Do crash rates really increase with increases in average speed?

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Abstract

For more than two decades speed limit enforcement has been supported by research that "shows" that crash rates increase with increasing average speed.

Safe driving is primarily determined by being alert, being unimpaired, and driving at an appropriate speed and with an appropriate clearance distance for the environment at the time. This should ensure that a driver can break or swerve in time to avoid an impact.

And note speed limits are never set based on maximum safe speeds, nor are they set with any precision.

This paper reviews the papers by Nilsson, TRL, Kloeden et al and others that show benefits from reducing average speeds, and shows they contain errors or are inconclusive. It supports that MUARC report 307 correctly determines enforcement cameras have virtually no effect on road trauma even though studies show average speeds are reduced at camera sites. And it reviews Allsop's 2013 report which claims speed cameras reduced KSI crashes, shows no correlation between the change in average speeds and the change in crash rates at camera sites.

It reviews research on crash rates by road type and speed limits, and finds no correlation between crash rates and average speeds.

This paper shows that it cannot be asserted that crash rates increase with average speed. This has serious implications for the reports that show speed limit enforcement reduces speeds and then use Nilsson, TRL, Kloeden or other results to claim there would be a reduction in casualty crashes.

Introduction – safe driving and the role of speed and speed limits

Safe driving/ riding requires:

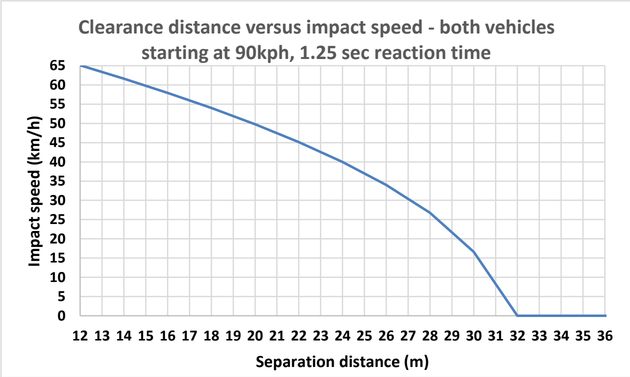
- an alert driver/ rider, not impaired by alcohol, illicit drugs, prescribed drugs, a medical condition or fatigue,
- the use of occupant protection equipment, and
- choice of an appropriate speed and appropriate clearance distance to allow them to stop or swerve in time to avoid a collision.

Speed has been recognised as a factor in crashes from before the “Speed kills” campaigns in the 1970s. And speed limits and speed limit tolerances have in some jurisdictions been increasingly used to control vehicle speeds. Since the early 1970’s there has been a progressive increase in speed detection/speed enforcement equipment. And in evaluating the effectiveness of these technologies it has been a fairly common practice to measure the effect of the devices on average speeds and then use relationships between average speeds and crash rates to predict changes in crashes.

Speed and crashes – a conceptual model

For a particular vehicle, driver and situation the chance of a crash is asymptotic. Take two vehicles, travelling at 90 km/h, with maximum deceleration rates of 8.5 m/s^2, and driver reaction times of 1.25 seconds, with the front vehicle suddenly braking. The impact speed vs separation distance can be modelled.

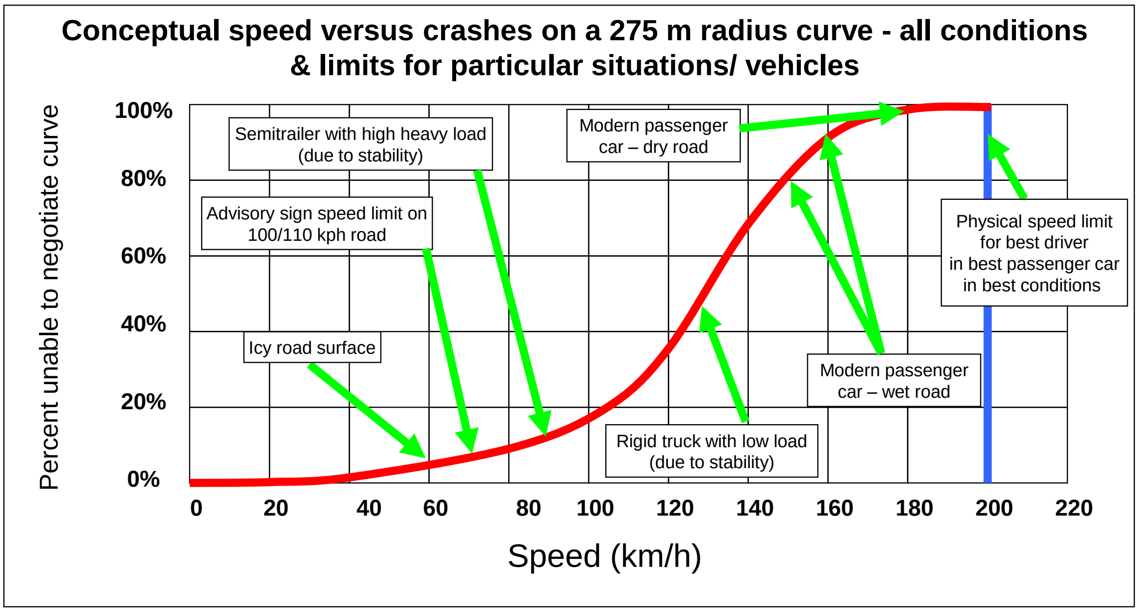
Figure 1. Impact speed versus initial separation distance



The results are shown in Figure 1. At separation distances greater than 32 m there will be no crash. And below 32 m the crash outcomes will escalate with decreasing separation distance from minor damage to serious damage, injury and possible death as impact speeds increase.

For a particular on road situation the overall crash risk factor will depend on the crash risk factors for the range of vehicles and conditions that occur at that location. For example consider a 275 meter curve with 4.5% superelevation. This curve would be likely to have a 70 km/h advisory speed limit.

Figure 2. Likely distribution of crash risk on a 275 m curve



In icy conditions vehicles would slide and crash off the road or into each other at around 60 km/h. A semitrailer with a high heavy load would rollover at around 90 km/h and so on. The crash risk for the population of vehicles over a range of weather situations approximates an S-curve. And in a 100/110 km/h speed zone the relevant crash risk curve would be the section from 0 to ~120 km/h. To this crash risk would need to be added risks associated with distracted, impaired of fatigued drivers crashing off the curve at any speed.

Provided the drivers of the various vehicle types adjust their driving to the conditions, crash rates will be very low at speeds up to around 120 km/h. Then they will begin to increase dramatically.

Driver populations and crash rates

Based on all the data I have seen over my 50 years of involvement in road safety and using Australian data I have been able to determine the following approximate crash causation rates.

Table 2: Crash causation rates per years of driving – Australian data

Crash type	Most responsible 30%	Next 50%	Less responsible 12%	Irresponsible 8%
Fatal	140,000 yrs	42,000 yrs	10,500 yrs	1800 yrs
Serious	8,700 yrs	2,500 yrs	950 yrs	155 yrs
Other injury	500 yrs	150 yrs	90 yrs	15 yrs

As shown the responsible 80% of drivers have very low crash rates. The chance of them causing a crash where someone is injured is around once in 2 to 3 driving lifetimes. And necessarily these drivers must be skilled at choosing appropriate speeds and clearance distances to avoid crashes, must not drive when they are unimpaired, and must use occupant protection devices.

And being the majority of drivers they have a huge impact in controlling driving behaviour on roads. Except where traffic is light this group basically controls vehicle speeds.

Driver behaviour – speed versus speed limits

Figure 3. Average speeds versus speed limits on a length of UK B class road

The Figure 3 is from UK DfT Traffic Advisory Leaflet 2/06. These average speeds are basically controlled by the 80% of responsible drivers. It is interesting to note the degree to which these drivers follow the actual speed limits. In the initial 40 mph zone the drivers chose generally to travel above the speed limit; in the following 50 and 40 mph zones the drivers chose to follow the speed limits with one significant variation; and in the 60 mph zone the drivers chose to travel below the speed limit. Note that the enforcement tolerance in the UK is 10% of the speed limit +2 mph so that except in the initial 40 mph zone the average driver would not be at risk of being infringed.

Average speeds reflect driver's responses to perceived varying levels of risk. And in the 60 mph zone, average speeds along this 7 km length varied from 40 mph to 60 mph. In a study of average speed versus crashes average speed measurements could be highly variable.

Figure 4. Average speeds versus traffic flow on a section of the Monash Freeway in Victoria Australia (speed limit 100 kph)

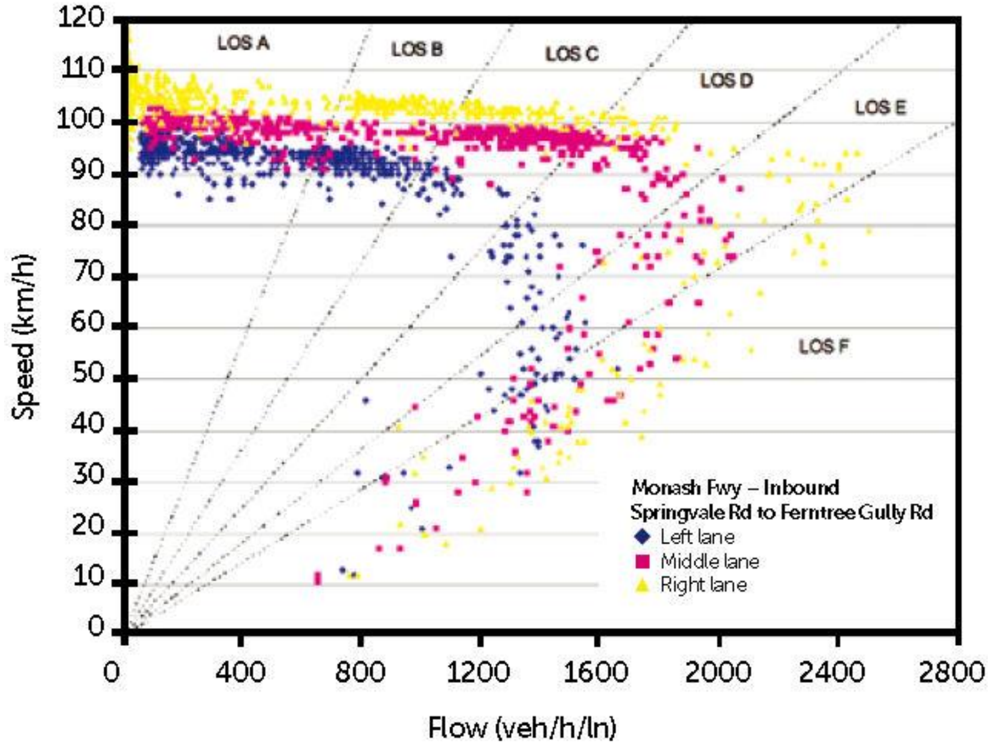


Figure 4 is from the VicRoads Managed Freeways Handbook (2013) Figure 24

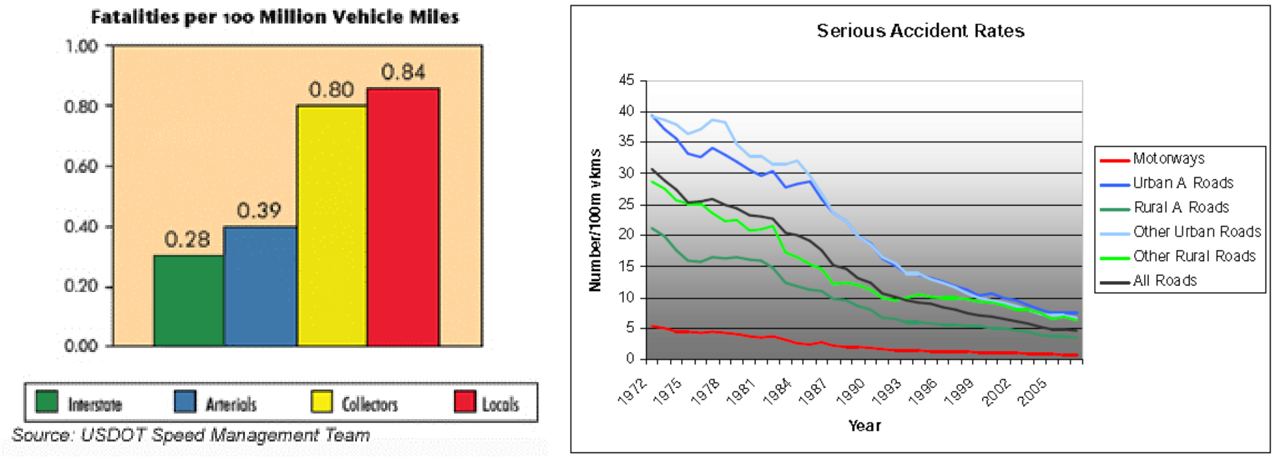
In Australia drivers drive on the left side of the road, so the left lane is the slowest lane and the right lane is the fastest lane in a three lane freeway situation. In the uncongested situation speeds in left-hand lane average 90-95 km/h; 95-100 km/h in the middle lane; and 100-105 km/h in the right lane. Once a lane reaches saturation the speeds rapidly drop. And lower speeds equal lower capacity.

As shown in this figure at 400 vehicles per hour in the uncongested situation vehicles are travelling at about 100 km/h, or 100,000 metres/h. Assuming the average vehicle length was about 4.5 m then the 400 vehicles would occupy 1800 m of the 100,000 m. Hence the average distance between them equals (100,000 – 1,800)/ 400 or of the order of 250 m. And at 800 vehicles per hour in the uncongested situation vehicles are travelling at around 96 km/h, or 96,000 m/h. The same calculation gives a separation distance of the order of 120 m. It would therefore be expected that crashes would be rare in a mid block situation. However low traffic flow would allow less responsible drivers to travel faster than the general traffic stream, and create a risk of serious crashes. In comparison in the saturation zone and congested zone, the average separation distances will be 25 metres to 55 m (1.2 to 2.5 seconds) with significant risk of nose to tail crashes especially at intersections. However because vehicle travel speeds before braking will be similar and lower, crash severity is likely to be low.
In summary figure 4 reflects a large range of speeds and clearance distances and varying crash type risks. For the purpose of average speeds and crash rates, a single value for average speed for this segment of road, or any other road that is subject too serious levels of congestion during peak hours is a nonsense.

Crash rates versus speed limits by road class

If crash rates increased with average speed in an absolute sense, it would be expected that the road classes with the highest average speed would have the highest crash rates.

Figure 5. Trauma rates versus road category USA & UK



As shown in the diagrams above (USDOT(2003) Figure 4 & Bayliss (2009) Figure 6) to a large extent the reverse is true – the roads with the highest speeds – the motorways and freeways – have the lowest crash rates. And the roads with the lower speeds have the highest crash rates.

And this supports that the role of speed is not as determinative as some road safety practitioners would like the public to believe.

Research by Nilsson (2004)

Nilsson's research used Swedish National Road Administration 1997 mean speed data for two lane roads with a road width of 13 m - 43 road sections had a speed limit of 90 km/h and 62 Road sections had a speed limit of 110 km/h. Crash data was for the period 1991 to 1997.

The data was grouped by average speed to give reasonable number of crashes per group. In the 90 km/h zones the groupings were 87-91 km/h (94 crashes), 92 km/h (154), 93-94 (200), 95-96 (144), 97 (190), 98 (190), 99 (116) and 100-112 (165). In 110 km/h zones the groupings were 97-100 km/h (53), 101-102 km/h (63), 103 (163), 104 (136), 105 (104), 106-108 (118), 109 (94) and 110-112 (96).

Figure 6. Nilsson (2004) Figure 28

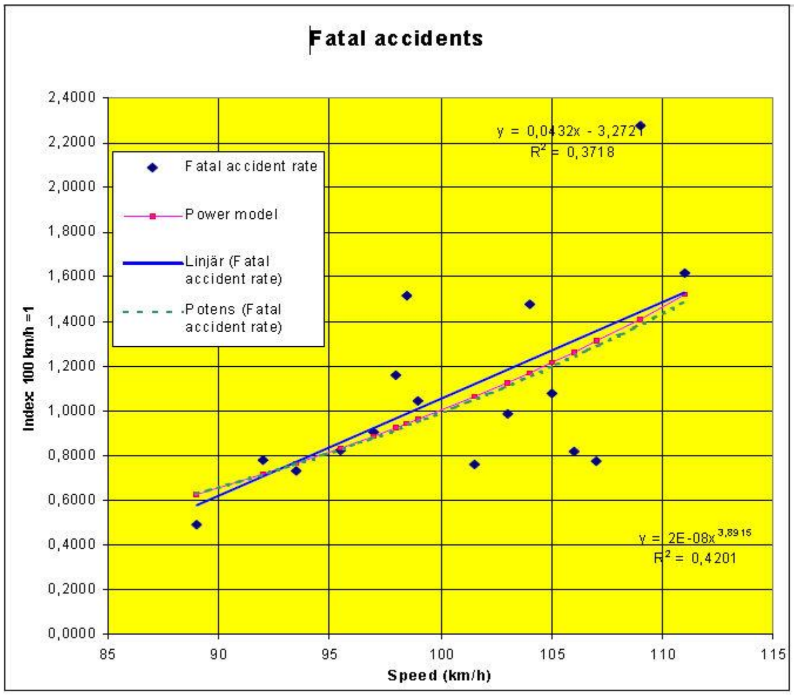


Figure 6 above shows the 16 fatal accident rates together with Nilsson's power model curve in pink, plus a linear model and a power model from be accident rate data. What is not highlighted is the fact that these data points relate to road sections with different speed limits. And the fact that the road managers had specified different speed limits is prima facie evidence that they perceived the risks with the two road types to be significantly different.

Figure 7. Based on Nilsson (2004) Figure 28

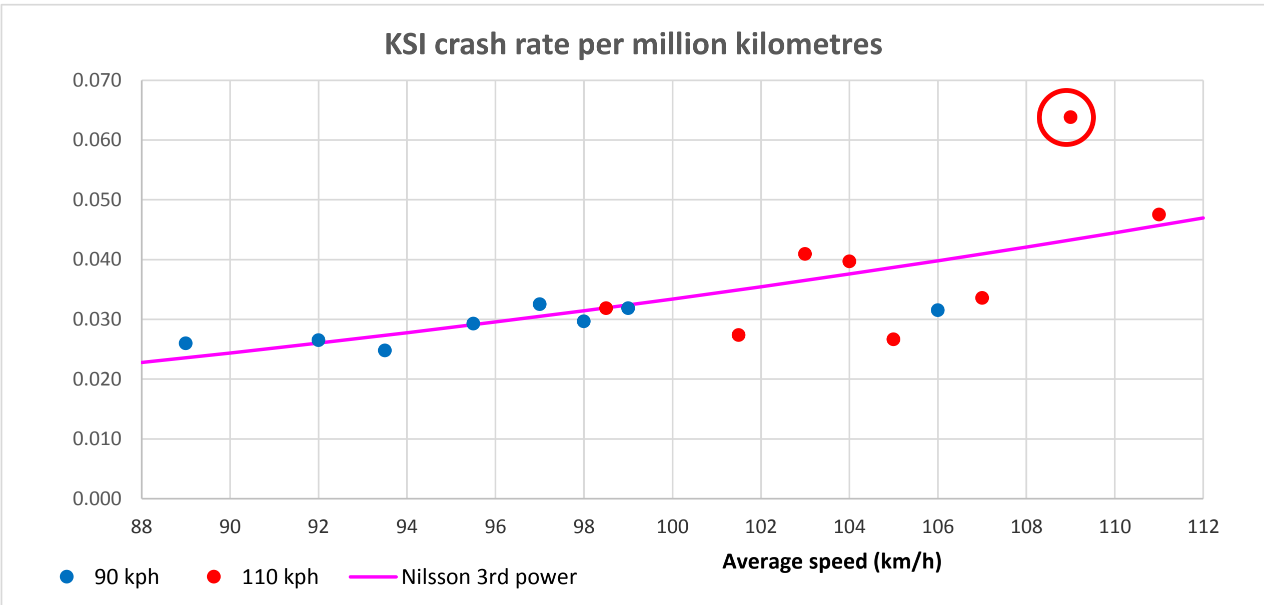
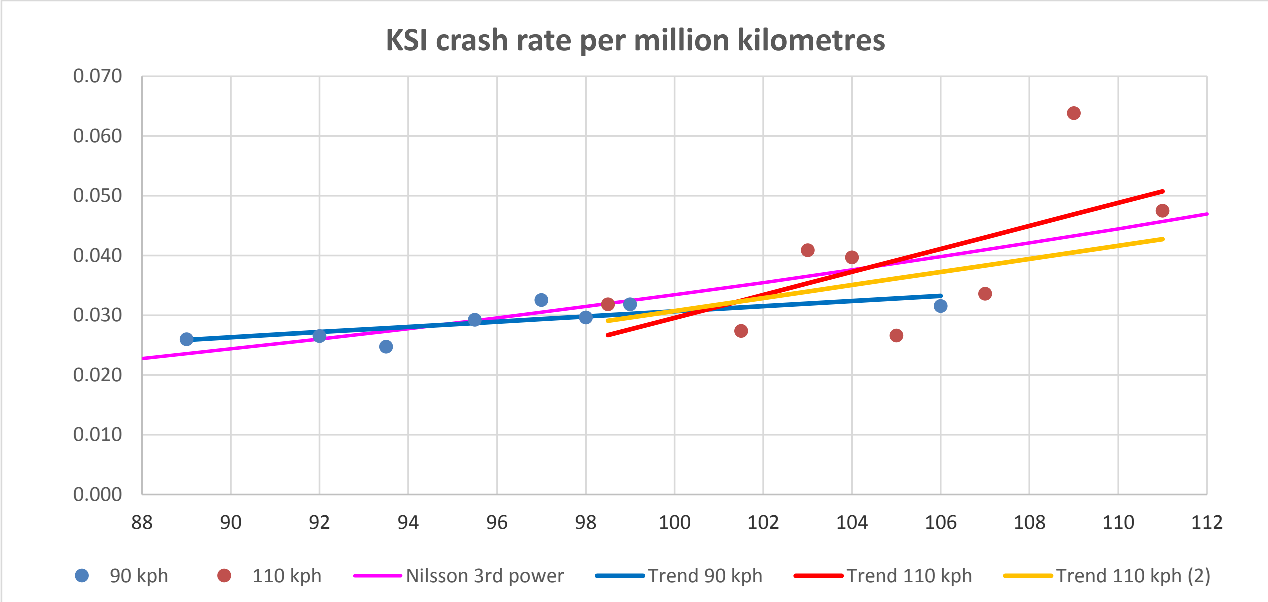


Figure 57 shows the two groups of data highlighted separately, plus one outlier value circled in red. Once again on Nilsson's power model curve is shown in pink.

Figure 8. Trend lines based on Nilsson (2004) Figure 28



Three linear trendlines have been added in figure 8 above - for the 90 km/h data; for the 110 km/h data; and for the 110 km/h data less the one outlying value. Note that the linear trendlines are significantly different in slope to the Nilsson third power model except for the adjusted trend for the 110 km/h data. Similar results are found for other crash types. This brings into question the validity of Nilsson's power model given that the trendlines are different for the different road types.

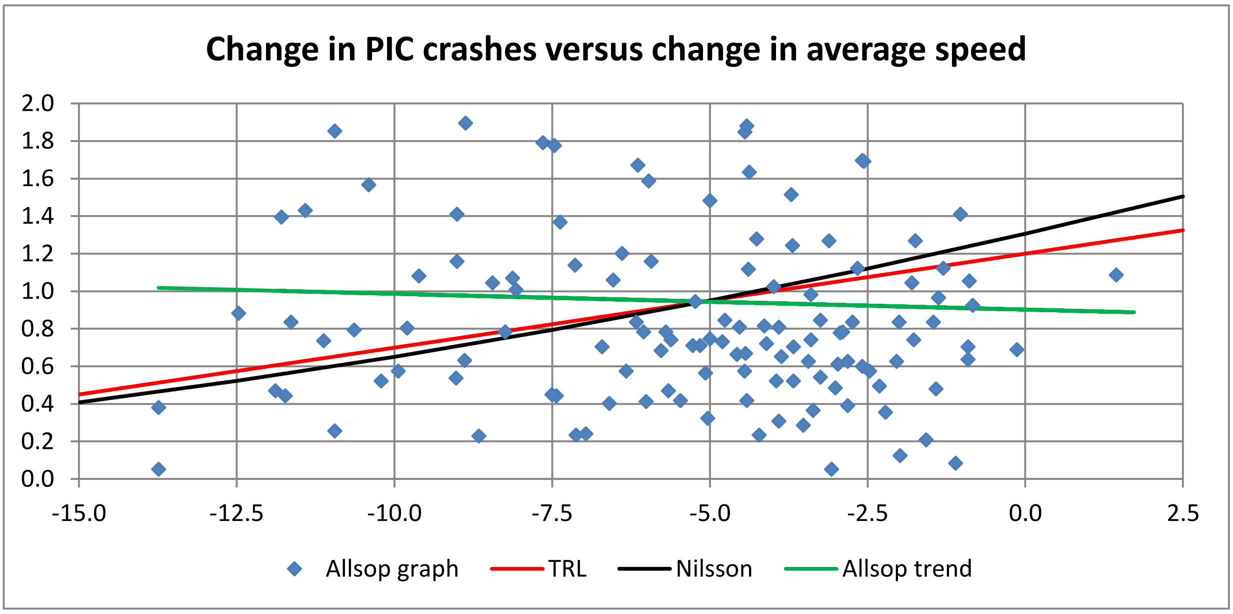
Research by Allsop (2013)

In Appendix 4 - Joint Analysis of Collision and Speed data, data was examined for eight UK Speed Camera Partnership (Partnership) areas. Where it was clear that one or more observations were made before establishment of a camera and one or more afterwards, the observations of mean speed before and after establishment were each averaged, and the difference between the two averages was taken as an estimate of the change in mean speed in the vicinity of the camera following its establishment.

Changes in mean speed were estimated in this way for 132 cameras in these eight Partnerships, and ranged from a reduction of 13.7 miles/h to an increase of 1.7 miles/h. All but three were reductions.

The change in collision occurrence at the camera concerned was measured by number of personal injury crashes (PIC) per year in the vicinity of the camera in years throughout which the camera may have been in operation.

Figure 9. Change in PIC crashes versus change in average speed – 132 UK speed camera sites



Allsop's data is shown above with the trend line shown in green. Note he found a slight increase in PIC crash crashes with reductions in average speed. I have compared Allsop's data and trend with the predicted trends by TRL and Nilsson based around the average of all Allsop's data. As shown Allsop's data does not support the TRL or Nilsson trendlines at all. And importantly it does not support that reducing average speeds necessarily reduces crashes.

Research by Kloeden and McLean (1997) – Urban roads

This study was a case/ control study

Case vehicles

The following criteria were used for the selection of case vehicles: Crash was in the Adelaide metropolitan area, with a 60 km/h speed limit, not on a section of road with an advisory speed sign of less than 60 km/h, case vehicle was a car or car derivative, at least one person was transported from the crash scene by ambulance, case vehicle had a free travelling speed prior to the crash, was not executing an illegal manoeuvre prior to the start of the crash sequence, the case vehicle driver did not suffer from a medical condition that caused the crash, and had a zero blood alcohol concentration (BAC), there was sufficient information was available to carry out a computer-aided crash reconstruction, the case vehicle did not roll over, and crash did not occur while it was raining.

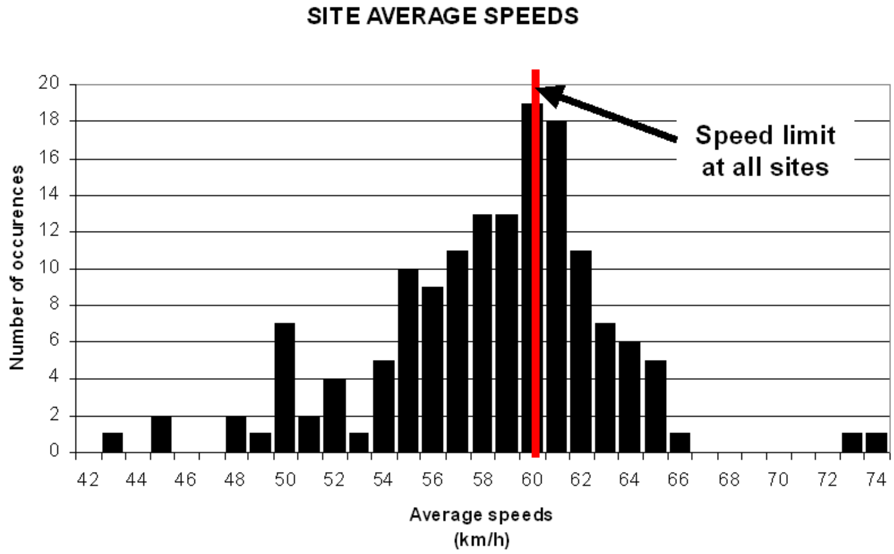
Cases were restricted in the interest of uniformity. Higher speed zones would have had fundamentally different speed distributions which would have made the case-control analysis more complicated to perform and the results harder to interpret.

The end result was that only 28% of the notified crashes were selected for analysis. Those crashes were disproportionally intersection crashes between cross traffic or turning traffic (60% of cases versus expected frequency of around 17%-20%).

Control vehicles

The selection of 4 control vehicles were based on same location, weather conditions, day of week, and time of day as the crash; same direction of travel as the case vehicle; car or car derivative, free travelling speed, and most were checked for zero BAC.

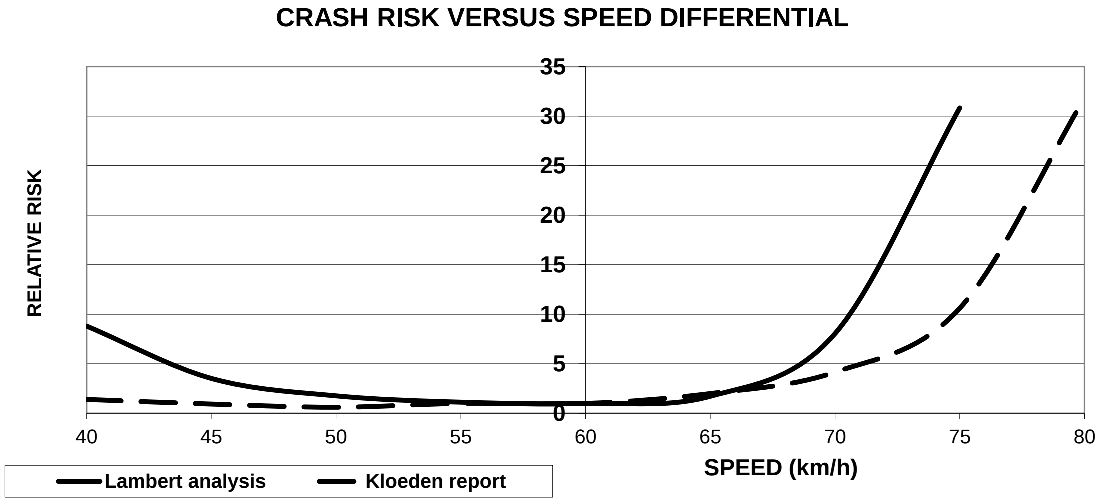
Figure 10. Distribution of average speeds of groups of control vehicles



As shown average speeds of the control vehicles varied dramatically from 43 km/h up to 74 km/h. As these average speeds are the result of decisions made the 80% of responsible drivers to vary their speed and clearance distances to suit to condition, it must be the case that the risks vary dramatically between sites. Reference to the actual Kloeden and Mclean data and drawings shows that the high speeds were recorded on roads where the pavement width in one direction was 12 m wide or more, whilst in the low speed situation the pavement width had been restricted to 6 ½ m wide in one direction using traffic calming methods.

Kloeden and McLean professionally used available information to determine the speed of the case vehicles prior to the crash. However inexplicably when they analysed the data to determine a crash risk, they used 60 km/h as the reference speed instead of the average speed of the control vehicles (as would be required the approach taken was to use the 85th percentile free speed for vehicles travelling on a particular length of road.

Figure 11. Crash risk versus speed differential



And in figure 11 above the dashed line shows the results of their analysis. Note that there is hardly any increase in crash risk for vehicles travelling much slower than 60 km/h. This is in conflict with the general experience in road safety that shows that vehicles travelling much slower than the traffic stream represent a significant crash risk – hence all the warning signs and lights required with slow moving vehicles.

In my paper Lambert (2000) I reanalysed the data using the control vehicle average speeds as the reference speed. The results of my analysis are shown in figure 11 in the full black line (I have overlaid the Kloeden and McLean graph placing the zero value at the 60 km/h value of the original graph).

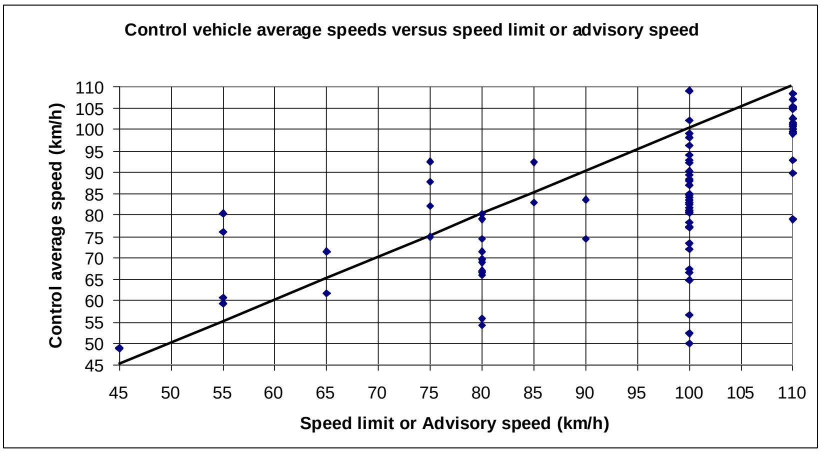
The implications of my analysis is that it’s not the average speed differential from 60 km/h that controls crash risk, it is the variation from the average speed that the 80% of responsible drivers choose that is the critical factor. And note that as expected vehicles travelling much slower than the average travel speed also generate a significant increase in crash risk. My graph shows that the increase in crash risk is around eight times at a speed 20 km/h slower than the average traffic speed, and about eight times at a speed that is around 20 km/h faster than the average traffic speed.

In summary the crash rate does NOT double for every 5 km above 60 kph - in fact 60 km/h has no relevance in this matter at all.

Research by Kloeden and McLean (2001) Rural roads

This research project was of a similar design to the previous research project but for rural roads. The differences were that rather than limiting cases to a single speed limit zone, it covered 80 kmh, 100 km/h and 110 km/h speed zones. In addition the analysis followed the approach in Lambert (2000).

Figure 12. Control vehicle average speeds versus speed limit or advisory speed



As is shown above at most sites the average speed for control vehicles are significantly less than the speed limit or advisory speed. In only 14 (8.4%) of the 167 cases is the average control group speed at or above the speed limit or within 5 km/h of the speed limit. Prima facie this reflects that responsible drivers perceive the sections of road where the crashes occurred as being of higher risk, and as a result reduce their speed to control that risk. And the implications of this are that the data in this research project is only appropriate in relation to speed limits at problem locations in the rural road network.

The results showed that the crash risk increases significantly where vehicles travel faster than the speed responsible drivers would choose for the particular location and environment. And as alluded to in the previous paragraph it gives no guidance as to how speed impacts on crashes in low risk section of the rule network – that is relatively straight sections of road good sight distances. And the research definitely does not show that crash risk in rural areas varies with average speed.

Research by Taylor et al (2002) TRL Report TRL511

This Research Report aimed at determining the relationship between speed and crash rate on UK Rural roads with 60 mph speed limits.

Four Groups of roads were identified that can be broadly described as follows:

Group 1: Roads which are very hilly, with a high bend density and low traffic speed - low quality roads.
Group 2: Roads with a high access density (lots of side roads and driveways), above average bend density and below average traffic speed - lower than average quality roads.
Group 3: Roads with a high junction density, but below average bend density and hilliness, and above average traffic speed - higher than average quality roads.
Group 4: Roads with a low density of bends, junctions and accesses and a high traffic speed - high quality roads.

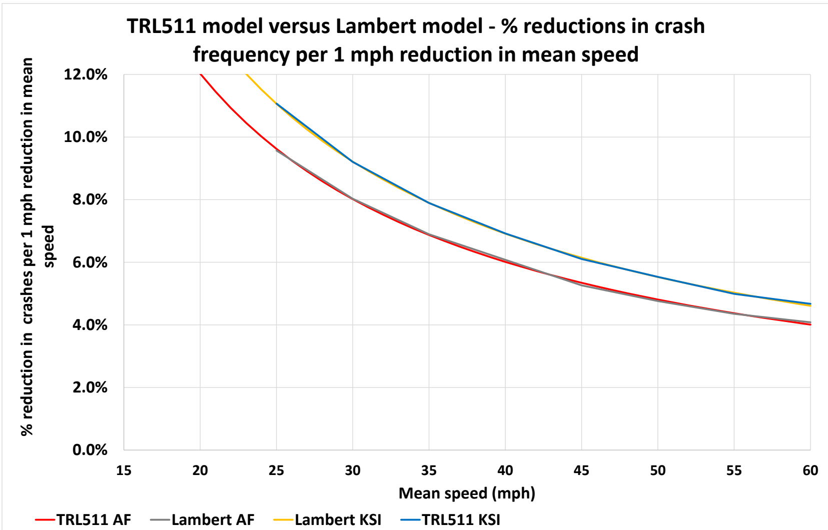
Unfortunately nowhere in the paper is the base data displayed so that readers are faced with a black box analysis. Two model structures were developed – Level 1 which was of the structure where accident count = Function(years of accident data; AADT flow; link length; mean speed); and Level 2 which was of the structure where accident count = Function(years of accident data; AADT flow; link length; mean speed; road geometry). Model results were presented in Figure 3 of the report.

The Report is puzzling to the writer for a number of reasons. Firstly it contains none of the base data. This is a critical deficiency in that a reader has no opportunity to review the base data or the analysis. And I am aware that others have tried to get this base data to review this paper and no one has been successful. And the current advice is that the data is no longer available! One is left to wonder why this paper is given so much credibility, other than the fact it supports the group thinking about speed and crashes.

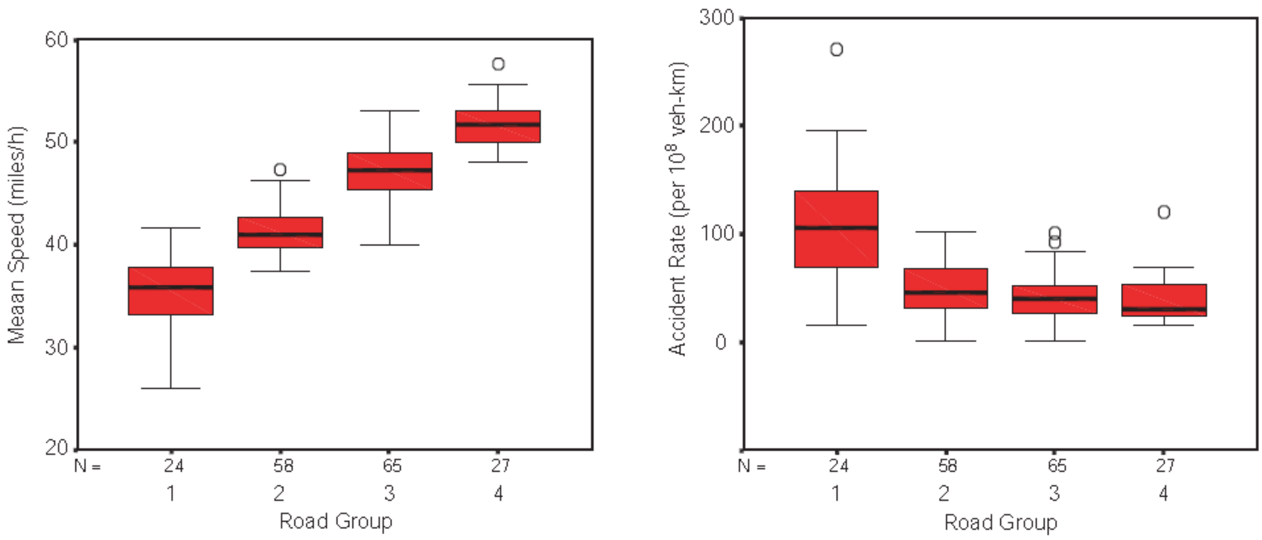
Figure 2 represents the model for a very specific situation, and figures is A1 and A2 are a synthesised construction to demonstrate a masking situation.

Further the trends shown in Figure 3 of the report did not make sense to the writer in relation to any hypothesis as to what factors would drive reductions in crash frequency or KSI crash frequencies versus mean travel speeds. This is especially so given that responsible drivers are very good at adjusting speeds and mean speeds to maintain a high level of safety. I decided to analyse the trend lines in Figure 3 of the report. That analysis showed the crash frequency trend line ≈ 2.405 x (1/V); and the KSI crash frequency trend line ≈ 2.765 x (1/V). The correlation between the TRL511 report data and my model is shown in figure 13 below.

Figure 13. Comparison between TRL511 trend lines and my model



And the authors of TRL 511 offer no hypothesis as to why % reductions are proportional to the inverse of the mean speed on rural single carriageway roads.



As shown in the segment of Figure 1 of the TRL report, low quality group 1 roads are associated with low mean speeds and high crash rates, whilst high-quality group 4 roads are associated with high speeds and low crash rates. Hence a reasonable hypothesis is that the relationship shown in figure 13 is the result of the influence of road standard. That is, on the high standard Road risks are low and so crash rates are low – and because of the lower risk responsible drivers choose to travel at higher mean speeds. And on the low standard roads the risks of crashes are much higher, and so the crash rate is significantly higher. And responsible drivers perceiving the increase in risk slow their speed in response to that increase in risk.

Conclusion

Almost universally studies into mean speeds versus crashes have failed to recognize that a) speed alone never defines safe driving – it is speed and clearance distance that underlies safe driving; b) that on heavily trafficked roads traffic flow has a complex and dramatic impact on speed and on types of crashes; c) that on lightly trafficked rural roads crashes are mostly concentrated at “black spots” connected by safe sections of roads– yet the safe sections are where speeds are checked; and d) that responsible drivers continually adjust speeds even within a speed zone so that any mean speed reading is highly likely to not represent the mean over all parts of any segment of section.

There is little consistency in the various models. The slope of the Allsop trend line is opposite to the slopes of other models, and the Kloeden serious crash trend is very different to the other trends.

In summary based on my analysis of the reports above, and the concerns stated, there is no robust model that can be used to predict reductions in crash frequency with reductions in mean speed. Further data from various jurisdictions show that the highest speed roads have the lowest fatality/crash rates per 100 million km, so there is no underlying relationship between speed and crashes that would indicate a reduction in crashes with a reduction in mean speed. And finally given that speed alone never describes safe driving, it is not unexpected that any research aimed at relating speed alone to crashes is likely to be inconclusive.

And as a result, when researchers find a reduction in speed, for whatever reason, there is no way for them to assert how that would translate into lower crash rates or reductions in trauma. To state the obvious if drivers are travelling at a safe speed for the conditions, forcing them to travel at a lower speed by applying an unrealistically low speed limit cannot achieve any significant gain in reduced crash rates. All it does is increased travel time and the cost of travel to society.

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