VEHICLE TRAVEL SPEEDS AND THE INCIDENCE OF FATAL PEDESTRIAN CRASHES

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ABSTRACT

The aim of this study was to estimate the likely effect of reduced travel speeds on the incidence of pedestrian fatalities in Adelaide, Australia. The study was based on the results of detailed investigations of 176 fatal pedestrian crashes in the Adelaide area between 1983 and 1991. The method developed to estimate the effect of reduced travelling speed is described, and supported by references to the published literature.

A reduction in the speed limit from 60 to 50 km/h was one of 26 speed reduction scenarios which were considered. The results for a selection of these 26 scenarios are presented in the paper. The smallest estimated reduction in fatal pedestrian collisions in the selection presented was 13 per cent, for a scenario in which all drivers obeyed the existing speed limit. The largest estimated reduction was 48 per cent for a scenario in which all drivers were travelling 10 km/h slower.

The estimated reductions in fatalities obtained in this study are compared with those observed in places where the urban area speed limit has been lowered.

WALZ, HOEFLIGER AND Fehlmann (1983) reported that the reduction of the speed limit from 60 to 50 km/h in Zurich was accompanied by a reduction of 20 per cent in pedestrian casualties and a 25 per cent decrease in pedestrian fatalities. These reductions were attributed to the change in travelling speeds caused by the change in the speed limit. The number of pedestrians with ISS scores greater than 30 decreased, with the mean ISS decreasing from 28 to 20. The incidence of fractures to the pelvis and ribs were reduced by 50 per cent. Those who were fatally injured also had fewer fatal injuries. In 18 per cent of the crashes the collision speed was equal to the travelling speed of the striking vehicle, but in 62 per cent the collision speed was reduced to at least one-fifth less than the travelling speed.

Fieldwick and Brown (1987) studied the road crash fatality and casualty rates of 21 countries to develop a regression model based on population, the number of vehicles and the posted speed limits in both urban and rural areas. They concluded that those countries which have an urban speed limit of 60 km/h could reduce their fatalities and casualties by 25 per cent if they lowered the limit to 50 km/h.

AIM

The aim of this study was to estimate the likely effect of reduced travel speeds on the incidence of pedestrian fatalities in Adelaide, Australia.

METHODS

DATA - One hundred and seventy six fatal pedestrian collisions that occurred in the Adelaide metropolitan area were investigated by the NHMRC Road Accident Research Unit as part of a continuing study of the mechanisms of brain injury. Each case study commenced with attendance at the autopsy of a fatally injured pedestrian and continued with an examination of the vehicle involved and the scene of the collision. In most cases statements were available, or were obtained from the driver and from any witnesses. Of the 176 cases, 153 occurred in zones which had a posted speed limit of 60 km/h.

DEFINITION OF A CASE - A case is defined as a crash in which at least one pedestrian received fatal injuries as a result of a collision with a vehicle.

COMPOSITION OF THE SAMPLE - For the purposes of the analysis, the cases were initially separated into two categories. The first category included all cases in which, based on the circumstances of the collision, it was assumed that the impact speed would have been unaffected by a general lowering of travelling speeds. Specifically, the cases in this category included (a) those cases where the vehicle was not travelling at a steady speed (e.g. the vehicle was accelerating from a standstill, or had reduced speed in a turn, etc.); (b) those cases where the driver had lost control of the vehicle and the collision with the pedestrian occurred off the carriageway; (c) cases where the pedestrian's intention was to commit suicide; and (d) cases where the driver had lost consciousness before the collision with the pedestrian (Table 1).

Table 1: Sample Characteristics

	60 km/h Zone Only	
	No. of Cases	No. of Fatalities
*Category 1**		
Vehicle manoeuvring	12	13
Off road	1	1
Driver unconscious	3	4
Suicide	4	4
*Category 2**		
Cases analysed	118	120
Insufficient information for analysis	15	16
Total	153	158

** See text*

The second category of cases were those in which the vehicle kinetics were relevant to the purpose of this study. It comprised 132 cases in which the striking vehicle was travelling at a free or steady speed. Not all collisions in this category could be analysed however. In 15 cases, not all of the information required to reconstruct the collision was available.

COLLISION RECONSTRUCTION - The travelling and impact speeds of the striking vehicle were estimated from the available physical evidence. In some cases that was supplemented by statements from the driver and any witnesses.

The beginning of the crash sequence was taken to be the instant before the driver recognised that a collision was likely (notated as time t_0). The position of the vehicle at this time became the reference position for further analysis.

In 45 per cent of the 118 cases the driver stated that no evasive action prior to the accident was attempted, typically because the pedestrian was not seen before the accident or the driver did not realise there was a danger of collision. The impact speed in these cases was equal to the travelling speed of the vehicle.

In the other 55 per cent of the analysed cases, some evasive action was taken. As the evasive action was typically emergency braking, the travelling speed of the vehicle could usually be estimated from braking skid marks (see for example, Reed and Keskin, 1989, Bullen and Ruller, 1992 and Warner et al 1988). In 11 per cent of the cases where some evasive action was taken, reconstruction of the impact speed was based mainly on the distance the pedestrian was thrown (Searle and Searle, 1982), with the corroboration of drivers and/or witnesses. The remaining cases were reconstructed using other techniques such as momentum transfer, such as in cases involving motorcycles that slid to a halt after the collision (Donohoe, 1991 and Searle and Searle, 1982), in conjunction with statements from witnesses. When no skid marks were left by the vehicle, but the driver did brake, we assumed that the vehicle was on the verge of wheel lockup and an assumed coefficient of friction was used to determine the position of the vehicle at the start of braking.

A base reaction time (including the time taken to realise the need to attempt avoiding action) of 1.5 seconds was used for each driver (Olson, 1991). This time was then multiplied by a factor which depended on the driver's Blood Alcohol Concentration (BAC). For BACs greater than zero but less than 0.10, reaction time was increased by 20 per cent; for BACs less than 0.15 but greater than or equal to 0.10, reaction time was increased by 55 per cent. If the drivers BAC was greater than or equal to 0.15 then it was assumed that their reaction time would be increased by 100 per cent (Pauwels and Helsen, 1993). The age and sex of the driver, as well as the task complexity of the situation, were not accounted for, as these factors have been reported to have a relatively smaller effect on reaction time (Bell, Loomis and Cervone, 1982).

The distance the vehicle travelled during the driver's reaction time and, where appropriate, the distance it travelled from brake application to the appearance of the skid marks plus the skid mark length before impact, gave the position of the vehicle at time t_0 relative to the point of impact. It was then a simple task to express the impact speed as a function of physical parameters associated with the collision;

i.e. impact speed = f(travelling speed, reaction time, friction coefficients, etc.)

We then used these functions to estimate the outcome of the cases if the travelling speed was changed, given all other parameters associated with the case were held constant.

REDUCED TRAVELLING SPEED SCENARIOS - A selection from the modified travelling speed scenarios that were applied to the case data is listed in Table 2.

Table 2: Summary of the Scenarios Tested

Scenario	Description	Notation
1	Uniform 5 km/h travelling speed reduction in all cases	$v_0^* = v_0 - 5$ (km/h)
2	Uniform 10 km/h travelling speed reduction in all cases	$v_0^* = v_0 - 10$ (km/h)
3	No speed to exceed the existing speed limit	$v_0 < 60,\ v_0^* = v_0$ (km/h) $v_0 \geq 60,\ v_0^* = 60$ (km/h)
4	Travelling speeds reduced to a speed limit of 50 km/h with the same magnitude of violation (those vehicles exceeding the existing speed limit by x km/h, exceed the new limit by x km/h).	$v_0 \leq 50,\ v_0^* = v_0$ (km/h) $50 < v_0 \leq 60,\ v_0^* = 50$ (km/h) $v_0 > 60,\ v_0^* = 50 + (v_0 - 60)$ (km/h)

v_0= estimated travelling speed
v_0^*= hypothetical travelling speed

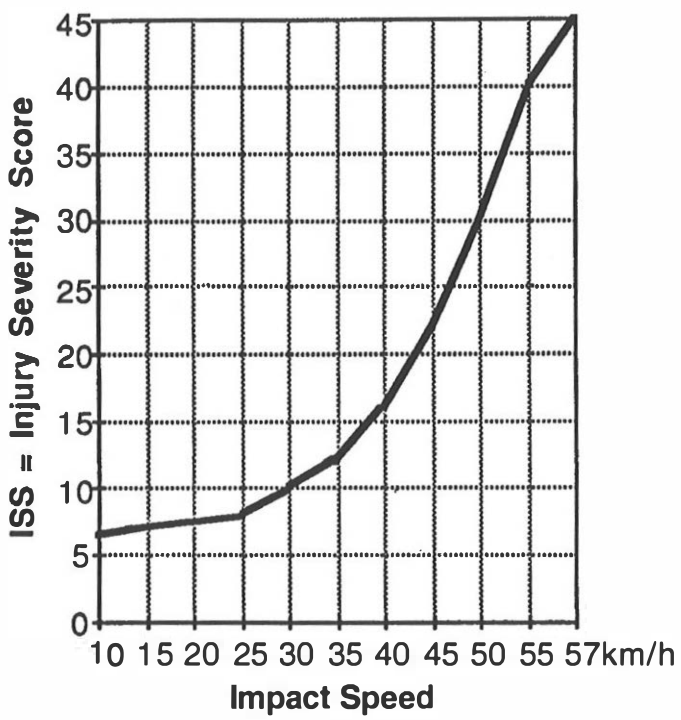
ESTIMATING IMPACT SPEEDS FOR HYPOTHETICALLY REDUCED TRAVELLING SPEEDS - The following assumptions were made when estimating hypothetical impact speeds for the reduced travelling speed scenarios: (a) The pedestrian involved in the accident was unable to take any action to avoid the collision. It could be argued that, in some cases, reducing the travelling speed of the vehicle may have given the pedestrian time to get out of the path of the oncoming vehicle. By ignoring that possibility, we may have arrived at a conservative estimate of the benefits of the speed reduction; (b) If no evasive action was taken by the driver of the vehicle in the actual accident then this behaviour would remain unchanged by changing the travelling speed; and (c) In any scenario tested, the impact point and the location of the vehicle at time t_0 remained the same as in the actual case.

IMPACT SPEED AND THE PROBABILITY OF SURVIVAL - An estimate of the probability of the pedestrian being fatally injured at a given impact speed was used to determine the likely effect of the reduced travelling speeds on the number of fatalities in the sample. The Interdisciplinary Working Group for Accident Mechanics (1986) assigned a potential Injury Severity Score (ISS) to a given impact speed (Figure 1). Although this data has acknowledged limitations in application, little alternative data exists. The probability of the pedestrian being fatally injured as a function of ISS (determined from 952 cases) was presented by Walz, Hoefliger and Fehlmann (1983). These data were combined to relate the probability of survival to impact speed (Figure 2).

Using the relationship shown in Figure 2, the probability of survival was calculated for each case under each scenario and hence the effect of the specified reduction in travelling speed over the entire sample, as described below.

Consider a case in which a pedestrian was fatally injured at an impact speed of 45 km/h. The predicted probability of an impact being fatal at that impact speed is 61%, as shown in Figure 2. Suppose that a hypothetical reduction in travelling speed results in an estimated reduction in impact speed of 5 km/h. At the resulting estimated impact speed of 40 km/h the probability of a pedestrian being fatally injured is predicted to be 24%. However, given that the collision at 45 km/h was fatal, the predicted probability of a fatality at an impact speed of 40 km/h in the circumstances of this particular collision is 24/61 or 39 per cent. The predicted probability of survival in this case is therefore (1-0.39) or 61 per cent. The predicted number of surviving pedestrians in the event of a hypothetical reduction in travelling speeds is then obtained by summing the probability of survival over all 118 cases.

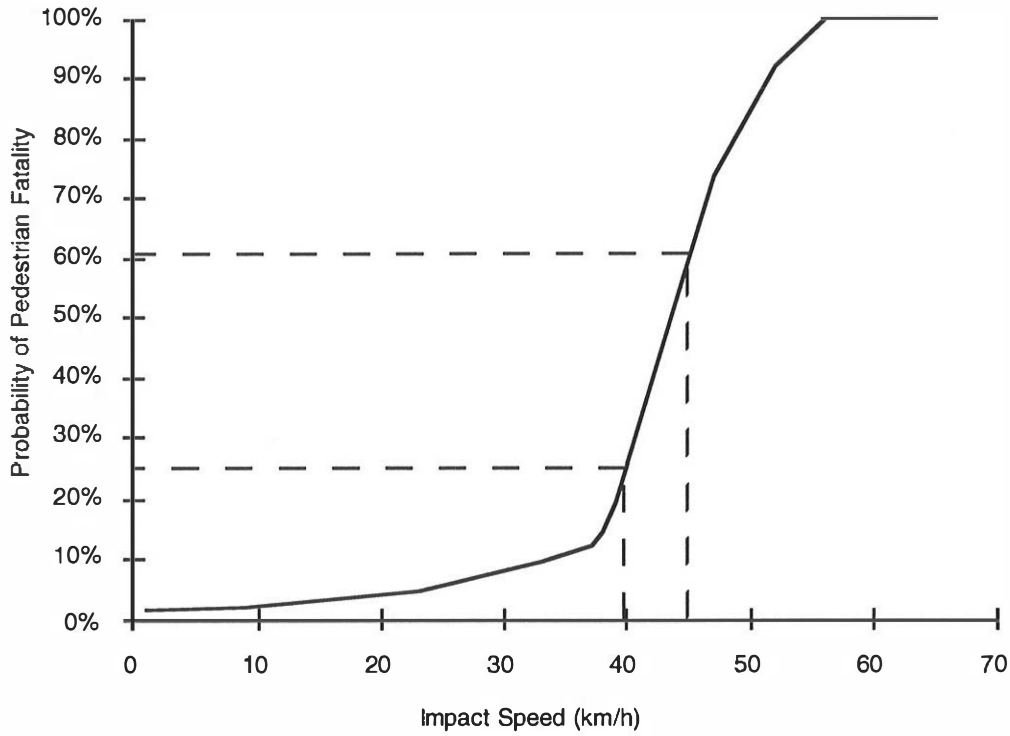
Figure 1: Impact Speed and Injury Severity (The Interdisciplinary Working Group for Accident Mechanics , 1986)



There were a further 15 cases in which the vehicle had a free travelling speed, but no reliable estimate was available of that speed (Table 1). Assuming that these cases were otherwise similar to the 118 cases discussed in the previous paragraph, we then adjusted the predicted number of surviving pedestrians by the ratio (118 + 15)/118. Finally, we divided this adjusted number by the total number of 153 pedestrians who were fatally injured in the actual collisions (Table 1) to obtain an overall predicted percentage of survivors for the whole sample. A similar procedure was followed to calculate the overall percentage of collisions which would have been prevented altogether had the vehicle been travelling at a specified reduced speed.

To further illustrate the procedure, an example is shown in Table 3. After the cases have been reconstructed (columns 2 and 3), the probability of the pedestrian being fatally injured is estimated using the relationship in Figure 2 (column 4). A modified regime of travelling speeds is then applied to the cases (in this example, all speeds are reduced by 5 km/h). Using the speed relationships for each case, hypothetical impact speeds are estimated for each case (column 6), and subsequently, new probabilities of death are calculated (column 7). Given that the original case was fatal, these probabilities are modified as described above (column 8). The probabilities of surviving the impact are summed over all the cases (total at the bottom of column 9), and the frequency of "zero speed" impacts in the scenario is noted (total at the bottom of column 6). The hypothetical percentage of survivors and the hypothetical percentage of collisions avoided can now be readily calculated as described above.

Figure 2: Probability of Pedestrian Fatality by Impact Speed.
Derived from the Interdisciplinary Working Group for Accident Mechanics (1986) and Walz, Hoefliger and Fehlmann (1983)



RESULTS

An example of the changes in distributions of travelling and impact speeds estimated by the reduced travelling speed scenarios is shown in Figures 3 and 4. In this scenario the travelling speeds of all vehicles in the analysed cases were hypothetically reduced by 5 km/h (Table 2). The actual and reduced travelling speed distributions are shown in Figure 3, and the corresponding impact speeds in Figure 4.

Using the methods described previously, estimates of the reduction in the number of fatal collisions were obtained, along with the number of collisions that could have been avoided completely. In each case in which the vehicle had a "known" travelling speed, the probability of the pedestrian surviving at a lower travelling speed was estimated together with the proportion of crashes that might have been survivable in each scenario. A zero impact speed indicated that, under the reduced travelling speed scenario, the collision would have been avoided altogether (i.e. had the driver been travelling at the reduced speed, he or she would have been able to stop their vehicle before it reached the pedestrian). The results for crashes that occurred in 60 km/h speed limit zones are shown in Figure 5.

Table 3 Example showing how the number of survivors in a particular scenario (all speeds reduced by 5 km/h) were estimated.

1 Case	2 Travelling Speed (km/h)	3 Impact Speed (km/h)	4 Probability of Death at Actual Impact Speed	5 Hypothetical Travelling Speed (km/h)	6 Hypothetical Impact Speed (km/h)	7 Probability of Death at Hypothetical Impact Speed	8 Hypothetical Probability of Death Given that the Actual Crash was Fatal	9 Hypothetical Probability of Survival
				as per Table 2			(7)/(4)	1.00 - (8)
1	71	54	96%	66	43	45%	47%	0.53
2	50	50	84%	45	45	58%	69%	0.31
3	71	63	100%	66	53	94%	94%	0.06
:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:
116	60	60	100%	55	49	82%	82%	0.18
117	79	45	56%	74	30	8%	14%	0.86
118	55	27	6%	50	0	0%	0%	1.00
Number of collisions avoided (impact speed zero)					13		Total	43
			Percentage of collisions avoided		$=13[(118+15)/118]/153$			= 10%
			Percentage of survivors		$=43[(118+15)/118]/153$			= 32%

Figure 3: Travelling Speed Distributions in Scenario 1

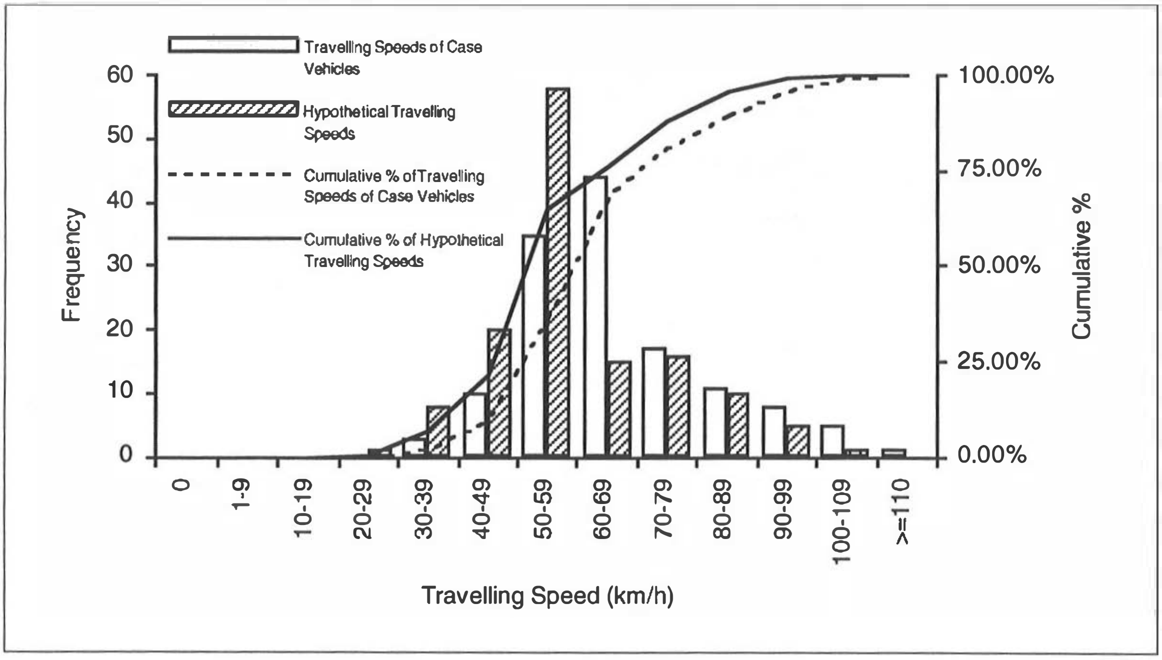


Figure 4: Impact Speed Distributions in Scenario 1.

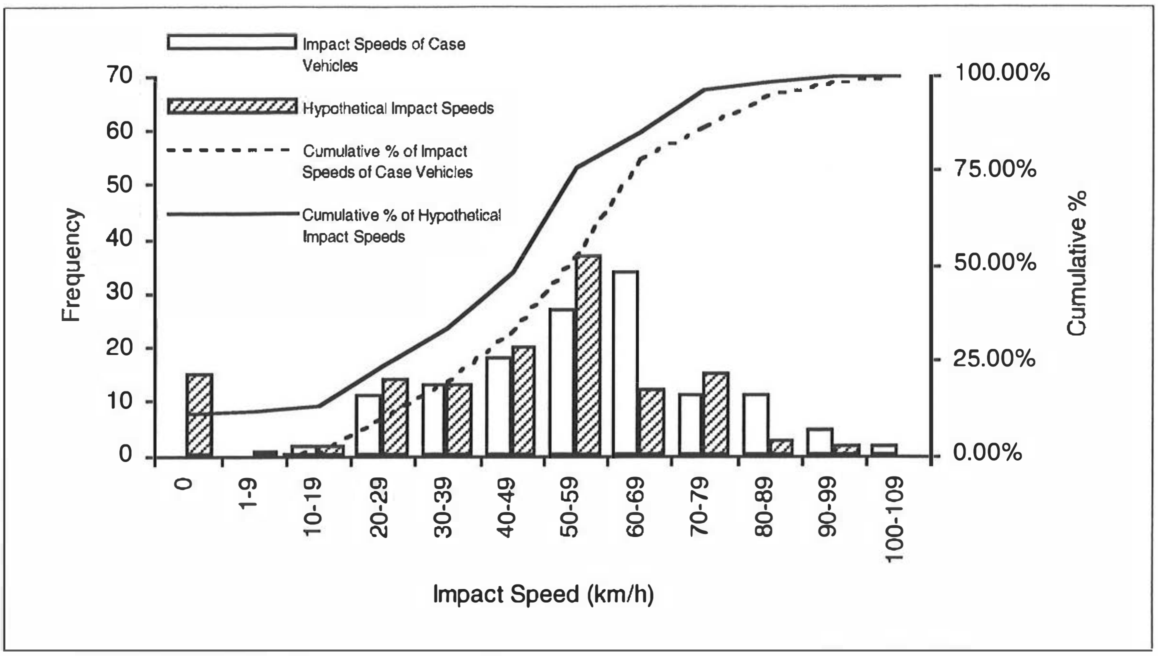
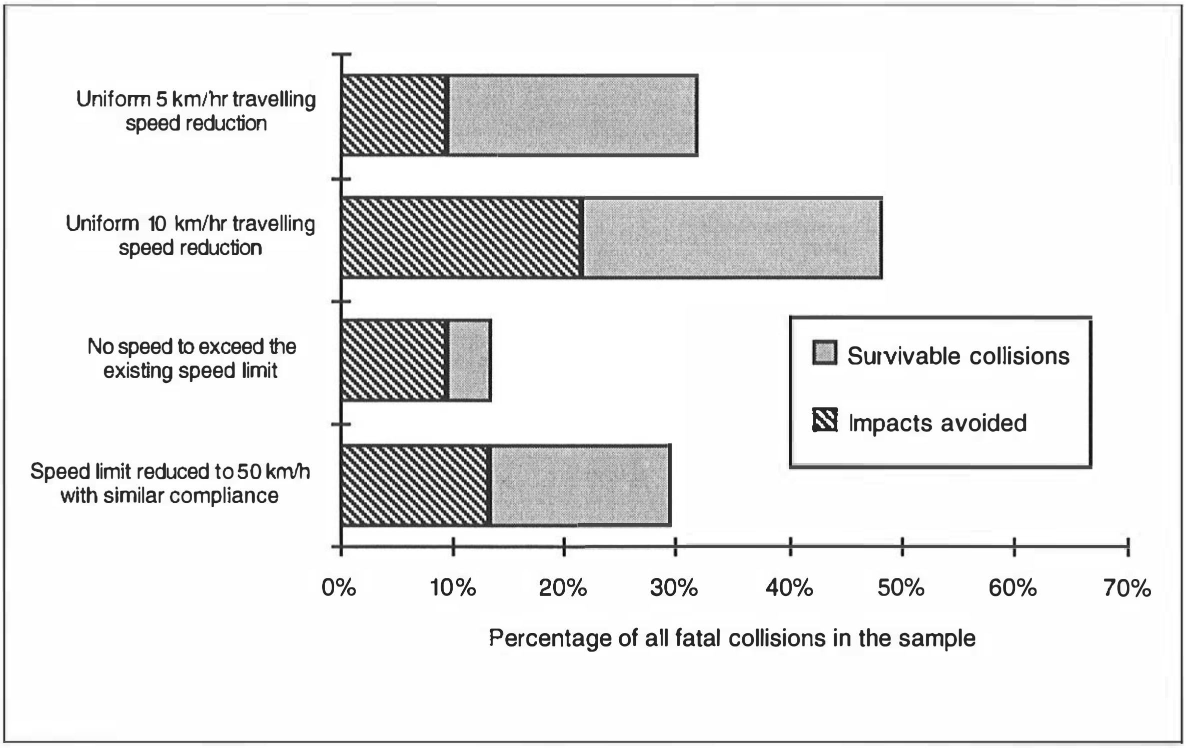


Figure 5: Fatality Reductions for Reduced Travelling Speeds in 60 km/h Zones.



DISCUSSION

The results of this study predict that small reductions in travelling speed are likely to result in large reductions in impact speed in pedestrian collisions, often to the extent of preventing the collision altogether. This is because when avoiding action was attempted by a driver, in virtually every case it involved emergency braking, and stopping distance under braking is, of course, proportional to the square of the initial speed.

Figure 6 shows the relationship between initial speed and stopping distance. The curves relating speed to distance commence in each case with a horizontal straight section which represents the distance covered during the driver's reaction time, with the vehicle proceeding straight ahead at the initial travelling speed. Once braking commences, the speed of the vehicle decreases with distance travelled in the manner shown, quite gradually at first and then decreasing more and more rapidly. It can be seen in Figure 6 that, from an initial speed of 80 km/h, the vehicle travels about 45 metres during the first 10 km/h decrease in speed, whereas the vehicle travels less than one metre during the last 10 km/h of speed reduction before the vehicle stops.

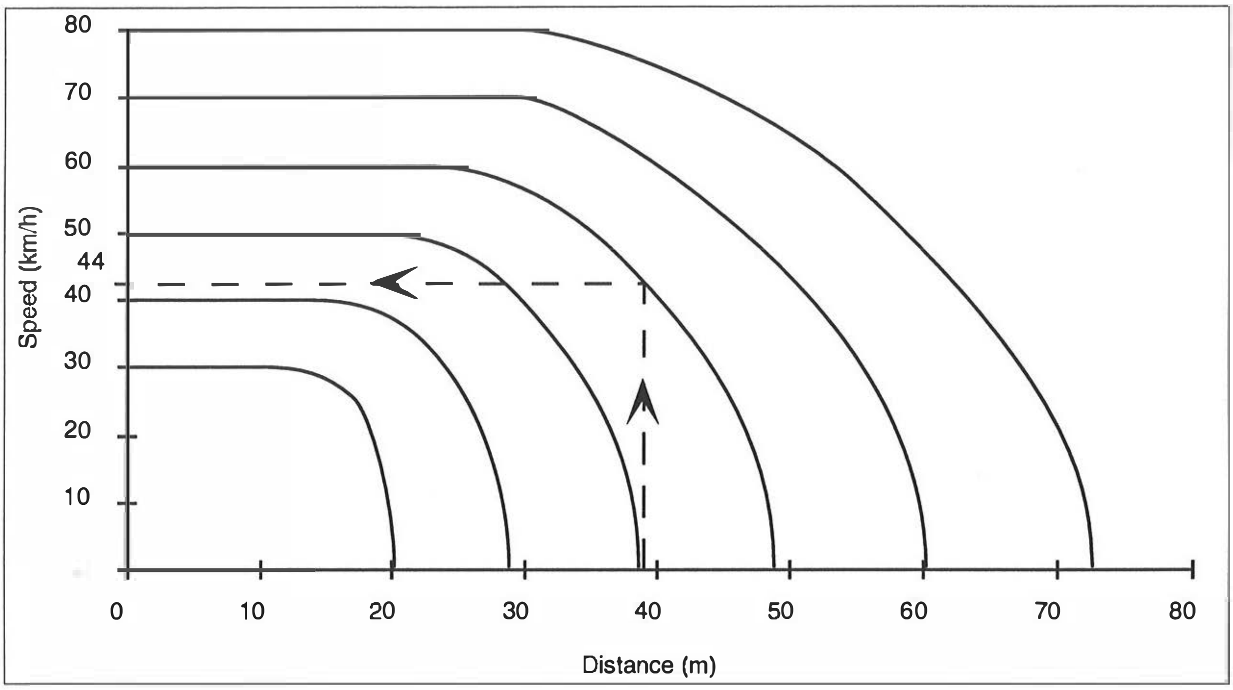
The effect on impact speed of a difference in travelling speeds of 50 and 60 km/h can be seen in the following example, which is indicated by the intercept lines in Figure 6. Consider two cars travelling side by side at a given instant, one car travelling at 50 km/h and the other overtaking at 60 km/h. Suppose that a child runs onto the road at a point just beyond that at which the car travelling at 50 km/h can stop. The other car will still be travelling at 44 km/h at that point, a collision speed at which a pedestrian has more than a 50 per cent probability of being fatally injured. This example has been presented previously (Walz, Hoefliger and Fehlmann, 1983) and we endorse the comment by the authors of that paper, made 12 years ago, that it is curious that there is a continuing need to demonstrate the validity of Newton's Laws of Motion.

In the present study we have estimated that a uniform reduction of 10 km/h in travelling speeds in 60 km/h speed limit zones would reduce the number of fatal pedestrian cases by 48 per cent in those areas, including the elimination of the collision altogether in 22 per cent of the cases (Figure 5).

Reducing the urban area speed limit from 60 to 50 km/h would not be expected to have as great an effect as a uniform reduction of 10 km/h in travelling speed because, for example, it would have relatively little or no effect on vehicles which were already travelling at less than 50 km/h. In estimating the likely effect of such a change in the urban area speed limit, we have assumed that the level of non-compliance would be similar to that for the existing 60 km/h speed limit. With the stated assumptions, we have estimated that 14 per cent of the collisions would not have occurred and in an additional 16 per cent of cases the pedestrian would not have been fatally injured, leading to a reduction of 30 per cent in fatal pedestrian collisions. Taken together with collisions which occur in other speed zones this leads to an overall reduction of 27 per cent. These percentages are remarkably similar to the changes which were observed when the urban area speed limit was reduced in this way in Zurich (Walz, Hoefliger and Fehlmann, 1983), and the changes which are predicted by Fieldwick and Brown (1987).

The estimated effect on pedestrian fatalities of reducing the urban area speed limit from 60 to 50 km/h is similar overall to that which would be expected from a uniform 5 km/h reduction in travelling speeds. The former change would be slightly more effective in preventing collisions but have less effect on the severity of those collisions which would still occur, as measured by the number of cases in which the collision would be expected to no longer result in a fatality.

Figure 6: Speed Versus Distance for Emergency Braking from Time = t_0



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