

Speeds and Pedestrians - what's the right mix?

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Abstract

Pedestrians are highly vulnerable in traffic with the young and the aged especially at risk. Impact speed, the stature and fitness of the pedestrian, and the frontal design of the striking vehicle are all influential in determining the severity of outcome of any collision involving a pedestrian. An area of special focus among researchers has been the relationship between impact speed with a pedestrian and the probability of death or serious injury resulting. More recent analyses have suggested that impact speeds as high as 50 km/h coincide with an approximate 10% risk of death to the pedestrian and also mark the commencement of a rapidly rising risk of death for increasing impact speeds above 50 km/h. This result could be construed to mean that travel speeds of 50 km/h are likely to produce acceptable outcomes under a Safe System vision. This paper seeks to briefly review the current state of knowledge regarding travel and impact speeds, and to provide evidence-based support for translating Safe System philosophy and principles into real-world practice.

Introduction

Crashes involving pedestrians in 2013 constituted 13% of all road deaths in Australia and 15% in Victoria (Hoareau, Logan, Oxley and Corben (2014)). Pedestrians are highly vulnerable in traffic with the young and the aged especially at risk. Over several decades, significant strides have been taken in improving protection for vehicle occupants in the event of a crash. The cars of today offer over 25% better protection than those that first came off the assembly line in the beginning of the nineties (Newstead and Scully, 2009). Fleet replacement over that time has meant that safety innovations such as side curtain airbags, improved cabin integrity and energy-absorbing componentry are increasingly taking effect in improving the outcome for vehicle occupants when a crash does occur.

Unfortunately, over this same period vehicle technology to improve protection for vulnerable road users such as pedestrians has shown much slower progress. It is true that ANCAP provides a very valuable rating of a vehicle's ability to protect a pedestrian upon impact. A vehicle's frontal design and energy absorbing properties are key determinants of the pedestrian safety rating. Notwithstanding, very few vehicles entering the market over past decades have displayed good to high levels of pedestrian protection. As a consequence, vehicle design factors historically have done little in practical terms to support improved outcomes for crash-involved pedestrians. Encouragingly, over the past decade there have been signs of improvement with Keall, D'Elia, Newstead and Watson (2014) estimating that there were savings across Australia of around 340 fatal and serious injuries to pedestrians relating to average improvements in vehicle characteristics over the period 2003 to 2011.

The importance of speed to pedestrian safety cannot be overstated. One of the most compelling, macro-level illustrations of this fact comes from a simple examination of long-term trends in pedestrian fatalities in Victoria over recent decades.

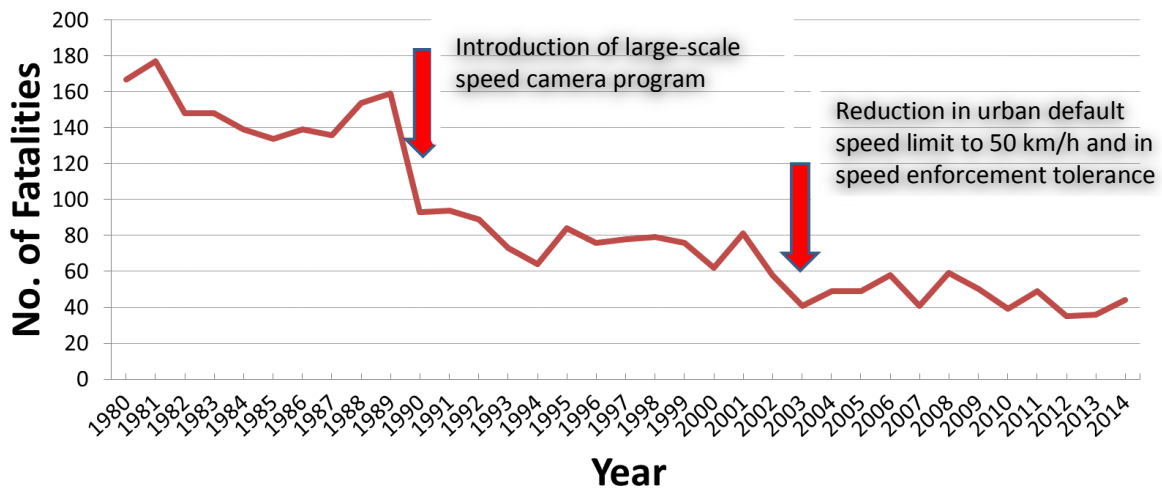


Figure 1: Pedestrian Fatalities on Victorian Roads (1980-2014)

Figure 1 shows the annual number of pedestrian fatalities occurring in Victoria between 1980 and 2014, inclusive. On two occasions over the 35-year period, distinct drops in fatalities can be clearly seen. Neither drop has rebounded to previous levels, as often happens when an observed reduction is likely due to chance rather than to a real effect. Over the last 25 years, the number of pedestrian deaths in Victoria has decreased by some 75 percent, from an average of around 150 deaths per annum in the late 1980s (159 in 1989) to between 35 and 50 deaths per annum since 2010, averaging around 40 fatalities each year for 2010-2014. The two large step-reductions occurred in 1990 and 2002-2003 following the introduction of two major speed initiatives in Victoria. They involved the introduction of 54 automated speed cameras with strong supporting public education in 1989/1990 and, in 2001, a lower urban default speed limit followed soon after in 2002 by a reduction in the tolerance level of compliance with speed limits (along with a range of other improvements in speed enforcement). Since 2003, however, reductions in pedestrian deaths have plateaued.

Impact speed is a key determinant of injury severity. Energy transferred to the human body, in excess of its biomechanical tolerance, will result in potentially life-disabling injury or even death. As a result, an area of special focus for researchers has been the relationship between impact speed with a pedestrian and the probability of death or serious injury occurring. This paper seeks to briefly review the current state of knowledge regarding travel and impact speeds, and to provide evidence-based support for translating Safe System principles into real-world practice.

Research on the Relationship between Fatal or Serious Injury Risk and Impact Speed

Estimating the risk of death or serious injury for a range of impact speeds is a complex exercise. Determining factors include the age and level of functionality of the pedestrian, error associated with the estimate of impact speed itself, varying vehicle frontal profiles and rigidity, orientation of the pedestrian to the striking vehicle as well as biases inherent in sampling cases only at the more severe end of the injury severity spectrum. The following discussion provides a brief overview of progress in the field based on reference to a select number of relevant studies.

Wrangborg (2005) gave prominence to the relationship between impact speed and the risk of a pedestrian being killed in the context of developing a safe traffic system in Sweden in his paper to the Road Safety in Four Continents Conference in Warsaw (refer to Figure 2 below).

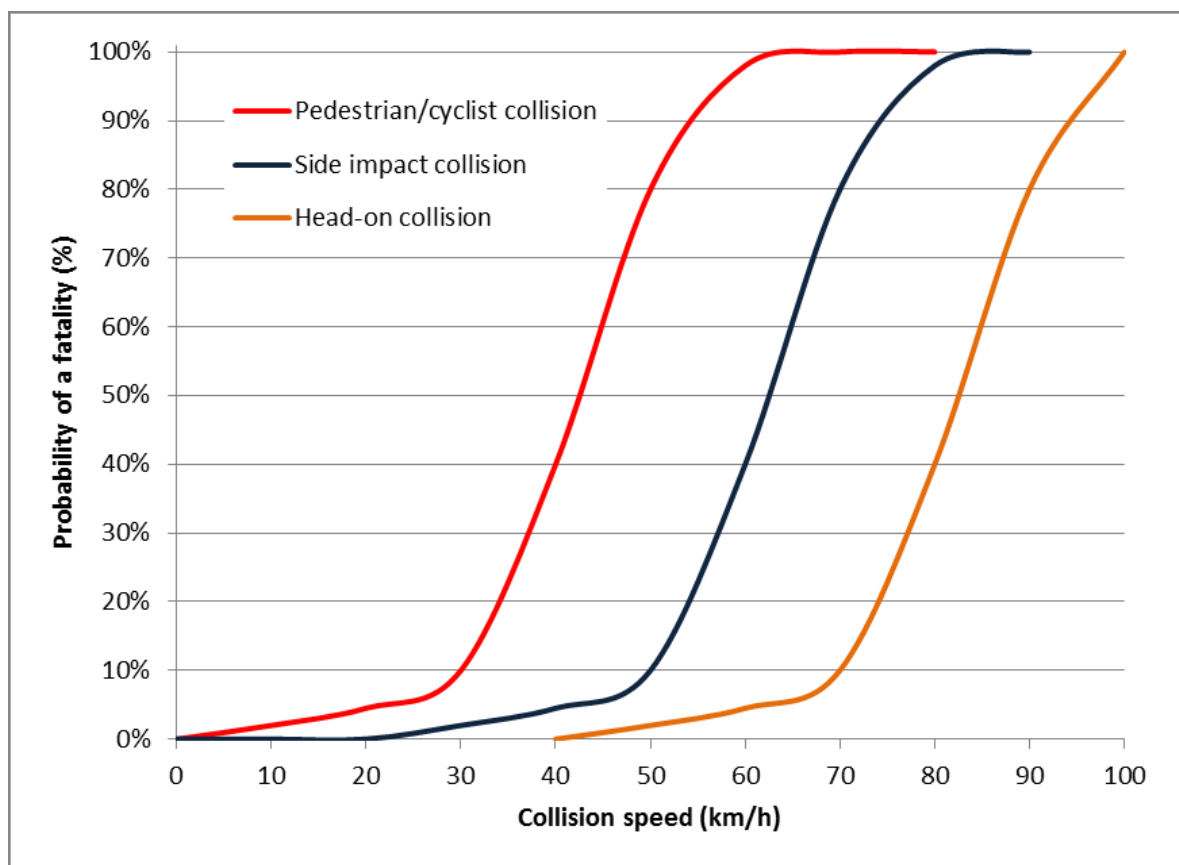


Figure 2: Risk of Pedestrian Death by Impact Speed (after Wrangborg)

The risk curves presented above are indicative only but, importantly, point to a general shape in the risk curve such that as impact speeds increase in excess of a threshold value (in the case of a pedestrian, approximately 30 km/h), the risk of death to a pedestrian begins to rise very rapidly.

Rosen, Stigson and Sander (2011) conducted a literature review of key studies that sought to relate fatality risk to the impact speed of a car. Eleven studies in total, conducted between 1980 and 2010, were reviewed. The authors noted that the risk estimates for a given impact

speed varied considerably with most studies drawing conclusions from samples of crashes that were biased towards the more severe end of the spectrum. This type of bias is likely to result in inflated estimates of threshold impact speeds. Two studies though, Davis (2001) and Rosen and Sander (2009) made adjustments to the sample to reflect better the profile of crashes across all severities with the result that threshold impact speeds at which there was an estimated 10% risk of a pedestrian fatality increased markedly. In the 2009 study, for example, that examined only car and car derivatives in collisions with pedestrians aged over 15 years, the fatality risk was estimated at 8% at 50 km/h, well in excess of the indicative threshold speed of 30 km/h proposed by Wrangborg in his 2005 paper.

Tefft (2011) estimated the risk of death or severe injury for pedestrians aged 15 years and over struck by a car or light truck in the United States using data for the years 1994 to 1998. Weightings were applied to adjust for oversampling of the more severe crash types while use of logistic regression made allowances for variations in pedestrian and vehicle characteristics. The risks so estimated were then re-scaled to represent average risks of death or serious injury to a pedestrian if struck by a car or light truck in the United States in the years 2007 to 2009. Figures 3 and 4 below show the estimated average risks for pedestrian death and serious injury respectively together with 95% confidence intervals. Serious injury was defined as an Abbreviated Injury Scale (AIS) score of 4 or more that equates to a very severe trauma outcome and can include death.

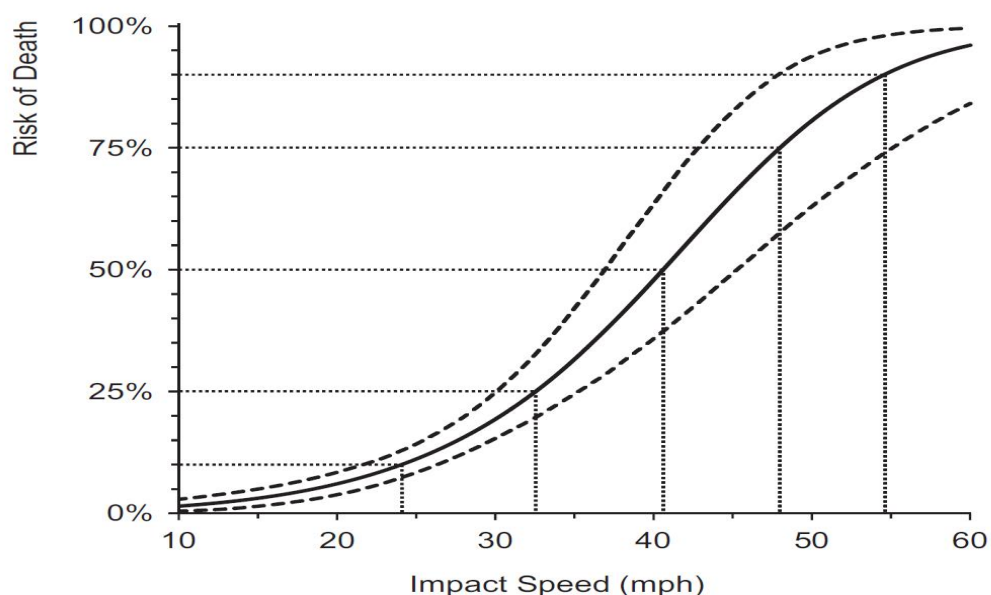


Figure 3: Average Risk of Pedestrian (15+ yrs) Death by Impact Speed (Tefft, 2011)

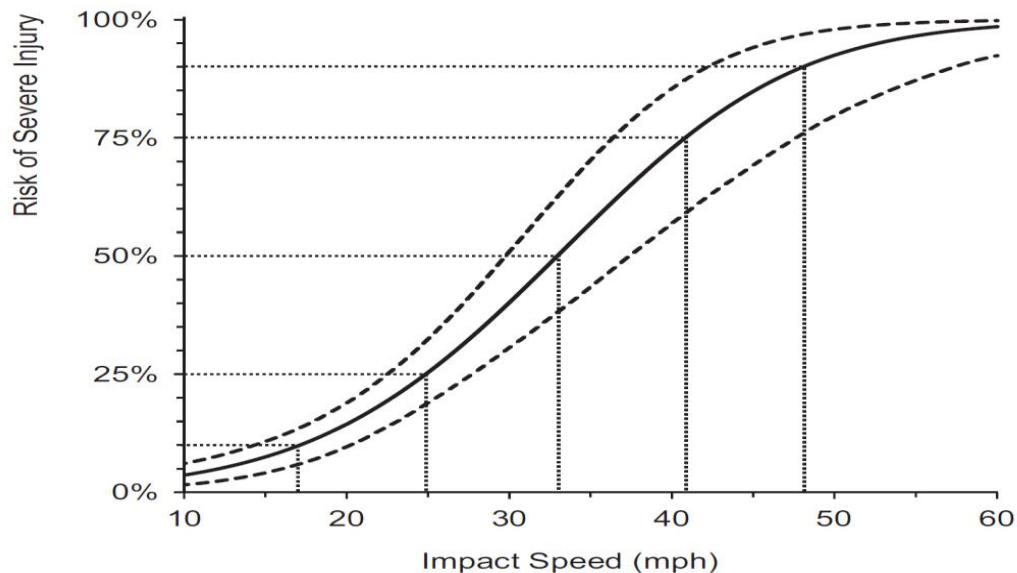


Figure 4: Average Risk of Pedestrian (15+ yrs) Severe Injury by Impact Speed (Tefft, 2011)

While the above results apply first and foremost to the American setting, they nevertheless are instructive for two very good reasons. Firstly, the confidence limits highlight the uncertainty of the estimation procedure notwithstanding every effort to manage confounding influences. Secondly, they point to the significantly lower impact speeds that are likely to result in severe injury compared with death - an approximate 10% chance of death at 23 mph (37 km/h) compared with a 10% chance of serious injury at 16 mph (26 km/h). Moreover, Tefft goes on to estimate how average impact speeds differ between cars and light trucks and between an average 30 year old and 70 year old for a given risk of death or severe injury. For the former, a light truck need only collide with a pedestrian at an average impact speed 6.3 mph (10 km/h) lower than for a car for the equivalent risk of severe injury. For the latter, the impact speed involving a 70 year old pedestrian can be 9.3 mph (15 km/h) lower than for a 30 year old pedestrian for a crash outcome of similar severity.

While the above review of the literature regarding the risk of death or serious injury to a pedestrian related to impact speed has been necessarily brief, it is instructive in terms of what we can reasonably glean from the research to date and what factors lie outside the research but are likely to be influential. A related but important finding relates to the relationship between impact speeds and the preceding travel speeds. These findings and their implications are discussed below.

The kinematics of speed and vehicle stopping distance

While the presentation of quantitative information on the kinematics of vehicle stopping distances, as a function of initial travel speed, is not new, it is discussed briefly here because it complements the overall discussion of the role of impact speed on injury risk, and is intended to provide the reader with greater insight.

Figure 5 shows the stopping distance profile for initial speeds of 30, 40, 50, 60, 70 and 80 km/h, for a driver perception-reaction time (PRT) of 1.2 seconds and coefficient of friction of 0.7; both values are regarded as reasonably typical and suitable for this application.

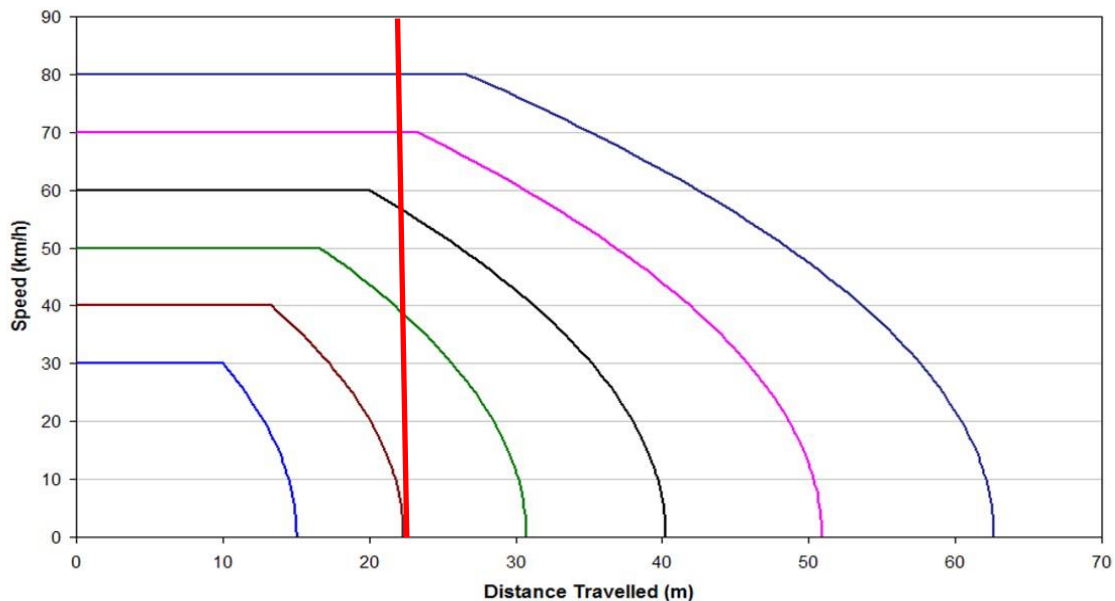


Figure 5: Stopping Distance Profiles for a Range of Initial Travel Speeds

The stopping distance profile is made up of two parts: first, the horizontal part, representing the distance travelled at the initial speed during the driver's PRT and, secondly, the curved part which reveals increasing reduction in speed as a function of distance during the braking phase. To provide a more complete picture on the role of speed, two fundamental points are made regarding Figure 5:

- The stopping distance decreases non-linearly with decreasing initial speed, due to the 2nd-power relationship with speed. For every reduction of 10 km/h in initial speed, there will be a *progressively larger decrease* in stopping distance, meaning that crash risk also falls non-linearly with reductions in initial speed;
- Studying the kinematics of bringing a vehicle to rest shows that half of the initial speed is washed off very late in the braking phase (typically during the last 20 percent of the braking phase). This helps to explain why small increases in initial speed lead to surprisingly large increases in impact speed. To further illustrate this point, the vertical line at the 22 metre mark on the x-axis of Figure 5 shows that:
 - a vehicle with an initial speed of 40 km/h can be brought to a halt within about 22 metres, thereby avoiding a collision with a hypothetical pedestrian;
 - drivers faced with the same hypothetical crash scenario when travelling at higher initial speeds, namely, 50, 60, 70 or 80 km/h would impact a pedestrian at approximately 38, 57, 70 or 80 km/h, respectively, assuming the driver PRT and road frictional characteristics noted above.

It is informative to compare these impact speeds with the risk relationships discussed above.

Discussion of Findings

While much of the research effort to date has been on defining as accurately as possible the shape and position of the curve on the risk vs impact speed axes, it must not be overlooked that there is no meaningful, precise relationship that can be defined.

Firstly, we all differ as individuals in our tolerance to energy exchange in a crash, due to factors such as age, health status, level of impairment due to alcohol or other drugs, physical stature, and stance and orientation at the moment of impact.

Secondly, while cars of the same make and model might be regarded as identical, there still remain major variations within vehicle fleets, with mass and design characteristics such as vehicle height, frontal profile and rigidity determining to a significant extent the severity of injury outcomes.

Thirdly, the crash circumstances and surroundings at the crash location can also be influential in determining injury outcomes. For example, it is common for struck pedestrians to be thrown in the air or to fall directly to the ground following the initial impact with the striking vehicle. The presence of hard surfaces, not capable of deforming during the secondary impact, increase injury risk as a result of high levels of acceleration experienced by the struck pedestrians. Energy absorbing surfaces in high pedestrian areas are now being assessed as a possible means of creating more forgiving surroundings should a crash occur or a pedestrian fall.

Given the very wide array of realistic crash circumstances described above, it is clear that there are innumerable possible combinations that make it meaningless to attempt to define a precise risk relationship. It makes more sense, therefore, to consider the research to date as indicative of the risks faced by pedestrians in general but that some groups will face lower risks on average (e.g., young, healthy males) while other groups will be subject to higher risk (e.g., older pedestrians, especially those with health problems). When viewed in this way, the evidence can guide decisions concerning design and operation both at the level of policies and standards, and at the individual location level where design and operational details must be defined.

The Safe System aspiration is to eradicate death *and serious injury*. Clearly, the threshold for serious injuries, as referenced in the brief literature review above, is much lower than for fatalities, for all age groups. While it is understandable that the focus of early work on operationalising the Safe System has been on *fatalities*, mainly because the research-based evidence has been largely focussed on fatalities, it is time to shift the focus to understanding better the serious injury risk relationships with impact speed. Further research is needed in this area. And while the indications are that achieving Safe System speeds for pedestrians may result in unacceptably low speed limits, that is, travel speeds that avoid impacts that produce severe injury for all pedestrians, it should be acknowledged that as speed limits reduce, not only does injury risk fall but so too does crash risk. This means that it may not be

necessary, ultimately, to set speed limits at Safe System levels in practice, since crash risk will approach very low levels, thereby making decisions on biomechanically tolerable impact speeds progressively less important.

Increasingly, a number of interventions will need to come into play to achieve high levels of safety for all pedestrians. They all will be aiming to either avoid a collision through separation or, in the event of a crash, to reduce impact speeds to mitigate the risk of severe injury to pedestrians. In the short to medium term, they will include reduced speed limits at locations and in areas where pedestrian exposure and resultant trauma is high in aggregate, infrastructure measures to moderate speeds especially at high-risk conflict points (for example, platform treatments at intersections and for raised pedestrian crossings at mid-blocks with kerb outstands) with supporting enforcement and public education where appropriate. In the longer term, vehicle safety features will increasingly come to the fore – technologies such as ISA (Intelligent Speed Assist) to ensure that drivers keep within posted speed limits and AEB (auto-emergency braking) that will initiate hard braking if the driver doesn't when collision with a pedestrian is imminent.

Conclusion

Much useful research has been conducted to establish relationships between impact speeds and the risk of a pedestrian being killed and, in some cases, being severely injured. Given that impact speed estimates will vary as a result of a range of confounding factors including pedestrian age, stature and level of fitness, vehicle frontal profile and rigidity as well as crash circumstances, outcomes can best be viewed as indicative only for any particular crash circumstance. Safe System principles steer decision-makers towards making conservative decisions with a view to minimising the risk of severe injury or death occurring in the event of a collision. Accordingly, the practitioner needs to call upon a range of measures including reduced speed limits, infrastructure improvements with supporting enforcement and public education where applicable to help ensure safe use of the road network by pedestrians. In the longer term, vehicle technologies such as broader deployment of Intelligent Speed Assist and Automatic Emergency Braking will come to the practitioner's aid.

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