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Use of Kloeden et al's relative risk curves and confidence limits to estimate crashes attributable to low and high level speeding

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Abstract

Kloeden et al.'s relative risk relationships have been used in conjunction with vehicle speed measurements to estimate the relative frequency of casualty crashes associated with each speed range. Risks associated with high speeds had generally been ignored because of uncertainty about the relationships. This study estimates the relative crash frequencies using the confidence limits for the relative risks on urban 60 km/h limit roads. The estimated relative risks were also adjusted to reflect the increased probability of serious injury outcomes associated with increased speed. The concept of "population attributable risk" was used to estimate the fraction of crashes attributable to speeding in each illegal speed range. The estimated attributable fraction of casualty crashes was found to be higher for speeds above 80 km/h than speeds in the 60 to 70 km/h range, and higher again when the attributable fractions for serious casualty crashes were estimated. However, the results need to be tempered by the wide confidence limits associated with Kloeden et al's relative risk relationship at high speeds on 60 km/h limit roads.

Keywords

Speeding, Relative risk, Population attributable risk, Attributable fraction

Introduction

Estimates of the relative risk of a casualty crash related to the travel speed of vehicles provide a valuable link between speed observations and crashes in the same road environment. It is possible to predict the crashes associated with each speed range on road and thus consider countermeasures focused on the speeds that make the highest contribution to road trauma. This study made use of Kloeden et al.'s [1] relative risk relationship for urban 60 km/h limit roads in a way that allowed the full range of on-road speeds to be analysed for the first time, including very high speeds. Previous researchers have generally not analysed very high speeds in this way.

Kloeden et al. [1] re-analysed data previously collected [2] on 151 vehicles' pre-crash travel speeds and 604 matched control vehicle speeds to determine the following relationship between the relative risk of a casualty crash and free speed (v) in 60 km/h speed limit zones:

$$RR = \exp(-0.822957835 - 0.083680149*v + 0.001623269*v^2) \quad (1)$$

Free speed was defined as unimpeded travel speed without any constraint by other traffic or slowing for manoeuvres. It was estimated that 56 per cent of casualty crashes in metropolitan 60 km/h speed zones involve a vehicle travelling at free speed [1].

Table 1 from Kloeden et al. [1] shows the estimates of the risk of a casualty crash, relative to the risk at 60 km/h, calculated from each travel speed using the relationship (1) above. Also shown in Table 1 are the 95% confidence limits within which the analysis has estimated that the true relationship between relative risk and travel speed lies, with 0.95 probability that it is included.

Figure 1 shows the fitted relationship and its confidence limits, viewed from two perspectives, the first covering travel speeds from 45 to 90 km/h, but truncated at an upper relative risk of 60, and the second only for speeds up to 75 km/h so that the relationship and confidence limits for speeds below 60 km/h can be more clearly seen.

Table 1: Kloeden et al.'s [1] relative risk relationship Free Travelling Speed and the Risk of Involvement in a Casualty Crash Relative to Travelling at 60 km/h in a 60 km/h Speed Limit Zone Using a Fitted Logistic Regression Model of Absolute Speed

Speed (km/h)	Relative Risk	Lower Limit*	Upper Limit*
45	0.27	0.13	0.49
50	0.39	0.26	0.54
55	0.60	0.50	0.69
60	**1****	**1**	**1**
65	1.82	1.60	2.15
70	3.57	2.70	5.28
75	7.63	4.66	15.55
80	17.66	8.08	55.49
85	44.36	13.73	236.10
90	120.82	22.98	1222.70

***95% confidence limits of the estimated relative risk**
**** Relative risk arbitrarily set to 1 for 60 km/h**

The criteria for inclusion of the crashed case vehicles in Kloeden et al.'s study included involvement in a crash from which "At least one person was transported from the crash scene by ambulance" [2]. Of the persons transported by ambulance, 12% were not medically treated, 56% were treated at hospital (presumably in Emergency Department), 3% by private doctor, 26% were admitted to hospital and 2.5% died. It is not known whether the case crashes were typical of casualty crashes in urban 60 km/h speed zones.

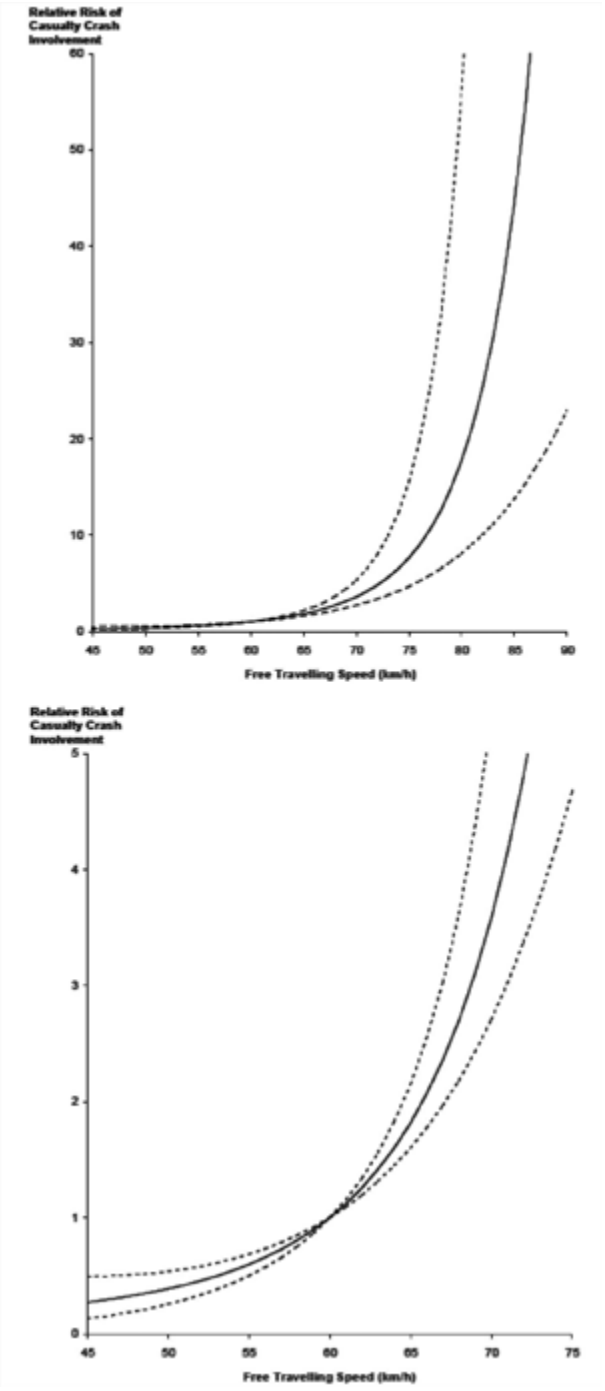

Figure 1: Relationship between relative risk and travel speed (two views) from Kloeden et al. [1]

Because of the strong effect of vehicle impact speed on the severity of injury outcome, it is important to note carefully the type of crash for which Kloeden et al.'s [1, 2] methods have measured the relative risk related to travel speed.

Diamantopoulou et al. [3] matched 149 of the 151 crashed vehicles from Kloeden et al.'s study [2] with South Australian Police crash reports. This matching found that 5% of the case crashes resulted in a fatality and 28% resulted in hospital admission. Higher pre-crash travel speeds were associated with the fatal crashes. The average travel speed of the vehicles involved in fatal crashes was 82.8 km/h (95% confidence interval: 72.8 to 92.8 km/h) compared with 67.7 km/h (95% CI: 63.0 to 72.4 km/h) for those involved in non-fatal casualty crashes.

The injury severity of the crash outcomes was related to the pre-crash travel speed. There was a statistically significant interaction between the injury severity of crash victims and increasing speed ranges (Figure 2). A total of 62.5% of the casualty crashes involving a vehicle travelling at more than 90 km/h in a 60 km/h speed limit zone resulted in a fatality or hospital admission.

Kloeden et al. [4] also developed a relationship between the relative risk of a casualty crash and free travel speed in rural speed limit zones. Because of the range of rural speed limits analysed, this study related relative risk to the difference between the free speed of the case vehicle and the average free speed of traffic in the same speed zone.

The criteria for inclusion of the crashed case vehicles in the rural study included involvement in a crash from which "At least one person ... was treated at, or admitted to, hospital or fatally injured". Of the case crashes 23% were fatal and 46% resulted in hospital admission [4]. Thus in the rural study, the relative risk measured was that for a more severe casualty crash than that measured in urban 60 km/h speed zones [1, 2]. The risk related to free travel speed on rural roads is closer to the risk of crashes resulting in a person being killed or seriously injured (KSI), the latter descriptor of crash outcome being normally reserved for hospital admission, not just treated at or taken to hospital.

Previous use of risk estimates to weight speed observations

Kloeden et al.'s relationships have been used in conjunction with real speed observation data in a variety of ways. The general aim has been to estimate the (relative level of) casualty crashes associated with each level or range of illegal speeds in different speed limit environments.

D'Elia et al. [5] applied Kloeden et al.'s [1, 4] risk relationships to free speed data collected twice each year in Victoria during 1999 to 2004 for the purpose of comparing changes in expected crash levels, estimated from changed speed distributions, with direct measures of the crash effects of a major program of speeding-related enforcement/publicity/legislative initiatives during 2001-2002. For speeds measured at 60 km/h limit sites, the relationship (1)

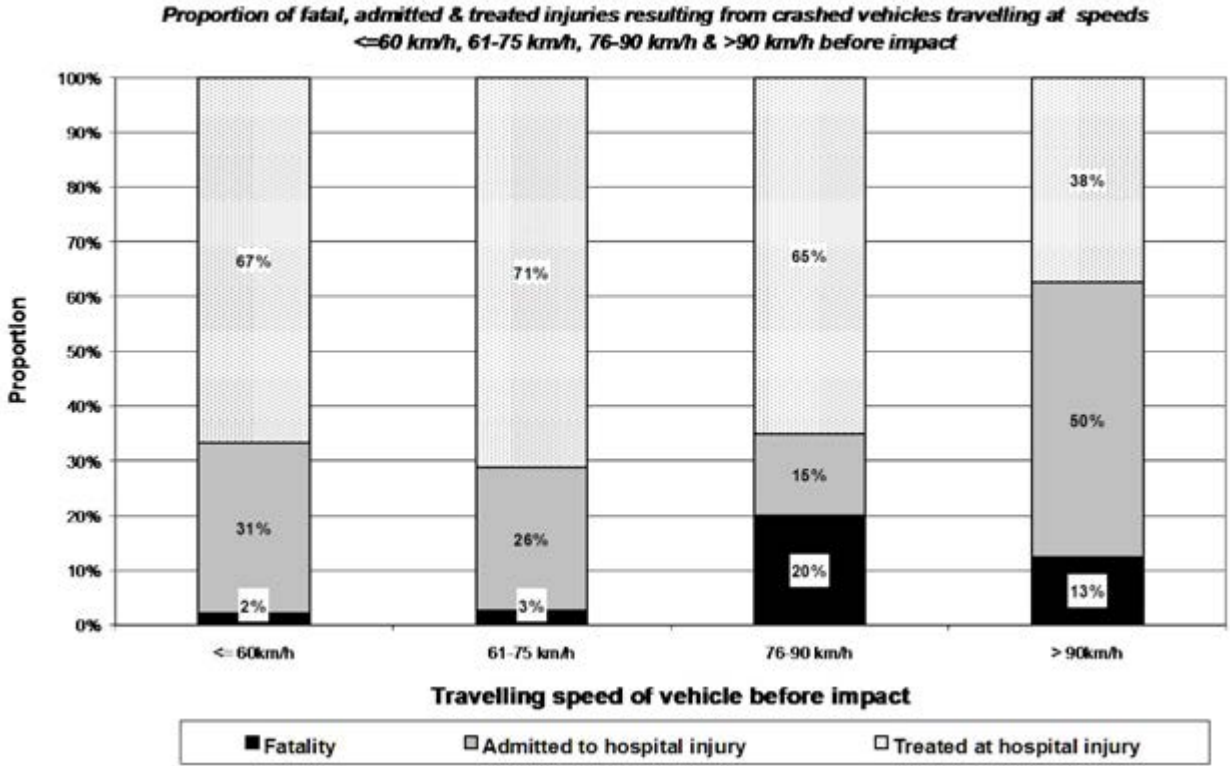

Figure 2: Injury severity related to pre-crash travel speed (60 km/h speed limit zones)

was used weight the speed observations in ranges up to and including "90 km/h or more" by the relative risk calculated at the mid-mark of the speed range. Speeds of 90 km/h or more (no more than 0.3% of observations) were assigned the relative risk for 90 km/h (120.8, from Table 1). The weighted speed observations were then summed (and standardised to the 1999 sum) to estimate a relative expected casualty crash frequency for each of the subsequent surveys during 2000 to 2004, compared with 1999.

Relationship (1) was also used, with 10 or 20 km/h shift of origin, to estimate the relative risks associated with the speeds measured at 70 and 80 km/h limit sites, respectively. For the observations measured at rural sites in different speed limit zones (80 to 110 km/h), Kloeden et al.'s [4] relationship was used instead. The analysis first calculated the zone-specific average free speed in each survey period and then used this to calculate the difference between each speed observation and the average before the rural speed-difference relationship was applied.

Gavin et al. [6] also applied Kloeden et al.'s [1, 4] relative risk relationships to speed observations collected on urban and rural roads in New South Wales during 2008. For the urban speed limit zone analyses, the alternative relationship developed by Kloeden et al. [1] based on the difference between the free speed of the case vehicle and the average free speed of traffic at the same crash location and time of week was used instead of relationship (1). The relative risk estimate was capped at that for 21 km/h speed-difference for speeds more than 20 km/h above the average speed (and capped at 41 km/h speed-difference in the rural analyses) because "[b]eyond these speeds the difference between the upper and lower confidence limits become increasingly large, and the relative risk increases to a level which appears unrealistically large". Gavin et al. grouped the risk-weighted speed observations into bands of speed above the speed limit to examine the association with the estimated relative number of "casualty" crashes in each band. The estimated crashes in each illegal speed band were labelled as being "attributable" to the specific level of speeding. They concluded that the largest proportion of casualty crashes associated with speeding is attributable to drivers exceeding the speed limit by up to 10 km/h and that drivers exceeding the speed limit by 11-20 km/h contribute the second highest proportion.

In a subsequent study, Gavin et al. [7] weighted the speed observations gathered before and after three major speed reduction initiatives in New South Wales for the purpose of comparing the changes in estimated relative casualty crashes with independent evaluations based on actual reported crashes. The speed observation data was available only in 10 km/h wide ranges and a separate process was applied to "smooth" the data into speed distributions for individual speeds. Again, Kloeden et al.'s [1, 4] relative risk relationships based on the difference between the free speed of the case vehicle and the average free speed of traffic in the same speed zone were used; the relationship depending on whether the initiative was relevant to urban or rural roads. Also again, the relative risk estimates were capped for high speeds, namely at 21 km/h above the speed limit on urban roads and 31 km/h above the limit on rural roads, for the same reasons as given by Gavin et al. [6].

Doecke et al. [8] used Kloeden et al.'s [1] relative risk relationship as a function of absolute speed (1) to weight speed observations from 50 and 60 km/h speed limit zones in South Australia during 2008. Only illegal speeds up to 20 km/h above the applicable speed limit were weighted because the "estimates of the relative risk of involvement in a casualty crash ... become less accurate at the higher speeds, being based on a very small number of crashes". They estimated the expected relative frequency of casualty crashes for individual speeds 1 to 20 km/h above the speed limit and found that the frequency decreased consistently as the illegal speed increased.

Holman [9] also used Kloeden et al.'s [1] relationship with absolute speed in conjunction with speed observations from 60 km/h speed zones in Perth during 2010. The analysis was similar to the previous studies outlined above, except that he estimated the "population attributable risk" (PAR) associated with each illegal speed range, i.e. the fraction of crashes in 60 km/h speed zones attributable to the increased risk due to the speeding. Table 2 (solid borders) extracted from Holman [9] shows the calculation, followed by definitions of the symbols used in the heading of each column.

Table 2: Calculation of population attributable risk for speeds in 60 km/h zones in Perth during 2010

Speed of vehicle	p	v	RR	PAR	p*RR	>60 km/h p*RR %
<60 kph	0.534	60*	1.0	0.00	0.534	NA
60-69 kph	0.396	65	1.8	0.16	0.713	46.3%
70-79 kph	0.062	75	7.6	0.20	0.471	30.6%
80+ kph	0.008	85	44.4	0.16	0.355	23.1%
Total	1.000	NA	NA	0.52	2.073	100.0%

Definitions and formulae

p = proportion of total vehicles travelling in this speed interval in 2010.

v = mid-point of this speed interval in kph. *Exactly the legal limit of 60kph is used as the baseline for risk assessment.

RR = incidence rate of [casualty] crash at speed v relative to the legal speed limit of 60kph = Exp[-0.822957835 - 0.083680149*v + 0.001623269*v^2].

PAR = population attributable risk in this speed interval = p*(RR – 1)/(Σp*(RR – 1)+ 1) = proportion of [casualty crashes] attributable to speeding in this speed interval. (Walter [10])

The rationale for the concept of population attributable risk associated with crash risk factors is outlined by Elvik [11]. Its calculation for each level of a polytomous risk factor (as is the speed range factor used in Table 2) is defined by Walter [10], who also suggests labelling the result as the "attributable fraction" of crashes associated with speeding in the specific speed range. In essence, the attributable fraction is the proportion of crashes that are estimated to result from the increase in risk, relative to that at 60 km/h, due to the speeding in the specific range. Some crashes apparently associated with speeding may be due to other factors that are present at legal as well as illegal speeds and that the speeding may only add to that inherent risk.

Also shown in Table 2 (cells with dashed borders) is the expected relative crash frequency (p*RR) typically calculated in previous studies [5, 6, 7, 8]. With this approach, it would be concluded that about twice the proportion of expected crashes associated with speeding lies in the 60-69 km/h range (46%) compared with the proportion above 80 km/h (23%). However, the population attributable risks estimated by Holman [9] suggest that the fraction of casualty crashes attributable to speeding in 60 km/h zones is about the same for 60-69 km/h and above 80 km/h (0.16 or 16% in each case).

Confidence limits on Kloeden et al.'s relative risk curves

Equation (1) indicates that the natural logarithm of the relative risk in urban 60 km/h zones is a quadratic function of travel speed. The natural logarithms (ln) of the estimated relative risks and 95% confidence limits published by Kloeden et al. [1] (Table 1) are shown in Figure 3, together with quadratic functions fitted to each series. The coefficients of the quadratic function fitted to

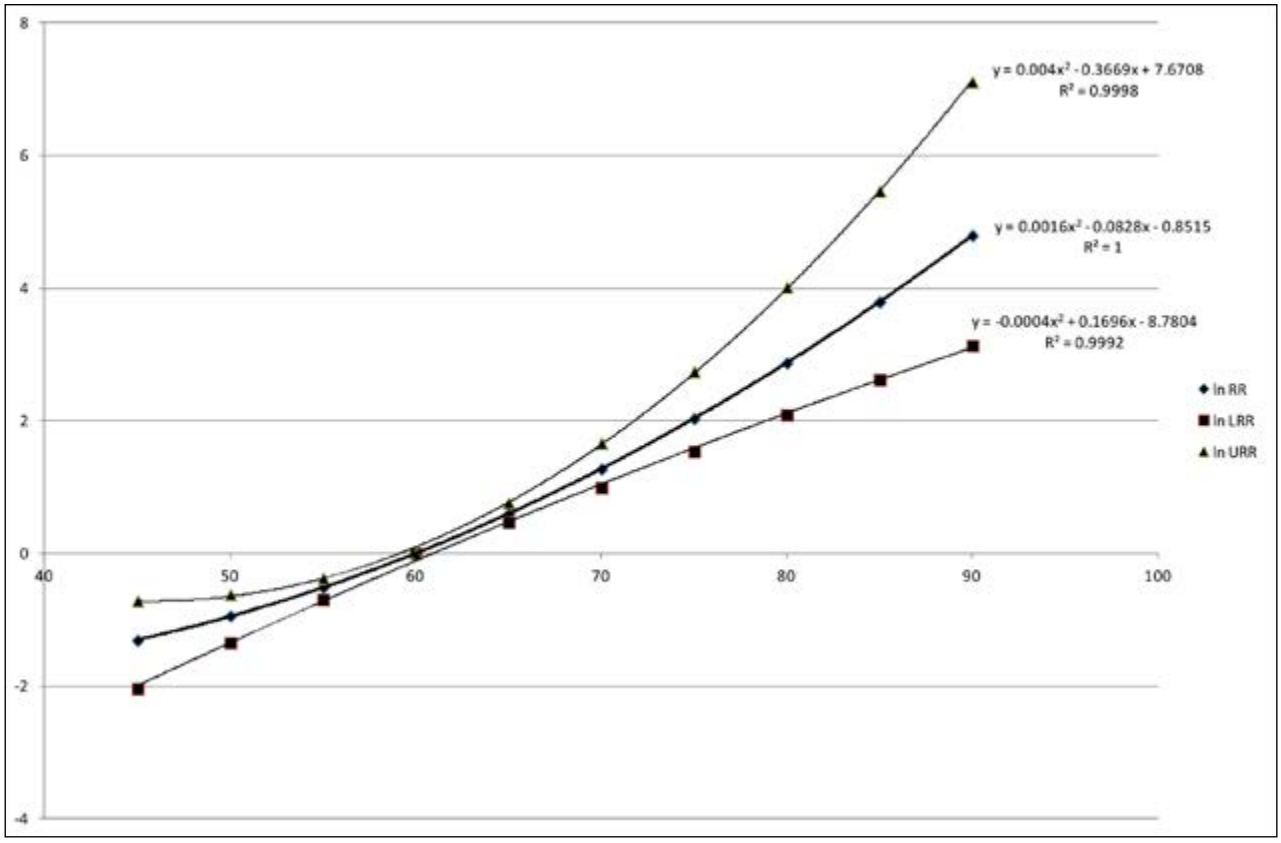

Figure 3: Natural logarithms of Kloeden et al.'s [1] relative risks (RR) and upper (URR) and lower (LRR) confidence limits versus travel speed in 60 km/h limit zones

ln(RR) are within rounding errors of those in equation (1). In subsequent analysis, equation (1) was used and the coefficients for ln(URR) and ln(LRR) were estimated with full precision.

Expected casualty crashes on 60 km/h roads in Perth

Kloeden et al.'s [1] relative risk relationship and the 95% confidence limits where used to estimate the expected relative casualty crashes and their upper and lower limits on 60 km/h roads in Perth, based on the same speed observations used by Holman [9]. The speed observations were classified in 5 km/h wide ranges (with reference speed at the mid-mark), except at the extremities where wider ranges were necessary and reference speeds were chosen as shown in Table 3. The expected relative casualty crashes and their limits are plotted in Figure 4.

Expected serious casualty crashes at illegal speeds

The relative casualty crashes in different speed ranges estimated in Table 3 do not reflect the increased injury severity of the case crashes in Kloeden et al.'s [1] study associated with the higher speeds (Figure 2). The risk of a serious crash outcome (death or hospital admission) of a casualty crash was estimated for each of the illegal speed ranges shown in Figure 2, relative to the risk at speeds in the range 61-75 km/h. These relative risks of serious outcome were used to inflate the risk of a casualty crash at higher speeds to estimate the relative risk of a serious casualty crash (one resulting in a death or hospital admission) in Table 4.

This process of estimating the relative risks of a serious casualty crash from Kloeden et al.'s [1, 2] original data and analysis has the advantage of avoiding the absence of a clear definition of the injury severity profile of the casualty crashes to which Kloeden et al.'s relative risk relationship refers. The crash victims forming the basis of Figure 2 are from the crash cases in Kloeden et al.'s [1, 2] urban study, and the serious injury outcomes are those recorded on Police crash reports. The resulting estimates of the relative risk of a serious casualty crash related to travel speed are also more likely to be compatible with the relative risk of a (severe) casualty crash estimated in Kloeden et al.'s [4] study, which as indicated earlier, is closer to being related to the risk of a serious casualty crash.

The relative risk of a serious casualty crash, together with upper and lower limits estimated in the same way, were used to estimate the relative serious casualty crashes (and limits) from the observed speed distributions in the illegal speed ranges (Table 4 and Figure 5). The expected serious casualty crashes at travel speeds above 80 km/h exceed those associated with speeds in the 60-70 km/h range, though the confidence limits suggest that the estimates associated with the higher speeds are much less reliable.

Table 3: Expected relative casualty crashes and upper and lower confidence limits versus speed on 60 km/h speed zone roads in Perth, 2010

Speed range (km/h)	Mid-mark or reference speed	Frequency of speeds observed in 2010	Percent of speeds observed	Estimated relative risk (relative to 60 km/h)	Expected relative casualty crashes	Lower relative casualty crashes	Upper relative casualty crashes
0-30	20	6,978	1.05%	0.158	0.0017	0.0000	0.0728
30-40	35	23,571	3.55%	0.171	0.0061	0.0012	0.0274
40-45	42.5	24,935	3.75%	0.235	0.0088	0.0037	0.0190
45-50	47.5	43,520	6.55%	0.321	0.0210	0.0124	0.0323
50-55	52.5	85,892	12.93%	0.476	0.0616	0.0462	0.0755
55-60	57.5	169,940	25.58%	0.765	0.1957	0.1696	0.2167
60-65	62.5	175,230	26.37%	1.334	0.3517	0.3177	0.3959
65-70	67.5	88,133	13.26%	2.521	0.3344	0.2844	0.4312
70-75	72.5	31,134	4.69%	5.168	0.2422	0.1751	0.4031
75-80	77.5	9,846	1.48%	11.491	0.1703	0.0945	0.4123
80-90	85	4,343	0.65%	44.360	0.2900	0.0894	1.5406
90+	90	892	0.13%	120.82	0.1622	0.0298	1.690
Total		664,414	100.00%		1.846	1.224	5.316

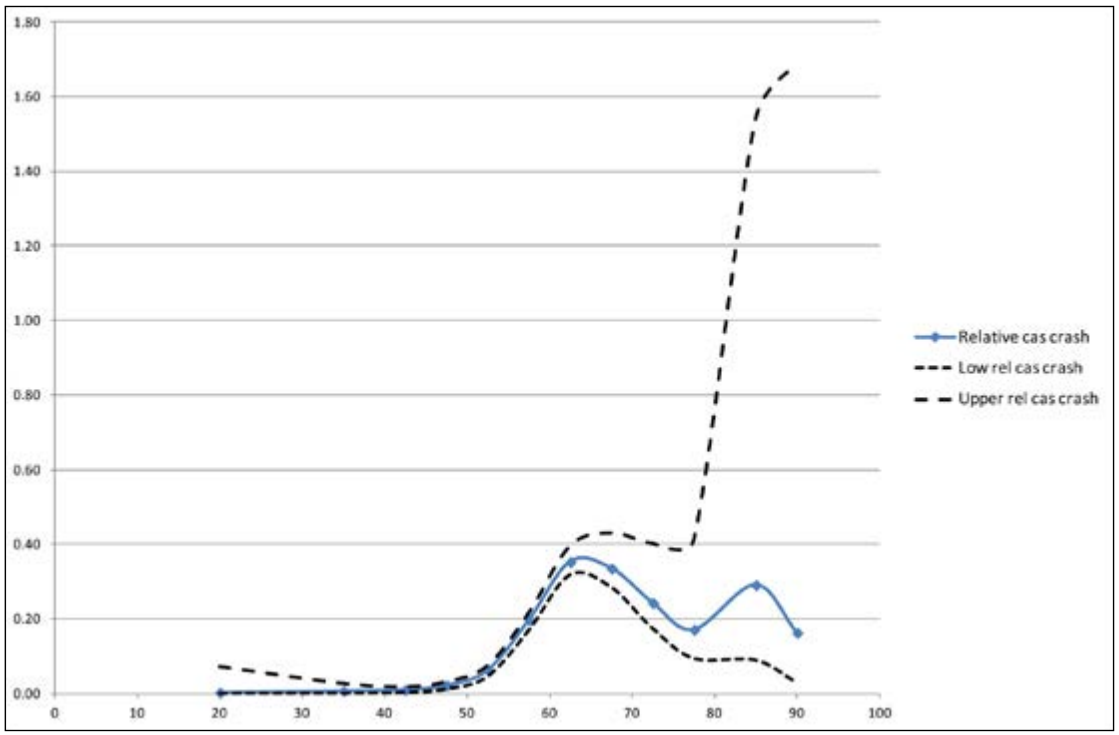

Figure 4: Expected relative casualty crashes and upper and lower limits on Perth 60 km/h limit roads

Table 4: Expected relative serious casualty crashes and upper and lower confidence limits versus speed on 60 km/h speed zone roads in Perth, 2010

Speed range (km/h)	Percent of speeds observed	Estimated relative risk of casualty crash (relative to 60 km/h)	Relative risk of serious crash outcome (relative to 61-75 km/h)	Estimated relative risk of serious casualty crash	Expected relative serious casualty crashes	Lower relative serious casualty crashes	Upper relative serious casualty crashes
60-65	26.37%	1.334	1.00	1.334	0.3517	0.3177	0.3959
65-70	13.26%	2.521	1.00	2.521	0.3344	0.2844	0.4312
70-75	4.69%	5.168	1.00	5.168	0.2422	0.1751	0.4031
75-80	1.48%	11.491	1.22	14.019	0.2078	0.1153	0.5030
80-90	0.65%	44.360	1.22	54.119	0.3538	0.1091	1.8795
90+	0.13%	120.82	2.17	262.18	0.3520	0.0646	3.666

Attributable fraction of casualty crashes

The attributable fraction of casualty crashes due to each range of speeds on Perth 60 km/h limit roads was calculated as defined by Walter [10], together with lower and upper limits again based on the confidence limits for Kloeden et al.'s [1] relationship (Table 5). The bottom part replicates Holman's [9] table (Table 2 here, with solid borders), except that more speeding categories are used. However the top part of Table 5 provides attributable fractions for speed ranges below the limit and, as would be expected, negative contributions of these speeds to crash attribution are estimated. Walter [10] describes factors with a negative contribution as "protective factors" and PAR for these factors as "protective fractions".

From Table 5, it is estimated that 59% of casualty crashes are attributable to speeding. However, based on this analysis, it is estimated that only 16% are attributable to speeding in the 60-70 km/h range compared with 24% exceeding 80 km/h. The attributable fraction due to each speed range, both below and above the 60 km/h limit, is shown in Figure 6.

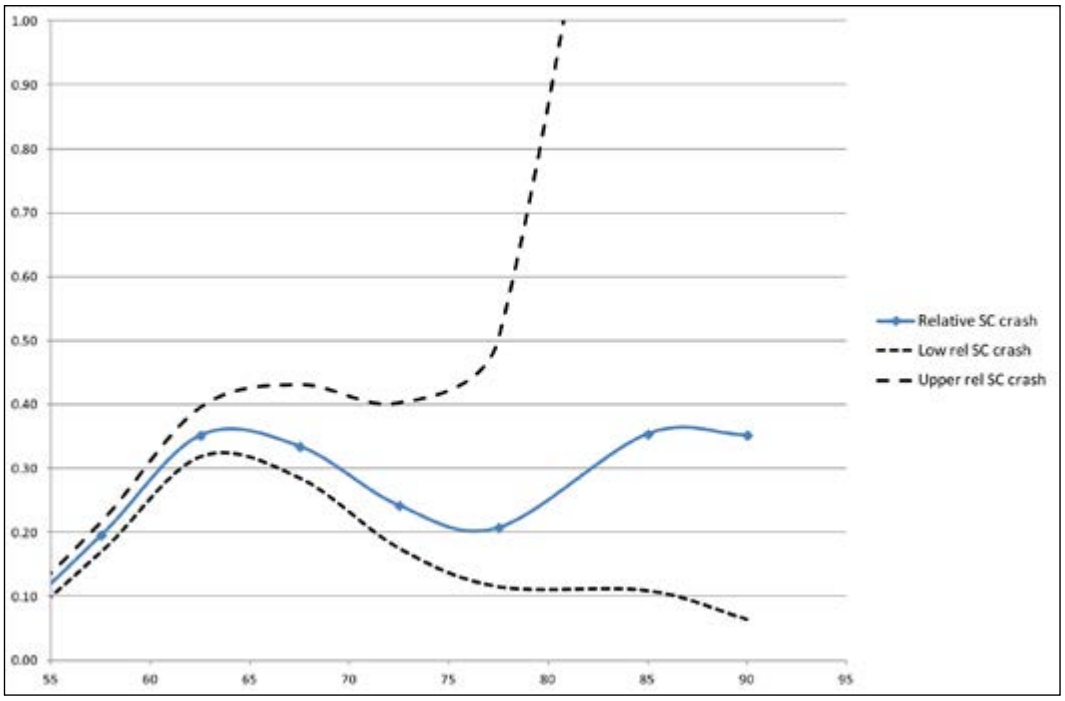

Figure 5: Expected relative serious casualty crashes associated with illegal speeds on Perth 60 km/h roads

Table 5: Attributable fraction of casualty crashes due to speeds on 60 km/h speed zone roads in Perth, 2010

			Contribution to speed attributable fraction: p*(RR – 1)			Estimated population attributable risk (PAR) fraction of casualty crashes		
Speed range (km/h)	Percent of speeds observed (p*100)	Estimated relative risk of casualty crash (RR)	Based on relative risk (RR)	Based on lower limit of relative risk (LRR)	Based on upper limit of relative risk (URR)	Attributable fraction (%)	Lower attributable fraction (%)	Upper attributable fraction (%)
0-30	1.05%	0.158	-0.0088	-0.0105	0.0623	-0.5%	-0.6%	3.4%
30-40	3.55%	0.171	-0.0294	-0.0342	-0.0081	-1.6%	-1.9%	-0.4%
40-45	3.75%	0.235	-0.0287	-0.0339	-0.0185	-1.6%	-1.8%	-1.0%
45-50	6.55%	0.321	-0.0445	-0.0532	-0.0332	-2.4%	-2.9%	-1.8%
50-55	12.93%	0.476	-0.0677	-0.0831	-0.0537	-3.7%	-4.5%	-2.9%
55-60	25.58%	0.765	-0.0601	-0.0862	-0.0391	-3.3%	-4.7%	-2.1%
60-65	26.37%	1.334	0.0880	0.0540	0.1322	4.8%	2.9%	7.2%
65-70	13.26%	2.521	0.2018	0.1517	0.2986	10.9%	8.2%	16.2%
70-75	4.69%	5.168	0.1953	0.1282	0.3563	10.6%	6.9%	19.3%
75-80	1.48%	11.491	0.1555	0.0797	0.3975	8.4%	4.3%	21.5%
80-90	0.65%	44.360	0.2834	0.0829	1.5341	15.4%	4.5%	83.1%
90+	0.13%	120.82	0.1609	0.0284	1.6882	8.7%	1.5%	91.5%

Attributable fraction of serious casualty crashes

The estimated relative risks of a serious casualty crash (Table 4) were used to estimate the attributable fraction of these crashes due to illegal speeds in each speed range (Table 6). The estimated attributable fractions, together with upper and lower limits, are shown in Figure 7.

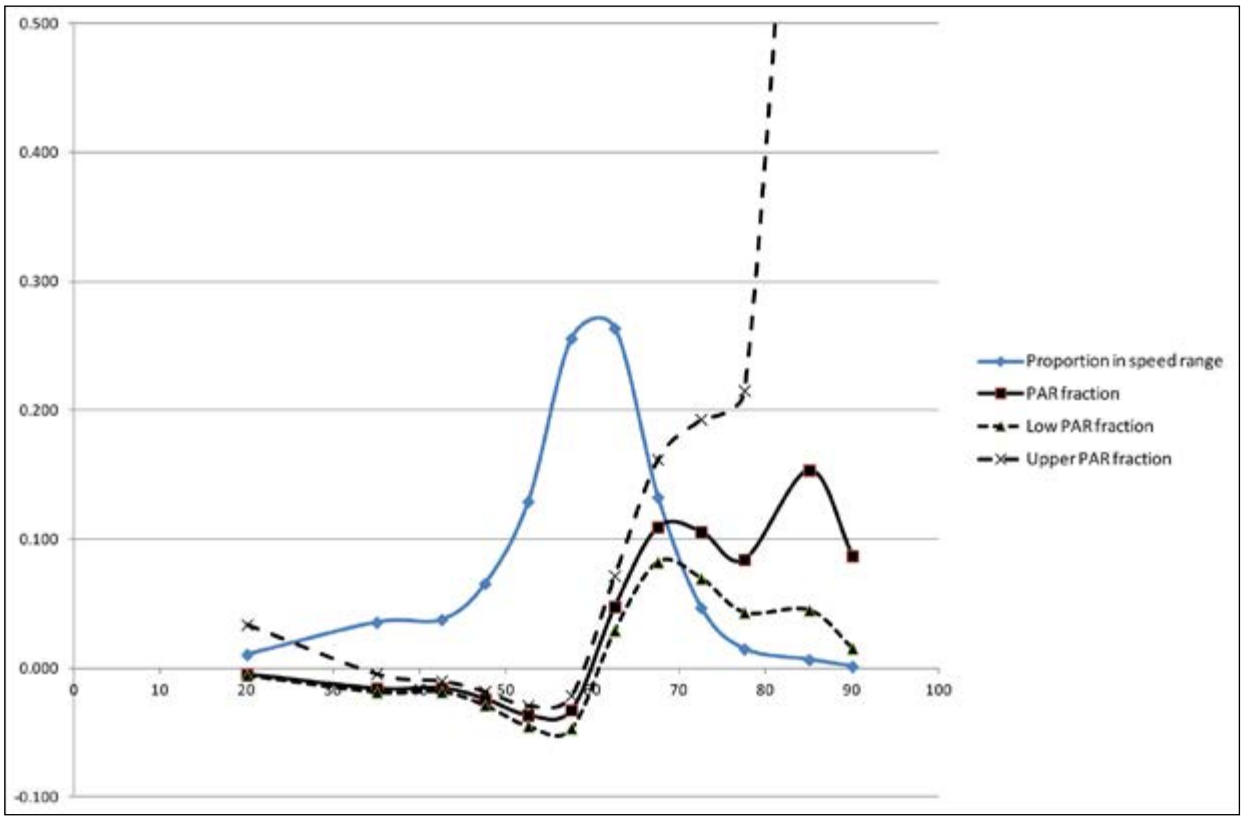

Figure 6: Estimated attributable fraction of casualty crashes for each speed range, plus high and low limits on the estimated attributable fractions

Table 6: Attributable fraction of serious casualty crashes due to speeding on 60 km/h speed zone roads in Perth, 2010

			Contribution to speed attributable fraction: p*(RR – 1)			Estimated population attributable risk fraction of serious casualty crashes		
Speed range (km/h)	Percent of speeds observed (p*100)	Estimated relative risk of serious casualty crash (RR)	Based on relative risk (RR)	Based on lower limit of relative risk (LRR)	Based on upper limit of relative risk (URR)	Attributable fraction (%)	Lower attributable fraction (%)	Upper attributable fraction (%)
60-65	26.37%	1.334	0.0880	0.0540	0.1322	3.7%	2.3%	5.6%
65-70	13.26%	2.521	0.2018	0.1517	0.2986	8.5%	6.4%	12.6%
70-75	4.69%	5.168	0.1953	0.1282	0.3563	8.2%	5.4%	15.0%
75-80	1.48%	14.019	0.1929	0.1005	0.4882	8.1%	4.2%	20.5%
80-90	0.65%	54.119	0.3472	0.1025	1.8730	14.6%	4.3%	78.8%
90+	0.13%	262.18	0.3506	0.0632	3.6650	14.8%	2.7%	154.3%*

* The fraction cannot exceed 100%. The calculated figure indicates that the upper limit is indeterminate.

Speeds on Queensland 60 km/h urban roads

The preceding analysis of risks associated with travel speeds on 60 km/h speed limit roads in Perth was based on 664,414 free speed observations collected during 2010. The analysis is sensitive to the reliability of the estimates of the proportion of vehicles in each of the high speed ranges. While the sample was large, the estimated proportion of vehicles exceeding 90 km/h was only 0.13% and the estimated proportion in the 80 to 90 km/h range was 0.65%.

Information was available on the free speeds travelled on urban 60 km/h limit roads in Queensland during 2010 [12]. There had been a decrease in mean speeds and the

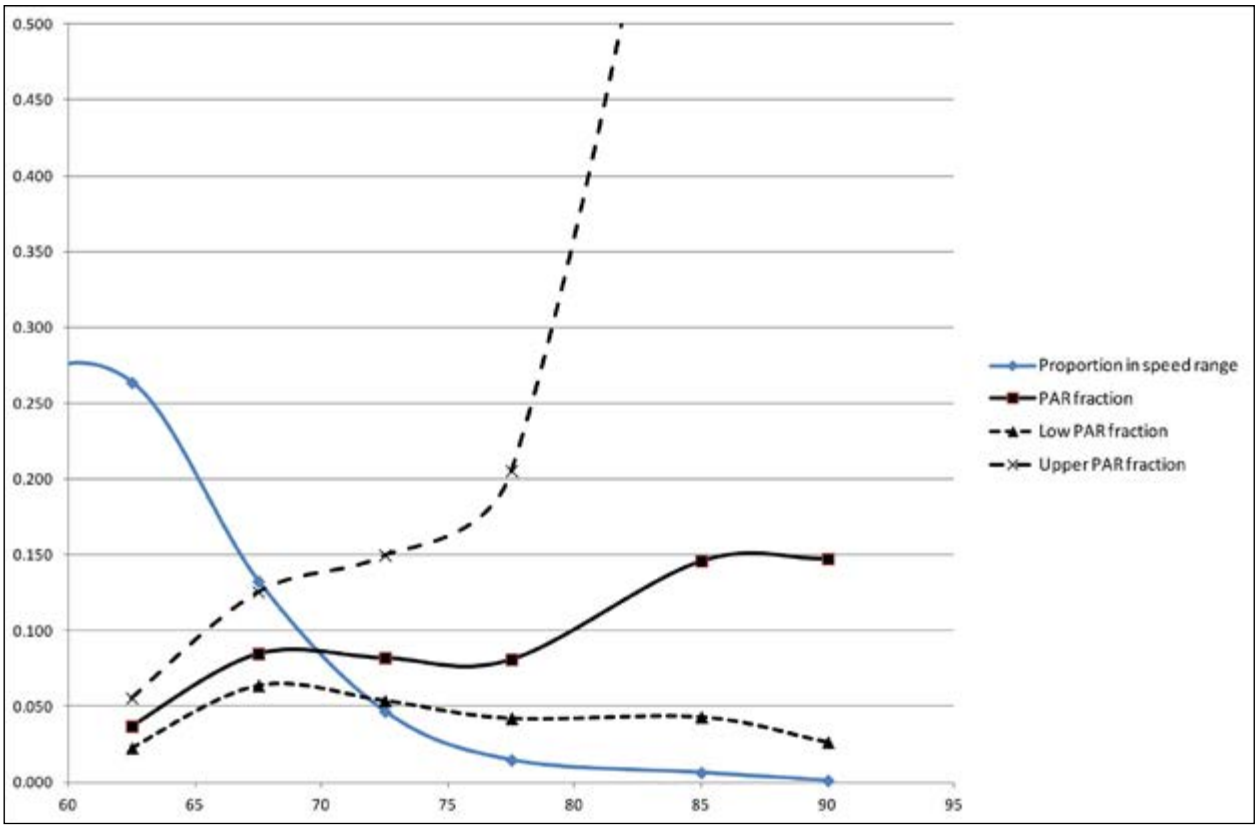

Figure 7: Estimated attributable fraction of serious casualty crashes for each illegal speed range, plus high and low limits on the estimated attributable fractions

Table 7: Attributable fraction (population attributable risk) of casualty crashes due to speeding on 60 km/h speed zone roads in Queensland, 2010

Speed range (km/h)	Percent of speeds observed	Estimated relative risk of casualty crash (relative to 60 km/h)	Attributable fraction (%)	Estimated lower attributable fraction (%)	Estimated upper attributable fraction (%)
60-65	24.01%	1.334	4.0%	2.5%	6.0%
65-70	10.93%	2.521	8.3%	6.3%	12.3%
70-75	4.18%	5.168	8.7%	5.7%	16.0%
75-80	1.62%	11.491	8.5%	4.4%	21.8%
80-90	0.93%	44.360	20.3%	5.9%	109.7%*
90+	0.21%	120.82	12.4%	2.2%	130.4%*

* The fraction cannot exceed 100%. The calculated figure indicates that the upper limit is indeterminate.

percentage exceeding the limit on these roads between 2009 and 2010, but speeds during 2010 were relatively stable. The two surveys in 2010 (May and November) recorded the free travel speeds of 2,532,322 vehicles on urban 60 km/h limit roads.

Using analysis identical to that described above for Perth 60 km/h limit roads, the attributable fraction of casualty crashes due to each speeding range on 60 km/h limit roads in Queensland was estimated (Table 7). Although there was a larger proportion of vehicles not speeding on these roads in Queensland (58.1%) compared with Perth (53.4%), there were also larger proportions in the higher speed categories in Queensland. This translated into Queensland having a higher attributable fraction of casualty crashes due to speeding above 80 km/h (33%, summed from Table 7) compared with the same type of attributable fraction in Perth (24% from Table 5).

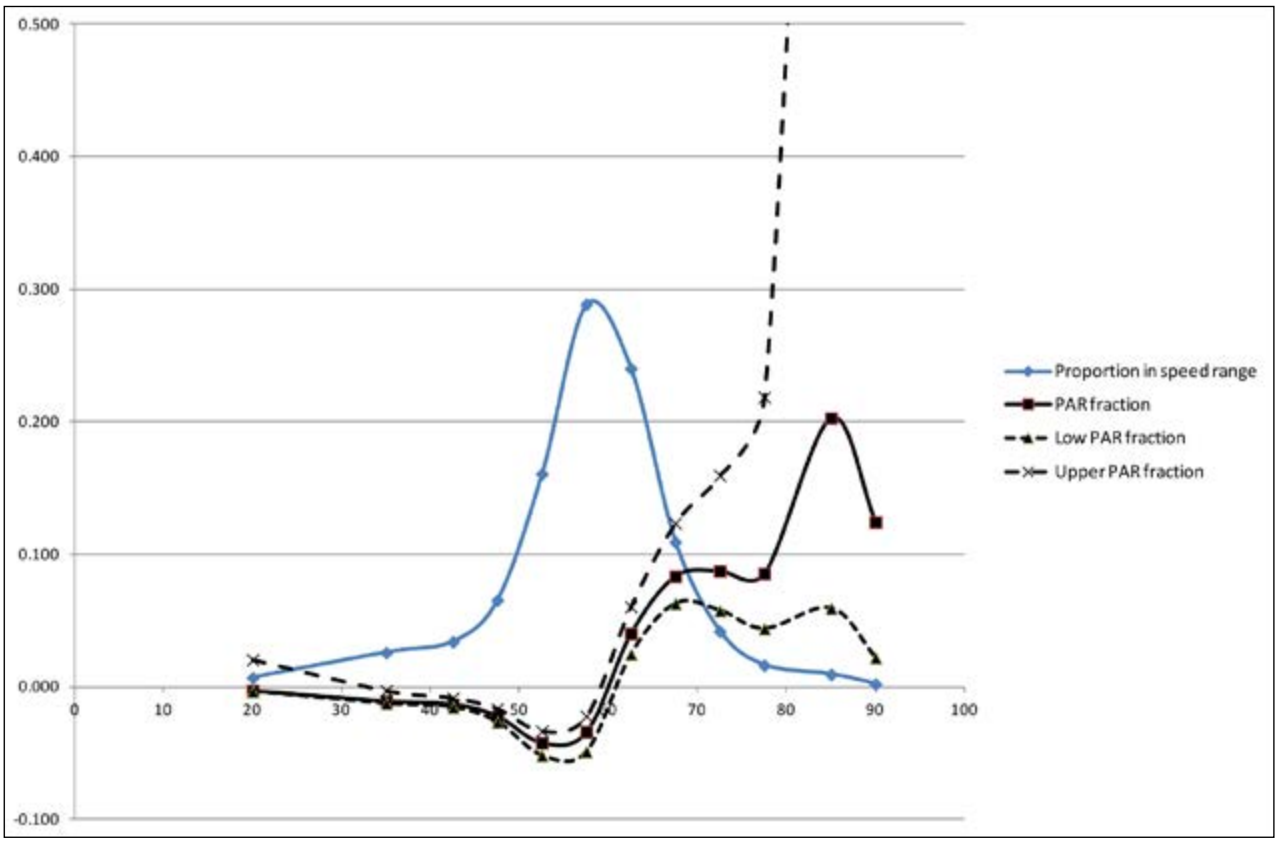

Figure 8: Estimated attributable fraction of casualty crashes for each speed range on 60 km/h zone roads in Queensland, plus high and low limits on the estimated attributable fractions

Table 8: Attributable fraction of serious casualty crashes due to speeding on 60 km/h speed zone roads in Queensland, 2010

Speed range (km/h)	Percent of speeds observed	Estimated relative risk of serious casualty crash	Attributable fraction (%)	Estimated lower attributable fraction (%)	Estimated upper attributable fraction (%)
60-65	24.01%	1.334	3.0%	1.8%	4.5%
65-70	10.93%	2.521	6.2%	4.7%	9.2%
70-75	4.18%	5.168	6.5%	4.3%	11.9%
75-80	1.62%	14.019	7.9%	4.1%	20.1%
80-90	0.93%	54.119	18.6%	5.5%	100.1%*
90+	0.21%	262.18	20.2%	3.6%	211.6%*

* The fraction cannot exceed 100%. The calculated figure indicates that the upper limit is indeterminate.

The attributable fractions in Queensland are shown in Figure 8, which can be compared with the same type of analysis for 60 km/h limit roads in Perth (Figure 6). This figure indicates that the speed ranges above 80 km/h can be attributed with a higher proportion of casualty crashes than each of the lower speeding ranges, or at least as great a proportion when the lower limits of these estimated attributable fractions are taken into account.

The analysis of the attributable fraction of serious casualty crashes due to illegal speeds on Queensland 60 km/h limit roads (Table 8) found an even higher fraction due to speeding above 80 km/h (39%) than the fraction of casualty crashes in the same speed range (33%). The lower limits of the attributable fraction for each speeding range (Figure 9) confirm that speeding in the 80-90 km/h range can be attributed with a higher proportion of serious casualty crashes than each of the lower speeding ranges.

Discussion and conclusions

Kloeden et al.'s [1, 2, 4] relative risk relationships have provided valuable opportunities for researchers to examine the share of crashes associated with each speed range by weighting speed observations by the relative risk in each range. However, in most cases [6, 7, 8, 9] the researchers have truncated Kloeden et al.'s relative risk estimates below the highest speeds because of concerns about the accuracy of the higher speed estimates. This study has attempted to avoid that limitation by making use of the confidence limits of the urban relative risk relationship as a function of absolute speed in 60 km/h speed limit zones [1]. However there is a limit to which the confidence limits were available and only those limits associated with 90 km/h speed were used in conjunction with speed observations of at least that speed.

This study has noted that the "casualty crashes" analysed by Kloeden et al. in their urban [1, 2] and rural [4] studies have different criteria for the case crash selection related to the transport to or treatment of persons at hospital. This is reflected in the injury severity profile of the crashes for which each risk relationship has been developed. Because of the availability of a previous study in which Kloeden et al.'s [2] case crashes had been matched with Police crash reports [3], it was possible to adjust the urban relative risk relationship (and its confidence limits) to represent the risk of a serious casualty crash at speeds above the 60 km/h speed limit.

An interpretation of previous research may be to label the estimated casualty crash frequencies in each illegal speed range as being crashes due to the speeding behaviour. Holman's [9] important contribution to this type of analysis was to introduce the concept of "population attributable risk" associated with speeding as a risk factor, i.e. a factor that increases the risk of a casualty crash compared with the risk when not speeding. This concept was used in the new analysis in this study to better estimate the proportion of casualty crashes ("attributable fraction") that is attributable to the increase in risk associated with each illegal speed range. The other previous researchers [5, 6, 7, 8] have estimated the relative number of casualty crashes associated with each speed range, but these crashes are not all attributable to the illegal speed in the range (particularly at low illegal speeds where the increase in relative risk is modest).

The analysis presented here suggests that the relative number of casualty crashes associated with speeds above 80 km/h on 60 km/h roads is at least as great as the number associated with illegal speeds in the 60 to 70 km/h range. Doecke et al.'s [8] analysis had suggested that the expected

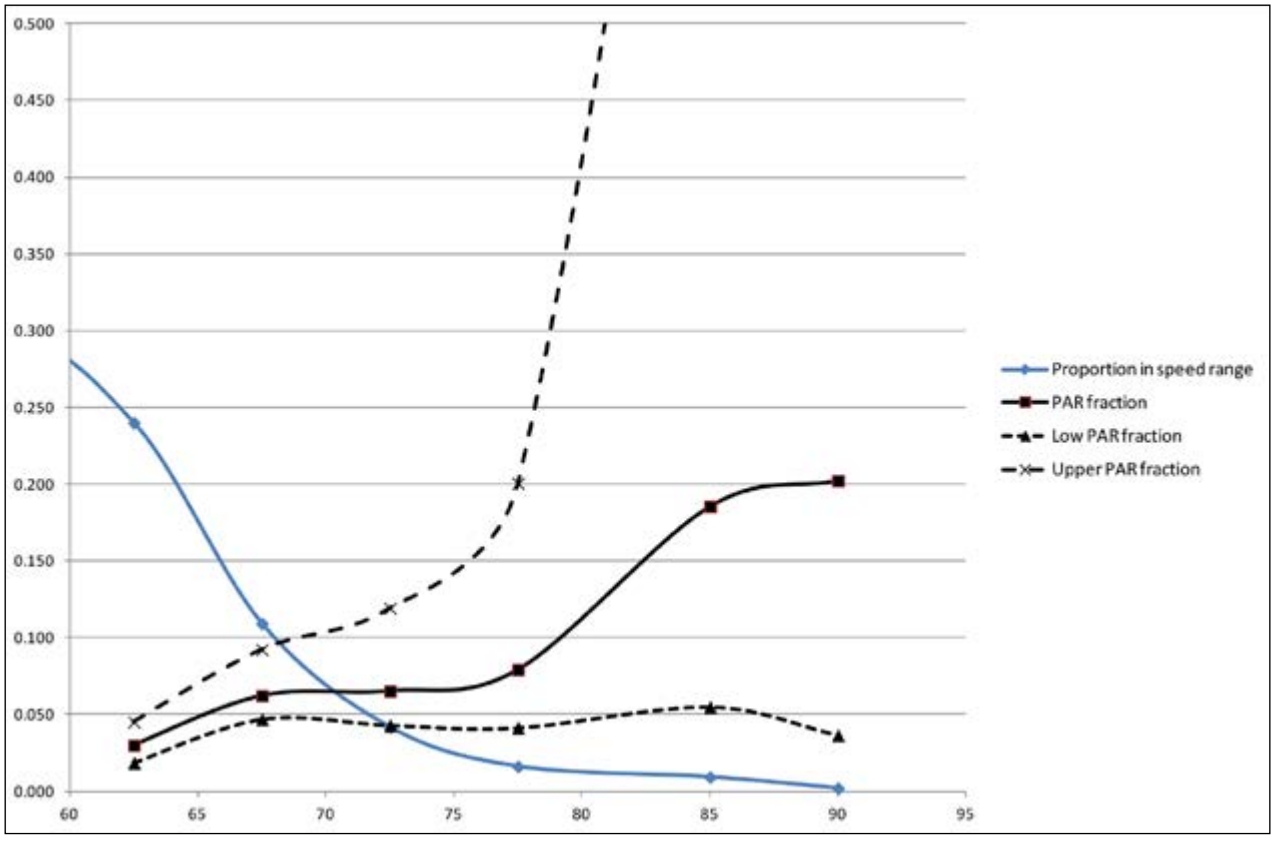

Figure 9: Estimated attributable fraction of serious casualty crashes for each illegal speed range on 60 km/h roads in Queensland, plus high and low limits on the estimated attributable fractions

number of casualty crashes falls consistently as illegal speed increases, but their analysis was truncated to speeds no greater than 80 km/h. When the attributable fraction of casualty crashes due to each illegal speeding range was estimated, the analysis found that it was higher for speeds above 80 km/h than speeds in the 60 to 70 km/h range. This difference was found to be greater on Queensland 60 km/h limit roads compared with those in Perth, and greater again when the attributable fractions for serious casualty crashes were estimated.

The conclusions of this study need to be tempered by the wide confidence limits associated with Kloeden et al.'s [1] relative risk relationship at high speeds on 60 km/h limit roads. Because of the importance of Kloeden et al.'s [1, 4] relationships for policy decisions about the relative contribution of low and high level speeding to road trauma, it is critical that research be undertaken to improve the reliability of relationships of this type. The urban relationship was based on 151 vehicles that crashed in Adelaide during 1995-1996. Intensive investigation of these crashes made it possible to reliably estimate the pre-crash travel speeds of these vehicles. Speed observations at the crash site were also required, but with modern technology the gathering of this information is not nearly as labour intensive as the crash investigations. With numerous police investigators and other crash researchers reviewing serious crashes throughout Australia, giving attention to estimating pre-crash travel speeds using technology such as in-vehicle Event Data Recorders, it should be possible to replicate Kloeden et al.'s [1, 2, 4] studies on a grander scale and provide the basis of more reliable relationships connecting speed and road trauma.

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