POTENTIAL BENEFITS AND COSTS OF SPEED CHANGES ON RURAL ROADS

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ABSTRACT

This study explored the potential economic costs and benefits of changes to speed limits on rural roads in Australia. Net costs and benefits were estimated over a range of mean travel speeds (80 to 130 km/h) for the following road classes:

- freeway standard rural roads (dual carriageway roads with grade-separated intersections and a design speed of 130 km/h, usually designed as such when originally constructed)
- other divided rural roads (not of freeway standard)
- two-lane undivided rural roads (standard-width and shoulder-sealed roads, with different crash rates, were considered separately).

Specific objectives were to explore a number of scenarios, such as:

- increasing limits on high standard roads with a low crash rate (per vehicle-kilometre) from 110 to 130 km/h (or intermediate speeds)
- increasing limits on high standard roads with a low crash rate from 110 to 130 km/h subject to a variable speed limit system that would reduce speeds under adverse conditions such as poor light, bad weather or dense traffic ('VSL option')
- decreasing limits on lower standard rural roads with higher crash rates.

PREVIOUS RESEARCH

Research in Europe has examined the collective impacts of vehicle speeds on road trauma, travel times, operating costs, and air and noise pollution (Nilsson 1984; Andersson et al 1991; Peters et al 1996; Rietveld et al 1996; Carlsson 1997; Toivanen and Kallberg 1998; Elvik 1999). The optimum speed for a class of road has been defined as one which minimises the total social costs of the impacts of speed. The optimum speed has been estimated for urban roads, where speed limits are generally 50 km/h in Europe, and for rural freeways and divided and undivided roads. The European research has generally found that optimum speeds on rural roads are 15-25 km/h lower than current European speed limits and travel speeds.

Cameron (2000) used similar methods to estimate the optimum speed on urban residential streets in Australia. He found that it depended on the method used to value road trauma. When the 'human capital' valuations of road trauma costs (BTE 2000) were used, the analysis suggested that the optimum speed on residential streets is 55 km/h. When the analysis was repeated making use of road trauma costs valued by the 'willingness to pay' approach (BTCE 1997), the analysis suggested that the optimum speed on residential streets is 50 km/h. Noise costs in urban areas could not be valued in the analysis, but the travel time on residential streets was.

METHOD OF THIS STUDY

The effects of speed on road trauma levels were calculated using well-established relationships linking changes in average free speed with changes in numbers of fatal, serious injury and minor injury crashes on rural roads (Nilsson 1984), as follows:

$$\mathbf{n_A = (v_A/v_B)^p * n_B}$$

where $\mathbf{n_A}$ = number of crashes after the speed change

$\mathbf{n_B}$ = number of crashes before the speed change

$\mathbf{v_A}$ = mean or median speed after

$\mathbf{v_B}$ = mean or median speed before

p = exponent depending on the injury severity of the crashes:

- **p** = 4 for fatal crashes
- **p** = 3 for serious injury crashes
- **p** = 2 for minor injury crashes.

These relationships were based on research linking changes in median speeds with changes in crash frequencies at various injury severities, as a result of a large number of changes in speed limits on Swedish rural roads.

Vehicle operating costs for cars, light commercial vehicles and rigid and articulated trucks were based on Austroads published models linking these costs with speed (Thoresen, Roper and Michel 2003). Emission rates of air pollutants of each type were derived from research conducted as part of the Managing Speeds of Traffic on European Roads (MASTER) project for the European Commission (Robertson, Ward and Marsden 1998, Kallberg and Toivanen 1998). Increased fuel consumption and emission rates associated with deceleration from cruise speeds for sharp curves (and occasional stops) on undivided rural roads, and then acceleration again, were estimated from mathematical models calibrated for this purpose in the USA (Ding 2000). The analysis also provided estimates of average speeds over 100 km sections of curvy undivided roads. Air pollution cost estimates were provided by Cosgrove (1994).

It was assumed that travel time = link length / speed of traffic flow. This was considered to be a reasonable assumption on rural roads where traffic congestion, and hence constrained speeds, are a rarity. Kallberg and Toivanen (1998) noted that, in urban conditions, a considerable part of the travel time may be spent not moving at all or moving at very low speeds. Travel time was valued by Austroads estimates of time costs reflecting the vehicle type and trip purposes (Thoresen, Roper and Michel 2003). Road trauma was valued by standard ‘human capital’ unit costs related to the injury severity of crash outcomes (BTE 2000), and also by ‘willingness to pay’ values (BTCE 1997) to test the sensitivity of the key results to this assumption.

Further details of the method of this study are given in Cameron (2003). The study also involved a number of assumptions given in the following section.

ASSUMPTIONS

1. The current speed limits on freeway standard and other divided rural roads are 110 km/h for cars and light commercial vehicles (LCVs) and 100 km/h for all rigid and articulated trucks, and the speed limit on undivided rural roads is 100 km/h for all types of vehicle.

2. Vehicles of each type cruise at their speed limit, so that their average speed is the same as the limit, unless their speed is reduced by slowing for curves or stopping in some parts of the road section.

3. Apart from where indicated, the rural roads are relatively straight without intersections and towns, allowing vehicles to travel at cruise speed throughout the whole road section.

4. The mix of traffic by vehicle type is the same on each class of rural road, namely 67% passenger cars, 20% light commercial vehicles, 5% rigid trucks and 8% articulated trucks. This mix was assumed not to vary by time of day, which may be questionable on rural freeways and other divided roads.

5. Crashes involving material damage only, and no personal injury, were not included in the analysis of crash changes with speed, and the likely increase in these crashes with increased speeds (albeit to a lesser extent than fatal and injury crashes) was not valued. Material damage crashes represented about 16.3% of total crash costs in Australia during 1996 (BTE 2000).

6. Scenarios in which truck speed limits are lower than light vehicle limits have been analysed on the assumption that the (increased) speed differential between these vehicle types does not in itself increase crash risk or the severity of the crash outcome. This assumption was considered reasonable for low differentials in speed but may be questionable for differentials more than, say, 15 km/h.

7. The changes in speed limits are assumed not to increase or reduce travel demand and traffic flows of each vehicle type on the road sections.

8. The travel time savings on the rural road sections are of sufficient magnitude to be aggregated and valued.

9. The current economic valuations of travel time, road trauma, and air pollution emissions provide an appropriate basis for analysis which summates their values, together with vehicle operating costs, in a way which represents the total social costs of each speed. In other words, the current valuations are an appropriate basis for ‘trading off’ these tangible and intangible values of each impact. (Results using alternative valuations of road trauma increases and decreases are also presented).

10. Assessment scenarios involving variable speed limit systems do not include any estimates of capital and maintenance costs for the systems.

11. Illustrative traffic volumes used in the analysis were 20,000 vehicles per day for freeways, 15,000 for divided highways and 1,000 for undivided roads. The analysis does not depend on these assumptions being correct.

RESULTS

The estimated effects of the different speed limit changes on 100 km sections of the three classes of rural roads are given in Tables 1 and 2. Table 2 also includes an estimate (to the nearest 5 km/h) of the optimum speed, for all vehicles combined, and also for the light vehicles and trucks separately.

Table 1: Travel time savings and road trauma increases per 100 km of road.

	Travel time saving per vehicle per 100km (min.)		**Road trauma increases per 100km of road per year**		
Scenario	Cars & LCVs	Trucks	Fatal crashes	Serious injury crashes	Other injury crashes
RURAL FREEWAYS (20,000 vehicles per day)					
Speed limit raised to 130 km/h (base scenario)[1]	8.4	13.8	2.8	11.1	14.1
Trucks limited to 100 km/h	8.4	0.0	1.6	8.4	11.6
Variable speed limit (VSL)[2]	5.6*	0.0	0.7	3.7	4.9
VSL (day limit 120 km/h)[2]	2.5*	0.0	0.2	1.0	1.3
RURAL DIVIDED ROADS (15,000 vehicles per day)					
Speed limit raised to 130 km/h (base scenario)[3]	8.4	13.8	3.4	13.6	17.2
Trucks limited to 100 km/h	8.4	0.0	1.9	10.3	14.2
Variable speed limit (VSL)[4]	5.6*	0.0	0.9	4.6	6.0
VSL (day limit 120 km/h)[4]	2.5*	0.0	0.3	1.3	1.6
STANDARD 7.0 M SEALED TWO-WAY UNDIVIDED ROADS (1,000 vehicles per day)[5]					
Speed limit raised to 130 km/h (base scenario)	13.8	13.8	0.8	3.3	4.1
Raised on curvy roads with crossroads and towns	9.8	9.8	0.9	3.7	4.6
SHOULDER-SEALED 8.5 M TWO-WAY UNDIVIDED ROADS (1,000 vehicles per day)[5]					
Speed limit raised to 130 km/h (base scenario)	13.8	13.8	0.5	2.1	2.6
Raised on curvy roads with crossroads and towns	9.8	9.8	0.6	2.3	2.9

[1,3] Speed limit raised from 110 km/h (cars and LCVs) and 100 km/h (trucks) to 130 km/h (all vehicles).

[2,4] Day speed limit for cars and LCVs raised to 130 km/h (or 120 km/h where indicated); night speed limit reduced to 100 km/h; truck speed limit fixed at 100 km/h during all times.

[5] Speed limit raised from 100 km/h to 130 km/h for all types of vehicle.

* Travel time savings averaged across all times of day (assuming 20% of total traffic at night).

Table 2: Economic impacts of scenarios, & estimated optimum speeds.

Scenario	Effect on total economic cost: Change ($ million) p.a./100 km	Effect on total economic cost: Percentage change	Optimum Speed (km/h) (speed which minimises total economic cost): All vehicles combined	Optimum Speed (km/h): Cars & LCVs	Optimum Speed (km/h): Trucks
RURAL FREEWAYS (20,000 vehicles per day)					
Base scenario[1]	2.350	0.6%	120	125	100
- 'Willingness to pay' (WTP) values of road trauma	10.497	2.7%	110	120	95
Trucks limited to 100 km/h	-3.641	-1.0%	n.a.	125	100
Variable speed limit (VSL)[2]	-3.483	-0.9%			
- WTP values of road trauma	-1.308	-0.3%			
VSL (day limit 120 km/h)[2]	-2.334	-0.6%			
- WTP values of road trauma	-1.735	-0.4%			
RURAL DIVIDED ROADS (15,000 vehicles per day)					
Base scenario[3]	6.454	2.2%	110	120	95
- 'Willingness to pay' (WTP) values of road trauma	16.453	5.5%	105	110	90
Trucks limited to 100 km/h	0.372	0.1%	n.a.	120	95
Variable speed limit (VSL)[4]	-1.201	-0.4%			
- WTP values of road trauma	1.468	0.5%			
VSL (day limit 120 km/h)[4]	-1.363	-0.5%			
- WTP values of road trauma	-0.627	-0.2%			
STANDARD 7.0 M SEALED TWO-WAY UNDIVIDED ROADS (1,000 vehicles per day)[5]					
Base scenario	2.040	9.8%	95	100	85
Curvy roads with crossroads and towns	14.781	66.3%	85	85	At most 80
SHOULDER-SEALED 8.5 M TWO-WAY UNDIVIDED ROADS (1,000 vehicles per day)[5]					
Base scenario	1.021	5.1%	105	105	90
Curvy roads with crossroads and towns	13.645	63.5%	85	90	85

[1,3] Speed limit raised from 110 km/h (cars and light commercial vehicles) and 100 km/h (trucks) to 130 km/h (all vehicles). Road trauma valued by 'Human Capital' approach (unless otherwise indicated).

[2,4] Day speed limit for cars and light commercial vehicles raised to 130 km/h (or 120 km/h where indicated); night speed limit reduced to 100 km/h; truck speed limit fixed at 100 km/h during all times of day.

[5] Speed limit raised from 100 km/h to 130 km/h for all types of vehicle. Road trauma valued by 'Human Capital' approach.

Rural freeways

An increase in the speed limit to 130 km/h on rural freeways would save each car 8.4 minutes and each truck 13.8 minutes per 100 km, but would increase the number of fatal crashes by 2.8 per year per 100 km of freeway. Casualty crash costs would increase by 89%, vehicle operating costs would increase by 7% and time costs would decrease by 17%. There would be a net cost increase of $2.35 million per year per 100 km of road, provided it is appropriate to value the road trauma increases by the 'human capital' approach. If road trauma is valued by society's 'willingness to pay' to prevent it, the net cost would be $10.5 million per year per 100 km. Since these alternative valuations of road trauma are central to the estimated economic output of the increased speed limit on rural freeways, the implications of their choice in making policy decisions needs to be considered carefully.

However, the analysis does indicate that the negative economic impacts of the increased speed limit on rural freeways could be overcome, and even made positive, if trucks were limited on such roads to 100 km/h. A further alternative would be a variable speed limit system, whereby the speed limit is reduced to 100 km/h for cars and light commercial vehicles under adverse road conditions (such as at night or other adverse condition approximately doubling the crash risk for about 20% of the traffic), and is fixed at 100 km/h for trucks at all times. (Issues associated with practical implementation, and cost, of a variable speed limit system were not part of the study.) If the increased speed limit under good conditions was no more than 120 km/h, the increase in road trauma would be minimal. This variable speed limit system would still result, however, in an increase in fatal crashes of 0.2 per year per 100 km of freeway, due to the increase in speed limit for 80% of the traffic, albeit during safer daytime conditions. This system would increase casualty crash costs by 7%, increase vehicle operating costs by 1% and reduce time costs by 4%.

Divided roads

The travel time savings if the speed limit were increased to 130 km/h on rural divided roads were estimated to be the same as on freeways, and the percentage change in crash costs would be similar. However the number of additional casualties would be higher because of the higher initial crash rate. Fatal crashes would increase by 3.4 per year per 100 km of divided road. Similar remarks regarding the economic analysis of rural divided roads apply as were made for freeways, except that a simple increase in the speed limit to 130 km/h would have a substantial economic cost ($6.45 million increase per year per 100 km of road). Even higher figures would be estimated with alternative valuations of leisure travel time and road trauma.

The economic loss on divided roads could be overcome to a large extent if trucks were limited to 100 km/h. However a variable speed limit system allowing speeds of 120 km/h under good conditions would not be as beneficial as on rural freeways. There would be an additional 0.3 fatal crashes per year per 100 km of road, but a saving of 2.5 minutes per car travelling over the 100 km section averaged over the whole day. A system allowing 130 km/h on divided rural roads during good conditions would result in greater road trauma levels.

Undivided roads

There is apparently no economic justification for increasing the speed limit to 130 km/h on the two-way undivided roads, especially the lower standard 7.0 m sealed roads without shoulder sealing.

On the straight undivided sections without intersections or towns, total costs on the 7.0 m roads would be increased by $2.04 million per annum per 100 km of road, or almost 10% of current costs. There would be travel time savings of 13.8 minutes per vehicle over 100 km, but an increase of 0.8 fatal crashes per year on the same road section. (The increase in casualty crash costs would be 142%, but the number of additional fatalities and casualties per 100 km road section would be lower than on divided roads because of the lower traffic volumes on typical undivided roads.)

On the lower standard undivided roads through curvy terrain requiring slowing and occasional towns requiring stopping, the average speed would be lower and the travel time savings would be only 9.8 minutes per vehicle over 100 km. The total cost associated with raising the speed limit, and hence the cruise speeds, to 130 km/h is estimated to be $14.78 million per annum per 100 km, due to increased fuel consumption predominantly and to increased air pollution emissions, each associated with the deceleration-acceleration required by slowing and stopping from 130 km/h cruise speed and returning to that speed.

The optimum cruise speed for cars travelling on these roads is estimated to be 100 km/h if the road is straight without crossroads and towns, but only 85 km/h if the road has many sharp bends and includes intersections and towns requiring stopping. The optimum cruise speed for trucks is estimated to be 85 km/h, and no more than 80 km/h on curvy undivided roads of the same standard. Optimum cruise speeds would be somewhat lower if ‘willingness to pay’ values were used for crash costs, or lower values were used for leisure time savings.

On the higher standard, 8.5 m shoulder-sealed undivided roads, an increase in the speed limit to 130 km/h would not result in as many additional crashes as on the lower standard roads, but the total cost would still increase by $1.02 million per annum per 100 km of straight road: about 5% of current total costs. The travel time savings would be the same as on the lower standard undivided roads, but on the straight sections without intersections or towns there would still be 0.5 additional fatal crashes per year per 100 km of road. These calculations assume equal traffic volumes on higher standard and lower standard undivided roads. In practice, traffic volumes are likely to be higher on the better roads, so the number of additional casualties and the net cost increase per section could be higher on these roads.

Again, as with the lower standard undivided roads, the higher standard roads through curvy terrain and passing through towns would experience substantial increases in total social costs associated with the increased speed limit, due to increased fuel consumption and emissions because of frequent deceleration and acceleration. The total cost associated with cruise speeds of 130 km/h on such roads would be $13.65 million per annum per 100 km of road. Travel time savings would be reduced compared with straight 8.5 m shoulder-sealed sections, and fatal crashes would be increased by 0.6 per year per 100 km of curvy road.

The optimum cruise speed for cars travelling on the higher standard undivided roads is estimated to be 105 km/h if the road is straight without crossroads and towns, but only 90 km/h if the road has many sharp bends and includes intersections and towns requiring stopping. The optimum cruise speed for trucks is estimated to be 90 km/h, but only 85 km/h on curvy undivided roads of the same standard.

DISCUSSION

Appropriateness of valuing travel time savings

There is a view that on some trips, the travel time saving per trip travelled at a higher speed is so small that the benefit cannot be perceived by vehicle occupants and hence has zero value. In rural areas, trip distances are typically longer than in urban areas and travel time savings per trip are potentially substantial if travelling at a higher speed. It has been estimated that 41 minutes per trip could be saved on a 700 km rural section of the Hume Highway if travelling at 130 km/h on the better one-third of road and 120 km/h on the remainder, compared with travelling at 110 km/h over its whole length (Crawford 2002). It is likely that vehicle occupants would perceive travel time savings of this magnitude over long rural trips and would place value on the time savings.

Another issue arising in the valuation of travel time savings on rural roads is the desirability of consistency in the valuation of leisure time in the travel time costs and in the road trauma costs. The 'human capital' crash cost estimates do not include any value for leisure time forgone by crash victims. For consistency reasons, it could be argued that when the human capital cost estimates are used, the leisure trip travel time savings should be valued at zero. This variation on the base scenario analyses for rural freeways and rural divided roads was considered in the study (Cameron 2003) but the results are not presented here.

'Willingness to pay' valuations of road trauma

There has been considerable attention given in the USA to valuing road trauma costs as comprehensively as possible, especially including values for lost quality of life in the case of killed and incapacitated crash victims. A leading US transport safety economist, Ted Miller, has argued that comprehensive crash costs, otherwise known as 'willingness to pay' values, should be used in benefit-cost analysis. This is because 'willingness to pay' values reflect society's consumer preferences when it comes to decisions about road safety initiatives.

Miller (1996) has also suggested that 'it seems essential to use compatible values of life and travel time in transport investment analyses'. Since the travel time values normally used for transport decisions reflect consumer preferences, this implies that 'willingness to pay' values of road trauma should be used when travel time savings are valued.

Reflecting this argument, the analysis in this study includes variations on the base scenarios for rural freeways and rural divided roads in which 'willingness to pay' values are used (Table 2). Travel time for all purposes of trip (including leisure trips) is valued in these analyses. It is suggested that this is technically the correct combination of valuations of these two important impacts of the speed limit changes analysed in this study.

Optimum speeds if road trauma valued by 'Willingness to pay'

On the basis of these valuations, the optimum speed on the rural freeways is 120 km/h for cars and light commercial vehicles and 95 km/h for trucks. If these speeds were to become the speed limits for each type of vehicle, respectively, there would be a net saving of $1.36 million per annum per 100 km of rural freeway. There would be a travel time saving of 4.5 minutes per car, but an increase of 3.2 minutes per truck, and there would be an additional 0.6 fatal crashes per year per 100 km of freeway.

On rural divided roads, the optimum speed is 110 km/h for cars and light commercial vehicles and 90 km/h for trucks, if 'willingness to pay' valuations of road trauma are used. If the truck optimum was to become their speed limit (but no change in limit for cars), the total impact would be a saving of $864,000 per annum per 100 km of divided road. There would be no travel time saving for cars, but an increase of 6.7 minutes per truck, and there would be a reduction of 0.3 fatal crashes per year per 100 km of divided road.

If speed limits on each class of rural road (including rural undivided roads) were to be moved closer to the optimum speeds, there could be a substantial net gain in total economic costs across the road network (and perhaps even a net reduction in crash costs). This is because a large proportion of rural road travel (and an even larger proportion of rural crashes) is on undivided roads. A reduction in crash costs may result because, although speed limits for cars would increase on freeways, their limits would decrease or remain the same on other roads, and truck speed limits would decrease on all roads, especially the undivided roads with higher crash rates. However, reliable data on rural traffic levels using each of the four classes of road analysed in this study was not available to calculate the total economic impacts across the rural road network.

CONCLUSIONS

Within the limits of the assumptions made and the data available for this study, a number of conclusions about rural speed limits were reached. In particular, it was assumed that the average speed of each vehicle type is the same as the speed limit, unless their speed is reduced by slowing for curves and stopping in some sections.

1. Increasing the speed limit to 130 km/h for all vehicles on rural freeways would have substantial social costs. The total social cost could be constrained, and even reduced, if trucks were limited to 100 km/h on such roads. A variable speed limit system allowing speeds of 120 km/h for cars and light commercial vehicles during good conditions, but reduced to 100 km/h under adverse conditions, while limiting trucks to 100 km/h at all times, would keep total social costs below current levels. However, all scenarios whereby speed limits are increased for some vehicle types and circumstances are necessarily accompanied by increased road trauma to provide travel time saving benefits.

2. Increasing the speed limit to 130 km/h on rural divided roads would have even greater social costs than the increased limit on freeways. If trucks were limited to 100 km/h, the impact on total social costs would be smaller but they would still increase. Even a variable speed limit like that for freeways described above would be associated with an increase in road trauma costs. The higher crash rate on the divided roads compared with rural freeways will result in any speed limit increase producing even greater road trauma increases than on the freeways, despite lower traffic volumes on non-freeway roads.

3. If the ‘willingness to pay’ valuations of crash costs reflecting consumer preferences are used, the optimum speeds on rural freeways would be 120 km/h for cars and light commercial vehicles and 95 km/h for trucks. On divided rural roads, the optimum speeds would be 110 km/h and 90 km/h, respectively. If the speed limits on each of these rural roads were to be set at these optimum speeds for each vehicle type, there would be a reduction in total social costs in each environment. However, there would be increases in road trauma on the rural freeways due to the increase in car speeds.

4. There is no economic justification for increasing the speed limit on two-lane undivided rural roads, even on the safer roads with sealed shoulders. On undivided roads through terrain requiring slowing for sharp bends and occasional stops in towns, increased fuel consumption and air pollution emissions associated with deceleration from and acceleration to high cruise speeds would add very substantially to the total social costs. Using ‘human capital’ costs to value road trauma, the optimum speed for cars is about the current speed limit (100 km/h) on straight sections of these roads, but 10-15 km/h less on the curvy roads with intersections and towns. The optimum speed for trucks is substantially below the current speed limit, and even lower on the curvy roads. The optimum speeds would be even lower if ‘willingness to pay’ valuations of crash costs were used.

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