening	1719.3 (142.2)	1719.3 (142.2)	1719.3 (142.2)
TOTAL	1912.4 (335.3)	1975.1 (398.0)	2053.1 ((476.0)

NOTE The figures in brackets relate to costs excluding the mountainous terrain

6.8.2 Vehicle Benefits

Vehicle benefits have been evaluated as transport cost savings per year. The yearly amounts have been discounted to present value totals at 10% discount rate, as shown in Table 9 below.

Table 9: Present Value Total Vehicle Benefits

	Weight Limit 1	Weight Limit 2	Weight Limit 3
Total Benefit ($m)	322.3	383.8	449.9

6.8.3 Benefit/Cost Ratios

Net Present Values and Benefit/Cost Ratios are given in Table 10 below.

Table 10: Economic Evaluation (All Roads)

Economic Indicator	Weight Limit 1	Weight Limit 2	Weight Limit 3
Net Present Value ($million)	-1590.1(-13.0)	-1591.3 (-14.2)	-1603.22 (-26.1)
B/C Ratio	0.17 (0.96)	0.19 (0.96)	0.22 (0.95)
Incremental B/C Ratio	0.17 (0.96)	N/A	N/A

NOTE The figures in brackets show the results if the mountainous terrain is excluded from the network that is upgraded for the new vehicles.

6.8.4 Margin for Error

The results in Table 10 are based on a combination of figures which have considerable variability. In particular the costs of road corner widening have a very significant influence on total costs, and the estimates for these have a range of +/- 45%. Variation in the order of +/- 30% could be expected in the combined costs.

7. CONCLUSIONS FROM STAGE 2

The economic viability of an increase in weight limits on all roads has been tested using a combination of vehicle types of up to 65 tonnes gross and 26 metres in length. The results show that the proposal is uneconomic, being penalised particularly by the high costs of corner widening.

When higher weight limits are applied to a reduced network which excludes the mountainous terrain the results indicate that the proposal is marginally uneconomic.

Although a range of load limits were investigated all options are of a similar order (ranking) in economic outcome.

The costs to accommodate the swept paths of the longer vehicles on the current road network are significantly greater than bridge and pavement costs.

8. HEAVY VEHICLE TRACKING PROJECT

Following the completion of the first phase of Stage 2 of the research project at the end of 1996 it was decided not to pursue the same line of investigation any further. Instead a separate project was commenced in 1997 to investigate further whether longer vehicles could be accommodated within the present geometry of the state highway network, and the extent to which the current network is deficient. The work completed to date has been in three stages as follows.

8.1 Vehicle Tracking Programs

A review was undertaken of software programs available for simulating the swept path of long combination vehicles and the dimensional characteristics of design vehicles. Recommendations were made for the subsequent stage of the project.

8.2 Tracking Simulations

Four vehicle types were selected and simulations were conducted using the AUTOTURN program which is currently adopted in several Australian states. An additional program known as VPATH™ (mentioned earlier in Section 6.6) assisted with the examination of speed-related effects. Several combinations of vehicle dimensions were used in the simulations.

From the results the researcher made recommendations to increase the total amount of curve widening contained in the current AUSTROADS Rural Road Design Guide by 0.5 metres. This would allow for the introduction of vehicle combinations of 10-15% longer than the current legal maximum. The recommendations are shown in Table 11 below.

Table 11: Recommended Revision to Table 3.5 of the AUSTROADS Rural Road Design Guide

Curve Radius (m)	**Total amount of widening in metres where normal width of two traffic lanes is**			
	6.0m	**6.5m**	**7.0m**	**7.5m**
30-50	2.5 (2.0)	2.0 (1.5)	1.5	1.0
50-100	2.0 (1.5)	1.5 (1.0)	1.0	0.5
100-250	1.5 (1.0)	1.0	0.5	
250-750	1.0	0.5		
over 750	0.5			

NOTE Current figures from the Guide are in brackets where different.

8.3 Frequency of Curves

The project concluded with an analysis of the frequency on the current state highway network of the horizontal curves that might be a restraint on longer vehicle combinations. All curves below 1000 metres in radius were examined.

The results indicated that there is one horizontal curve of 750 metres or less for every two kilometres of state highway. About half of these curves have a radius of 250 metres or less for which the effect of longer vehicles is greatest. It was concluded that there is potential for a large number of curves to benefit from widening treatment.

8.4 Extent of Curve Widening

The next stage planned for the project is to measure the actual extent of curve widening that exists for one or two test sections of highway and compare this with the revised recommended amount of curve widening. The results will then be extrapolated to infer the likely amount of additional curve widening that then might result from increasing the legal dimensional limits.

9. FURTHER STUDIES

Following the completion of the Heavy Vehicle Tracking Project Transit has discussed the options for further studies with the road transport industry. The industry has undertaken to examine two scenarios:

Scenario A Operating the existing vehicle fleet at higher weights on the current road network.

Scenario B Increasing vehicle dimensions and weights on upgraded selected routes.

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Reference to the Heavy Vehicle Tracking Project has been made with the kind permission of Peter McCombs, Managing Director, Traffic Design Group Limited.

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12. REFERENCES

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13. AUTHOR BIOGRAPHIES

David Wanty was formerly employed by the Ministry of Works and Development and thence Transit New Zealand prior to joining aconsultancy in December 1994.

David is a qualified civil engineer with thirteen years experience in traffic engineering, transportation planning and safety research administration. He has been a co-author of several papers relating to traffic engineering matters including the paper "Application of the Road Geometry Data Acquisition System (RGDAS)" which he presented at the 7th WCTR Conference held at Sydney in July 1995. He has been a member of the Land Transport Safety Authority Technical Advisory Committee since its formation in 1995.

David presently holds the position of Traffic Engineer in the Wellington office of Traffic Design Group Ltd undertaking a wide variety of work for government agencies, local councils, and commercial developers. He is married with a rather active two year old.

Lynn Sleath has been with Transit New Zealand since it was formed in 1989. He has concentrated principally on developing and maintaining policies and strategies for the safe movement of heavy transport on the national state highway network.

From 1992 he has also become involved in Transit's drive for quality on the roads, which involves the introduction of quality assurance requirements into all physical works and professional services contracts.

Lynn is a qualified civil engineer with thirty years of experience in design, construction, and administration both in the UK and New Zealand. He has attended conferences in the UK, USA, Canada, and Australia, and presented several papers on heavy vehicle issues and quality assurance. He has been a member of the AUSTROADS Heavy Vehicle Reference Group since 1994.

Lynn currently holds the position of Senior Roading Engineer in the State Highway Policy Division, which is based in Wellington. He is married with two adult children.

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FOOTNOTE

VPATH™ is a vehicle tracking computer program produced by Traffic Planning Consultants Limited, Auckland

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